Secondary successions after shifting cultivation in a dense tropical forest of southern Cameroon (Central Africa)

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Chapter 1 Introduction

During the past decade, 13 million hectares of tropical forest have been destroyed (FAO 2010). Although this value is lower than the 16 million hectares of the 1990s, it remains high, with the highest forest loss in South America and Africa being the two parts of the world (FAO 2010). Causes of this deforestation are either natural or anthropogenic and in the last case logging and agriculture are viewed as the main factors (Brown & Lugo 1990, Laurence 1999, Gemerden 2004, Lawrence 2004). The two practices are often linked in the sense that tracks opened in the forest by logging companies with their heavy machines are afterwards used by peasants to access the forest for cultivation. The main agricultural practice in the tropical areas is shifting cultivation. Summarily, this practice consists of clearing of a patch of forest during the dry season, burning of plant debris and planting of the crops when rains start to fall. After two or three years of cultivation, the field is abandoned because the fertility of the soil is decreasing. Then the farmer looks for another place in the forest where a new field will be created. The abandonment of the field, apart from aiming to allow the soil to recover its physical and chemical property, is the starting point of forest recovery. This farming system leads to a patchwork of secondary forests of different ages, and which representing different successional phases of forest recovery (Richards 1955, Brown & Lugo 1990). In other words in tropical areas, deforestation is responsible of the existence of patchwork of different vegetation types dominated by secondary forest (Uhl 1987). In this context, tropical forests are often been mistakenly considered as pristine (Richards 1955, Whitmore 1991, Chazdon 2003, Gemerden et al. 2003a) and have always undergone anthropogenic changes during the past centuries and millennia. Under tropical forests remains of pottery, iron artifacts, charcoal and other signs of past settlement activities give evidence of past human impact on the forest (Gomez-Pompa et al. 1987, White & Oates 1999, Chazdon 2003, Willis et al. 2004). Most of the present tropical forests are in fact very old secondary forests (Brown & Lugo1990) that result from an ongoing process which had started many centuries ago. Their present physiognomy is similar to that of the original forest (Richards 1955, Whitmore 1991, Chazdon 2003, Gemerden et al. 2003b, Willis et al. 2004). On this basis our present era is best regarded as “era of secondary vegetation” (Gomez-Pompa & Vasquez-Yanes 1974, Lugo 2009).

The return of a degraded forest to a state structurally similar to the original forest takes place through a sequence of different successional phases (Richards 1952, Finegan 1996, Chazdon 2003) each of which is dominated by one or a group of species (Alexandre 1978, Kahn 1978, Mosango & Lejoly 1987, McKey 1988, Tchiengué et al. in press). They are exclusively found in openings and cannot develop under close canopy. Many terms such as “espèces cicatricielles à vie courte” (Mangenot 1955), “ephemeral biological nomads” (van Steenis 1958), and “pioneers” (Budowski 1965) have been used to name them, the last being the most widely found in the literature. Their ecological behavior as well as their growth had been subject of many studies (Coombes 1960; Coombes & Hadfield 1962, Vasquez-Yanes, 1974, Alexandre 1978, Kahn & Namur 1978, Brokaw 1985, McKey 1988, Vasquez-Yanes & Orozco-Segovia 1990). Several authors paid special attention on either patterns of secondary successions (Denslow 1980, Kahn 1982, Chapman & Chapman 1999, Finegan 1996, Guariguata & Ostertag 2001, Kassi N'Dja & Decocq 2008) or their structural characteristics (Guariguata et al. in 1997, Rivera & Aide 1998, Tucker et al. 1998, Uriarte et al 2004). The floristic composition and species diversity of abandoned agricultural fields has also been matter of concern (Horn 1974, Swaine & Hall 1983 Mosango & Lejoly 1987, Finegan 1996, Turner et al. 1997, Chazdon 2003). Most of these studies were carried out in South and Central America or in Asia and only few in the Congo Basin which is the second important forest block in the world after Amazonia. The rainforest of the Congo Basin is rich in economic timber species which are felled by logging companies, and many studies describe the impact of this practice on biodiversity (Gemerden et al. 2003a, Hall et al. 2003, Duveiller et al. 2008, Karsenty & Gourlet-Fleury 2008, Clark et al. 2009) whereas there are very few on secondary successions (Lubini 1982, 1986, Bebwa 1990).

In Cameroon in particular, the state of knowledge on forest secondary succession after shifting cultivation is scattered. Although Letouzey (1968a, 1985) described the main vegetation types of Cameroon, he did not treat any aspect relevant to forest succession but only summarized the species that can be found in former agricultural fields. Mbarga Bindzi (1992) distinguished vegetation types on abandoned agricultural fields in the semi-deciduous forest zones around Yaoundé. Zapfack et al. (2002) assessed the impact of shifting cultivation on the biodiversity in the Ebolowa area. In the Akom-Bipindi area, Gemerden (2004) compared forest recovery in abandoned agricultural fields with that of logged areas.

Taking into account that the ecological conditions prevailing throughout the tropical regions and even in the same forest block are highly diverse, the pathways of forest recovery are also different with a multitude of trajectories in the course of succession. For such reasons, Richards (1955) found it convenient to say “successions” instead of “succession”. Forest recovery is influenced by the type of disturbance, its intensity and its duration.

The current study falls within the framework of the DFG Research Unit 510 (DFG/BMZ programme) entitled “Late Holocene vegetation history and development of agriculture in West and Central Africa” (Eggert et al. 2006, Neumann et al. 2011, Sangen 2011) and was carried in a southernmost area far from the research area of Gemerden et al. (2003a, b) and Gemerden (2004). In Central Africa, many studies (Elenga et al. 1996, Maley & Brenac 1998, Ngomanda et al. 2009) have shown the abundance of forest pioneer species in the pollen diagrams, interpreted as a climatic change that had caused the fragmentation of the forest leading to the migration of Bantou, regarded as first agricultural settlers in the area. One major difficulty is to know whether the abundance of forest pioneer in pollen diagrams, is due to climatic change or results from forest recovery following the agricultural activity of the first cultivators in the forest area.

No study on secondary succession had been carried out in this area which is near the border between Cameroon and both Gabon and Equatorial Guinea. The aim of this study was to provide data and information that can help to understand different vegetation types of forest recovery after shifting cultivation. At the same time, the results can enable palynologists and archaeobotanists to compare their data with that of modern forest succession. The influence of the different ecological factors on forest recovery is analyzed as well as the farming system and the floristic composition of the different vegetation communities.

Chapter 2: Study area

2.1. Geographic location and administrative organization

The research area is located in the southern Cameroon and stretches between 2°22’- 2°23’ N and 9°49’- 11°17’E (fig. 2.1). Administratively, it is part of the Southern Province and covers two divisions out of three: the Ocean (Kribi) and the Ntem valley (Ambam). The administrative subdivisions of Campo and Ma’an are the only one concerned by this study and many ministries are represented in the area by either provincial or divisional delegations or both. In the rural area their dismemberment is in charge with local populations. Since the study deals with forest and agricultural system, the ministries concerned by the current research are those of Forestry and Wildlife and of Agriculture.

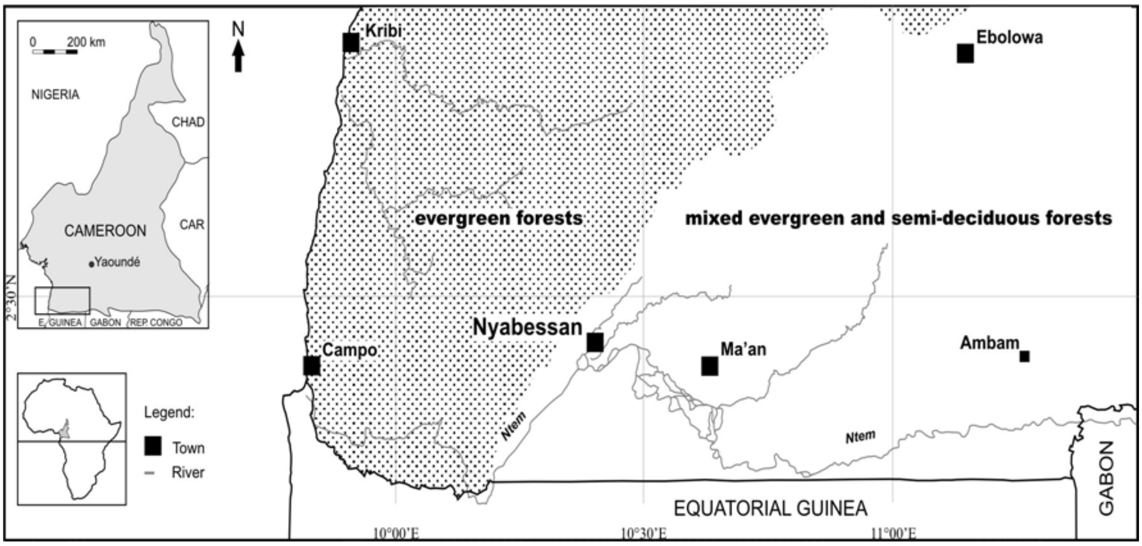


Figure 2.1: map of the study area

The area is bordered in the West by the Atlantic Ocean and in the south by Gabon and Equatorial Guinea.

In the north many agro-industrial plantations such as rubber plantations (Hevecam), palm oil plantations and many logging concessions are located.

Within the research area, the Campo-Ma’an National Park is classified as a Technical Operation Unit (TOU) where any agricultural, logging or hunting activity is prohibited.

From the coast in the West to the Campo-Ma’an National Park, the entrance village is Mvini while from the East, Ebianemeyong is the entrance locality.

2.2. Geology and relief

The geology of southern Cameroon has been described by Vicat (1998). The region belongs to the Congo craton which covers the major part of Central Africa and is divided in many geological units like the Ayina, the Nyong and the Ntem units. The major part of this study has been carried out in the Ntem unit which is about 2.9 to 2.5 billion years old (Ngako 2007). The basal complex of the Ntem formations is mostly of metamorphic nature comprising gneiss, quartzites, migmatites and charnokites dating from the Precambrian era (Nougier 1979).

The eastern region around Campo, Mintom and Ipono is part of the Palaeoproterozoic, made of intrusive rocks associated with iron rich quartzites. This Palaeoproterozoic unit is constituted of the Nyong and Ayina units. The Ntem and the Palaeoproterozoic units form what is known as the Ntem complex which is best regarded as the foundation of the Pan-African formations (Ngako, 2007). The only mineral resource present in the region is iron around Les Mamelles between Kribi and Campo.

One of the main relief features in Cameroon and concerned with the present study area is the coastal plains. They are situated at the eastern side of both the South Cameroon Plateau and the western highlands. These plains form a narrow strip of about 360 km long in three main segments (Tchawa 2007): the first one around Mount Cameroon is 60 km long, the second segment is 220 km long and comprises the lowlands of the Sanaga delta and the Wouri estuary while the last segment from Kribi to Campo is 80 km long. The coastal plains do not exceed 150 km in E-W direction and then bound with the South Cameroon plateau. Relief features rank from lowlands to few mountains rising around an altitude of 1000 m.

2.3. Soil

The soils of the region are of two major types: typical ferralitic soils and hydromorphic soils. Typical ferralitic soils are rich in iron oxides and hydroxides and are either yellow or red.

The yellow soils are characteristic of the coastal area and spread up to Ebolowa and Ambam. These soils are typical of an equatorial climate with annual rainfall of 2000 to 4000 mm and mean temperature of 26°C, and they support evergreen forest. They are developed over either a sedimentary or a metamorphic substrate. On sedimentary substrate, the organic matter content is very low and these soils have poor fertility. These soils form a belt around Douala and Campo. On metamorphic substrate, the clay content of the soils is high and ranges from 40 to 60%. Gravels are represented by pieces of quartz or iron concretions. The pH of these soils lies between 4.8 and 5.2 while the organic matter content runs from 1.8 – 3% at the surface. These soils support large cocoa plantations and their fertility is low.

The red soils derive from both metamorphic and old eruptives rocks and are found under equatorial climate with annual rainfall of 1200 - 2000 mm with a less pronounced dry season. Morphologically, these soils are close in colour to yellow ferralitic soils but their structure is less compact and seems to be stable. Their pH is around 5 - 6 and the ratio SiO_2/Al_2O_3 of tin ground is between 1.5 and 2.0. In these soils, the nitrogen and organic matter are in the same proportion, and they have a low content in exchangeable bases and a high mineral content.

Hydromorphic soils are found at the border of the Ntem River, along the various streams and also in the periodically inundated forests. These soils are not suitable for agriculture because of their high water content. However, in periodically inundated areas, some crops like *Musa paradisiaca*, *M. sapientum*, and *Cucumeropsis mannii* are often cultivated.

2.4. Hydrology

The Atlantic basin which encompasses the study area is the most important hydrologic basin in Cameroon. It is crossed by the Sanaga, the longest river in Cameroon with a length of 920 km. The major river of the region is the Ntem which has its source near Oyem in Gabon and discharges in the Atlantic Ocean (Runge et al. 2006). Its valley covers 18,000 square kilometres in Cameroon out of a total area of 30,000 (Vivien 1991 cit. Carrière 1999). Rapids and falls of which the most important is the Memve'ele fall at Nyabessan are the results of tectonic faults crossing its flow. Small streams play an important role in the drainage of the area. They are also responsible for some vegetation features such as swamps, riparian and periodically inundated forests and all flow towards the Ntem.

2.5. Climate

Cameroon is under the influence of two trade-wind systems, harmattan and monsoon which originate from centres of high pressures (anticyclones) situated on both sides of the Equator. The harmattan blows from North-East in the Açores anticyclone and is both dried and stable. Its humidity percentage rarely exceeds 50% during the day and can be lower than 10 % and even 5% (Suchel 1972). The second trade wind called monsoon originates in the Saint Helena anticyclone and blows South-West/North-East when it crosses the equator. This trade-wind is unstable and very humid. The two air masses meet along a front called the InterTropical Convergence Zone (ITCZ).

Ngomanda et al. (2009) report that southern is under the influence of two climatic regimes situated at both sides of the equator. In the northern hemisphere (northern regime), the dry season occurs in winter with a rainy season stretching from March to November. In the southern hemisphere (southern regime), the dry season occurs in summer and the rainy season from October to June. In southern Cameroon, the two climatic regimes meet and are opposite. The consequence is the existence of four seasons: two rainy seasons and two dry seasons.

This seasonality is highly governed by the fluctuations of the ITCZ throughout the year (Nicholson 2000). Other factors like sea surface temperatures (SST), the jet streams and ENSO play a role in this seasonality (Nicholson 2000) by mitigating low rainfall at some period of the year especially in the Gulf of Guinea (Leroux 1980).

From the coast to the interior, the annual rainfall decreases from 2797 mm at Campo to 1690 mm at Nyabessan (Suchel 1972).

On the two diagrams (fig. 2.2), July records the lowest rainfall with 73 mm in Campo, and 7 mm in Nyabessan. This month is considered in Nyabessan as dry since precipitation is less than 50 mm (Bagnouls & Gaussen 1953). Nyabessan is situated at least at about 100 kilometres from Campo.

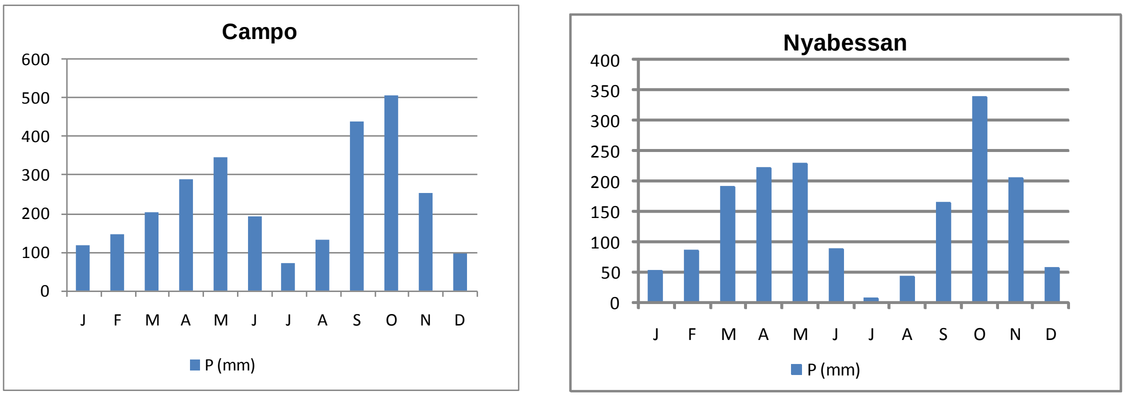


Figure 2.2: Rainfall diagrams of Campo and Nyabessan, localities of the study area

The high difference in precipitation between the two localities can be explained by the mountain range of Nkolebende, situated at the western side of Nyabessan which probably shields the humid winds coming from the Atlantic Ocean. October is the month with the highest rainfall.

Since the study area stretches between 2° and 3°N, it then falls within the domain of the equatorial climate. Temperatures are moderate in the area with an average of about 25°C.

2.6 Vegetation

The study area falls within the Congo Basin, the second largest forest block in the world after Amazonia. The area is covered by a dense tropical forest and Letouzey (1968b) reports that since early nineteenth century, many botanists, especially Germans and Dutch, collected plants there of which some like *Hoplestigma pierreanum*, *Ardisia batangaensis* are endemic.

According to the sharp rainfall gradient from West to East, forest types change quickly as one proceeds from the Atlantic coast to the interior (Letouzey 1985):

- Coastal forest in the West where *Sacoglottis gabonensis* and *Calpocalyx heitzii* are abundant. This forest borders the Atlantic Ocean and is found around Campo. In this forest, many coastal indicator species are present and mixed with a relative abundance of Leguminosae-Caesalpinioideae, *Sacoglottis gabonensis* and *Calpocalyx heitzii*. However, the abundance of Caesalpinioideae is less than that of the evergreen forest rich in Caesalpinioideae which does not occur in the study area.
- Mixed evergreen and semi-deciduous forest species where evergreen forest species are dominant. This forest occurs on the track between Afan-Essokie and Nyabessan. The canopy comprises numerous evergreen species like *Erythrophloeum ivorense, Coula edulis, Hypodaphnis gabonensis,* and *Ongokea gore*.
- Mixed forest composed of evergreen and semi-deciduous forest species, the latter being the most abundant. It is mostly found in the Ma'an area and many typical species of semi deciduous forest species such as *Celtis mildbraedii, C. tessmannii,* and *Canarium schweinfurthii* are well represented.
- Faces of degraded evergreen forest. This vegetation type is found throughout the area in the West of Nyabessan. The original evergreen forest has been converted to agricultural lands in which farmers spared some trees like *Alstonia boonei, Terminalia superba, Irvingia gabonensis,* and *Pycnanthus angolensis.*

Chapter 3: Shifting cultivation in southern Cameroon

3.1 General description

Agriculture is considered as one of the main causes of deforestation in tropical regions and it is undertaken in intensive and in extensive forms. In the intensive form, vast plantations of food or industrial crops (rubber, teak, bananas, pineapple, etc) are created by using both modern techniques as well as manual labour. The extensive form consists of small areas of a few hectares or less which are cultivated by farmers using machetes and hoes relying on the family's support. On these areas they cultivate fields with different crops like cassava, maize, groundnuts, yam, etc.

The extensive system is practiced as shifting cultivation concerns the majority of farmers in the tropics (Ickowitz 2006). According to Klemick (2011), this widespread agricultural system is practiced by not less than 300 million persons in tropical regions and uses about 30% of the soil resources in the tropics (Hauser 2006). Spencer (1955 cit. Christanty 1986) recorded not less than 48 English terms used to name this agricultural system. Terms like swidden or slash and burn agriculture are interchangeably used for shifting cultivation (Ickowitz 2006). The best definition, mostly used as standard, is from Pelzer (1957 cit. Christanty 1986) who considers it as an agricultural system characterized by rotation of fields (and not of crops), alternation of short cropping periods (of one to three years) with long fallow periods (more than six years) and clearing by the means of slash and burn. This definition shows the difference between shifting cultivation and slash and burn agriculture. Slash and burn means that the forest is cleared and plant debris is burnt. It is only one method used in the shifting cultivation. The term swidden agriculture refers to the fact that the field was created by burning the previous vegetation and does not implicate the shift of the fields (Christanty 1986). The most important difference between shifting cultivation and other agricultural systems is the abandonment of the field after the last harvest (Christanty 1986).

3.1.1 Different steps of shifting cultivation

Shifting cultivation comprises five different steps (Conklin 1961). The farmer starts by selecting the part of the forest he will clear to establish his fields. Conklin (1961) reports that many parameters such as the type of vegetation (mature forest, secondary forest, etc.), distance from the village or from the other fields, religious taboos, topography, and type of soil are taken into account. In the dry season the selected part of the forest is cleared. The clearing can be divided into two sub-steps, slashing and felling. Slashing consists in cutting the vegetation in the understory of the forest (vines, saplings and seedlings). During felling, trees are felt down using axes, machetes or chainsaws. All plant material cut during this step is left on the site to dry. Few weeks after, when all plant debris is dry enough, the farmer will stack it in piles and burn. During this burning step and according to the type of crop to be planted, fire is set more than once. Afterwards, cropping takes place. Conkling (1957) distinguishes grain cropping for cereals and non grain cropping for other types of plants. This phase of shifting cultivation comprises planting, weeding and harvesting. Various crops are interplanted. Planting is carried out when rains start to fall. A few weeks after the growth of the plant, weeding begins. Harvesting takes place when the crops are mature as the final cropping step. As the fertility of the soil decreases, so is the yield of the crops. After two or three years, the field is abandoned after the last harvest. The abandonment of the field or fallowing is the last step in shifting cultivation which aims to allow the soil to recover its physical and chemical properties. Christanty (1986) distinguishes three categories of fallows according to the fallow length. Short fallows are those whose fallow period is between one to two years. Bush fallows have a fallow length of six to ten years while forest fallows need at least 20 to 25 years.

3.2 Shifting cultivation in southern Cameroon

The southern part of Cameroon is covered by a dense tropical forest and local farmers practice shifting cultivation. Their living conditions are hard, the majority of the people are poor and cannot afford modern means to cultivate their land. They use machetes, hoes and axes to fell down trees of moderate size.

3.2.1 Selection

The timing of site selection depends on the personal agenda of the farmer. During field work, we realized that while clearing part of the forest, farmers knew already where new fields will be established for the next cropping season and which crops will be planted there. Some criteria are taken into consideration. The type of vegetation covering the plot guides the farmer who can clear a mature forest, a secondary forest or dense thicket of *Chromolaena odorata*. Vegetation with many trees and shrubs indicates increased soil fertility when the woody individuals will be burnt. However, since the invasion of tropical regions in general and Cameroon in particular by the Siam weed *Chromolaena odorata,* farmers prefer to have it in their fields. They have realized that in fields established by clearing thickets of this plant, some of their crops like cassava do well (Koutika et al. 2004, Koutika & Rainey 2010). The importance of *Chromolaena odorata* in the fields and the farmers’ perception vis-à-vis of this plant will be presented further. The selection of particular vegetation depends upon the type of crops to be planted. Generally mature or old secondary forests are preferred for *Cucumeropsis mannii* and *Musa paradisiaca* while secondary forests are cleared to establish groundnut fields. Apart from the type of vegetation, the nature of the soil is another important criterion for site selection. Farmers do not touch forest growing on sandy soil in case they have other alternatives. These soils are acidic and not good for agriculture.

The distance from the new field to the existing ones as well as to the village is also taken into consideration. The reason is that during the same day, the farmer can visit more than one of his fields which are not necessarily situated in the same place. For example, he can work in one field and later on go to another one to harvest food crops which will be cooked for dinner.

3.2.2 Clearing

During the dry season locally referred to as "essep" (December to February / March), farmers clear parts of the forest in order to establish their new fields. The farmer clears the part of the forest on which based on experience, the cultures will have a good yield. In southern Cameroon the different steps of plant cultivation are shared according to gender. Men are responsible of the clearing while women do the cropping. Slashing consists of cutting systematically all plants in the understory of the forest. Men often organize themselves in groups to clear the forest for each member of the group. The joint effort enables them to clear larger areas of forest. However, some widows have to clear their future field themselves (Diaw 1997).

After slashing, the felling of shrubs and other trees takes place using machetes or axes which are sufficient for trees with soft wood. Some trees are spared during clearing because the wood is too hard or the diameter is too large. The felling of such tree requires too much physical effort and time or the use of a chainsaw which most of the farmers cannot afford. *Lophira alata* is a good example of a tree spared during clearing because of its hard wood. Trees are also spared because of their usefulness. Most of them are sources of non-timber forest products such as *Irvingia gabonensis, Ricinodendron heudelotii, Garcinia kola* and *Allanblackia floribunda* or are medicinal plants like *Alstonia boonei, Picralima nitida* and *Annickia chlorantha*. Some trees are spared because they can be used as building material later as is the case with some mahogany species (*Entandrophragma* spp.) and other important timber species.

3.2.3 Burning

Fire is set on plant debris which had been gathered somewhere in the plot. Foresta (1984) recognizes four main effects of fire in shifting cultivation. Fire helps to create free space in the cumbersome environment of the plot after clearing and felling. It burns trunks of trees as well as branches and other plant remains. The farmers use fire to kill some big trees. In this case, plant debris is gathered at the base of the tree and set on fire. Fire also plays an important role in the fertility of the soil. It contributes to transfer albeit temporarily the mineral elements stored in woody stems and branches to the soil in the form of ashes which Lebrun & Gilbert (1954) consider an easily absorbable form. However, while on one hand the soil is enriched in mineral during burning, on the other hand there is loss of nitrogen and sulfur. Fire contributes to minimize the crop infestation because high temperatures may kill some plant parasites and phytophagous insects. The last effect of fire is the destruction of plant residuals and part of the seed bank of the soil and at the same time the elimination of most competitors before planting.

In some cases and depending on the type of crops the farmer will plant in his field, more than one burning is done plant remains are set on fire again if they did not burn well.

3.2.4 Cropping

Cropping comprises planting, weeding and harvesting and is done by women. With the arrival of the rains, when the plot has already been burnt, planting takes place using machetes and hoes. Many types of crops are planted in a sequential way. The first crop to be planted after clearing is *Cucumeropsis mannii* (white-seed melon). The field for the white-seed melon, a creeping plant, does not need to be burnt exhaustively as branches and old stems of trees cut during clearing serve as supporting poles. In the next cropping season, the same field is cleared and *Arachis hypogaea* (groundnut) is planted. The farmer can also clear an abandoned field or secondary forest to plant groundnuts. Planting of groundnuts requires a special preparation of the plot. Any shading plant must be cleared, and more than one burning must be done in order to avoid any obstacle that may negatively affect the growth of groundnuts. The preparation of groundnut planting includes building a fence and even setting traps around the field to avoid rodents to destroy the crops. The fence building and trap setting are done by men. The planting of groundnuts is exclusively done with hoes as community work by women with their daughters or friends. *Musa paradisiaca* (plantain banana), *Manihot esculenta* (cassava), *Xanthosoma sagittifolia* (cocoyam) and other crops are planted after harvesting of the groundnut. *Musa paradisiaca* and *Manihot esculenta* are not so demanding in terms of cultivation because they can withstand weeds. Planting of banana can also take place at the same time as *C. mannii*. Plantain can last long in the field. The farmer will need only few visits to the field to monitor its growth and no special weeding is required. This step can already be considered the beginning of secondary succession. However, in case the farmer wants to have a permanent banana field, he will maintain the field by eliminating shoots, sprouts and weeds using a machete. For good growth and yield of the crops, weeds are suppressed and eliminated as well as new shoots and sprouts from trees and shrubs that had been cut during clearing and felling. For groundnut fields, weeds are completely removed with their roots about two months after planting. These fields are more infested by weeds the abundance of which is related to the nature of the previous vegetation (young secondary forest).

Harvesting ends the cropping step. For the harvest of *C. mannii* and *A. hypogaea* farmers require help of their children or friends. Later maturing crops such as plantain and cassava, the farmer harvests himself gradually, according to his need (financial, food and other) and the maturity time of the crop. These crops are not in competition with weeds because their stems are higher.

3.3 Land tenure

Shifting cultivation in southern Cameroon is practiced by most of the local farmers. Access to land for agriculture follows traditional rules.

In southern Cameroon like in various parts of the country, there are people from different ethnic groups. Depending on whether the farmer is a native of the area or not, the access to land will not be the same and this factor can partly justify his farming technique. Land tenure is a serious and delicate problem in southern Cameroon. Land belongs to the first person (native) who cleared. For people belonging to the same family, “land belongs to the dead, the present and the unborn” (Diaw 1997). The same land can be farmed by many households only if they have the same family roots or kin. Land is shared in parallel lines from the village towards the dense forest. This system helps to avoid conflict between villagers (Carrière 1999). Every year, new farms are created at the detriment of mature forest in such a way that young fields are far from the village and the old fallows are nearby. In case members of the same household do not have mature forest in their plot anymore, they will convert a former field (fallow) into a new one.

It is difficult for non-natives to claim ownership of land. It is not possible to buy land because tradition does not allow such a transaction between a non-native and an individual instead of the community (Diaw 1997). However, a native can allocate a plot of land to a “stranger” to cultivate for a well determined period. Non-natives have few plots with fields of different ages. Given that they do not have easy access to land, meaning mature forest, the probability of converting a former field abandoned few years ago to a new one is therefore higher for them than to the natives. Also old native farmers, who do not have the means to hire a worker, rely mostly on their former farms where clearing is not so difficult because they are physically not fit enough to clear a dense mature forest.

Chapter 4: Method

4.1. Trends in vegetation study

The choice of a method is essential in the study of vegetation. This method depends on the structure of the vegetation. There are two conceptions or trends in study of vegetation: the discontinuous and the continuous trends.

4.1.1 The discontinuity trend

This tendency was largely developed in Europe. According to this trend, the vegetation is made of distinctive vegetation units which change from one region to another. Disciples of this trend however use different criteria to define vegetation units what lead to the raising of different schools.

4.1.1.1 The Zürich Montpellier school

According to this school, the vegetation is made of different floristic units called plant associations. A plant association is defined as a homogenous plant community and results from an analysis of relevés. Other concepts such as cover-abundance index and sociability are relevant to the Braun Blanquet system of phytosociology. For the cover-abundance index, there is a scale of 6 values with a corresponding mean value (Table 3.1).

Table 3.1: Scale of cover-Abundance of Braun Blanquet and their mean values

Index	Meaning	Corresponding mean value (%)
+	Simply present with cover of less than 1 %	0.5
1	Cover between 1 and 5%	3
2	Cover between 5 and 25%	15
3	Cover between 25 and 50%	37.5
4	Cover between 50 and 75%	62.5
5	Cover greater than 75%	87.5

This system is widely accepted and used in the field of vegetation study.

Many other authors developed ideas of this school (Pavillard 1935, Guinochet 1955, 1973, Tichy 2002).

4.1.1.2. The Scandinavian school

This school was created and based in Uppsala. If the plant association under the Zurich Montpellier School is an abstract unit, in this case it is considered as a concrete entity made of constant species. The phytosociological unit is defined by its constant species which therefore is responsible of its physiognomy.

4.1.1.3. The Russian school

Developed by Sukatchev (1943), adepts of this school give more weight to phytocoenocis concept. Plant association is defined as a natural unit with focus on relationships amongst species and between species and their natural environment.

4.1.1.4 The Anglo-Saxon school

Concepts relevant to this school were developed by American and English ecologists such as Clements and Tansley. Tansley (1934, 1954) defined plant formation as an entity essentially constituted by the habitat and which is materialised by distinct life forms. They were not satisfied with the Braun Blanquet system of vegetation classification. Disciples of this school also rely of floristic criteria like in the Zurich Montpellier School but they mainly use dominant species or dominant species groups to vegetation classification (Whittaker 1962 cit. Mueller-Dombois & Ellenberg 1974).

4.2 The trend of continuity

This trend was mainly developed by North American ecologists such as Curtis, McIntosh and Whittaker. They consider plant species and its habitat individually. Vegetation is not made of different units. There are gradual vegetation changes without any boundary between two communities.

From the views developed by each trend, there is change in vegetation and it is the acceptation of these changes which matters. In fact, if the vegetation is made of distinct floristic units, the difference is due to changes in properties of the environment (soil, climate) which take place in a gradual manner. Finally, the two trends in vegetation ecology instead of being opposite are complementary.

4.3 Choice of a method

Despite the fact that it had been criticised, the Braun Blanquet method remains widely used in the field of phytosociology. It is applied with some improvements either in its cover abundance index (van de Maarel 1975, 1979) or by including the concept vegetation synusia (Gillet 1986, Yongo & Foucault 200 1). However, the aim of choosing one of the methods depends to the objectives the researcher wants to meet. In the present study, the Zurich Montpellier school method was used.

4.4 Data collection

4.4.1 Approaches in study of secondary successions

The study of secondary successions can be done under two main approaches which are diachronic and synchronic.

Under the diachronic approach, forest reconstitution is permanently analyzed according to a regular frequency. Following a well defined study program or calendar, a census of both plant species and environmental parameters is made to assess temporal variations. This approach has the advantage that the age of the fallows or a gap is absolutely well known and enables to follow the establishment of different species and to assess change of the floristic composition. It is possible to know the sequential appearance and disappearance of species during succession.

Its main disadvantage is that it is time consuming and requires long period of observations, often longer than the lifespan of the investigator, which makes it almost impossible (Knight 1975).

For the synchronic approach, succession is analyzed by studying at the time, fallows of different ages. It enables to gather information on processes that took place many years ago. This method also has its limits which are:

The farmer does not record somewhere when exactly the farm was abandoned. Age of fallows is approximately estimated. Very often it is only by crosschecking events which took place in the village that the age of the fallow is determined.

The phenomena occurring between different ages cannot be clearly analyzed. Some dynamic details are missed.

Despite the limits of the synchronic approach, it is this method that was used in the present study.

4.4.2 Searching of fallows and their ages

This step is one of the most difficult since it involves the commitment of farmers who are owners of fields where the study will be conducted. Generally with the help of a local guide, direct contacts are established with farmers who are most of the time women. In southern Cameroon, men help their wives especially during forest clearing. The rest of the work is deserved to women. However, there are some men who also have food crop farms.

On the site the farmer shows the fallows and answers questions regarding when the farm was created and abandoned. This exercise is hard because the farmer in many cases does not often know the exact dates or periods the farm was created and abandoned. However, from answers to other questions related to events that took place in the village (death or birth of a person, wedding, divorce, chieftaincy...) or the country (local, parliamentarian or presidential elections, resignation of the former president in November 1982, performance of the national soccer team either at the World Cup or African Nations Cup, National Immunization Campaign against a particular disease), it had been possible to determine approximately the age of each fallow. The farmers provided information on the crops which were planted and the vegetation type which was cleared before farming the plot for the last time. In southern Cameroon, a farmer can have more than one field crop. Depending on how physically he is strong, he can either come back to one of the farm he abandoned few years ago or clear a mature forest. A code was assigned to each previous vegetation type: (1) for mature forest, (2) for secondary forest and (3) for *Chromolaena* thicket.

The vegetation type surrounding the fallow in which the plot was demarcated was also considered. This vegetation type was categorized as follows: (1) for mature forest, (2) for *Chromolaena* thicket, (3) for secondary forest and (4) when the fallow was bordered on one side by forest either mature or secondary, and *Chromolaena* thicket.

The number of farming cycles in the same plot was also taken into account and codified as follows: (1) for one farming cycle, (2) for two cycles, (3) many cycles and 4 when the number of farming cycles was not known. The last case happened when the fallow owner was not present and the other fallow details were given by the relatives.

4.4.3 Soil texture

The study was carried out in a forest area where soils are known mostly to be of ferralitic type and yellow. Using an eating spoon and a machete, soil samples were collected at different points in each fallow. The minimum total number of spoonfuls was thirty. All the spoonful samples collected in each fallow were put in a plastic bag and homogenized by shaking the bag. The texture varies from sandy to clayed with all intermediate in between. The main component of the soil texture was considered and a code given as follows: sandy (1), silty (2) and clayed (3).

4.4.4 Degree of canopy closure

In each fallow, canopy closure percentage was estimated. In some fallow without trees and shrubs (*Chromolaena odorata* thickets), this percentage was zero. The assessment consisted in estimating the projection of the crown of trees on the ground.

4.4.5 Floristic composition

In each fallow, a square plot of 20 m side was demarcated in its centre. The centre was chosen to avoid border effects and overlapping in two different vegetation types.

The geographic coordinates of the plot were recorded using a GPS. The floristic inventory consisted in recording all species found in the plot. For each species found, a Braun Blanquet cover- abundance index was assigned.

Individuals of trees and shrubs of a diameter at breast high (dbh) of at least 5 cm (at 1.30 m from the soil) were taken into consideration. For trees developing buttresses and still-roots, their dbh was measured above the buttresses and still-roots.

Each plot was given a number and a name referring to its rank and region. For example, CPO_1 means plot number 1 in the Campo region. The life-form was also recorded. The classification of life-forms comprises trees, shrubs, herbs and climbers.

In the field, fertile herbarium specimens were collected. Their field identifications were confirmed by comparing them with herbarium reference specimens. Duplicate were stored at the National Herbarium of Cameroon (YA) and at the Senckenberg Herbarium of Frankfurt (FR).

4.4.6 Diameter classes

Many classifications of trees in tropical regions exist. Most of them are based on the height of erected individuals. However, due to the fact that the tropical forest is very dense, it is not easy to measure the height of phanerophytes. The presence of vines also does not facilitate the task. Letouzey (1982) proposed a classification that considers the dbh of trees (tab. 3.2).

Table 3.2: Strata classification of Letouzey (1982)

Diameter of trees or shrubs	Type of plants	Categories
5 cm $\leq$ dbh < 10 cm	Small shrubs	Lower stratum
10 cm <dbh <20 cm	Big shrubs	Lower stratum
20 cm $\leq$dbh < 50 cm	Small trees	Medium stratum
50 cm $\leq$ dbh <100 cm	Medium size trees	Upper stratum
100 cm $\leq$ dbh	Big trees	Upper stratum.

4.4.7 Precipitations

Due to the lack of meteorological centres in the study area, precipitation data considered are those of Suchel (1972, 1989). Only two localities are concerned: Campo (2797 mm) on the cost and Nyabessan (1690 mm) situated at about not less than 100 km east of Campo in the hinterland. For plots demarcated in the Campo area, precipitations of Campo were considered while for those in the hinterland, those of Nyabessan were used. The last village in the Campo area involved in this work was called small Ma’an. The Campo- Ma’an National Park is situated between Mvini (after the small Ma’an in Campo area) and Ebianemeyong (west of Nyabessan).

4.4.8 Auto ecological characters of recorded species

The auto ecological characters refer types of plants, phytogeographical distribution and types of diaspores of the species

4.4.8.1 Life-forms

Vegetation is a physiognomic concept which depends on life forms of the plants. Many life-form classifications were defined but that of Raunkiaer (1934) had a great success and is widely used. It is mostly based on the behaviour of the species during the bad season. Due to the fact that his classification was well adapted for temperate regions, it was not suitable for tropical regions where there is no winter and snow. For the present study plants were classified as follows:

Phanerophytes: plants which are more than 25 cm high (trees, shrubs and vines) and can be divided as follows:

- Nanophanerophytes (NnPh) which comprise woody individuals not more than 2 m high. Seedlings of tree and shrub species were also considered as nanaophanerophytes.
- Microphanerophytes (McPh) are individuals with height between 2 and 10 m;
- Mesophanerophytes (Meso) are tree individuals of 10 to 30 m high while
- Megaphanerophytes (Mega) are trees with a height exceeding 30 m.
- Climbing phanerophytes (Cph) which represent vines and others climbing or creeping plants

Chamephytes: sub shrubs, herbs and sub woody not exceeding a height of 40 cm

Geophytes: Plants with the most important part of the stem grows underground (rhizomes and bulbs)

Hemicrytophytes: low plants with perennial buds at floor level

Therophytes: annual plants, surviving the bad season as seeds.

4.4.8.2 Types of phytogeographic distribution

The first chorological subdivisions for Africa date from Engler (1910) cit. Lebrun (1947). After him many other authors such as Lebrun (1947), Robyns (1948), Monod (1957), and Keay (1959) suggested other phytogeographical subdivisions for tropical Africa. During the AETFAT congress held in Genoa in 1963, one main concern was to draw a vegetation map of Africa. Sponsored by UNESCO, AETFATand UNSO, a vegetation map of Africa with major subdivisions was produced by White in 1983 and had since been widely used. The phytogeographical types distinguished in this study are inspired from White (1983). The classification adopted is as follows:

Species widely distributed in tropical areas which encompass the following chorological types:

Cosmopolite (Cos): species distributed throughout the world

Pantropical (Pan): species which are found in tropical Africa, America and Asia

Paleotropical (Pal): species present in tropical Africa and Asia, Madagascar and Australia

Afromalgaches (AM): species present in Africa and Madagascar

Afroamerican (Aa): species known from tropical Africa and America

Species widely distributed in tropical Africa:

Afro tropical species (At): species present in tropical areas of Africa

Species with regional distribution in Africa and the chorological types concerned are:

Guinean (G): species present in the entire Upper Guinean region

Lower Guinea or Central Congo Guinean (LG): species with distribution stretching from Cameroon to the Democratic Republic of Congo

Cameroonian (Cam): species endemic to Cameroon

4.4.8.3 Types of diaspore dispersal

Types of diaspores' dispersal of the different species recorded in the current study were determined according to the classification of Dansereau & Lems (1957) which had been widely used in tropical Africa (Evrard 1968; Mosango & Lejoly 1987, 1990; Lubini & Kusehuluka 1991; Sonké 1998; Ngok Banak 2005). The classification is also suitable to non tropical regions (Luftensteiner 1980). The different types of diaspores' dispersal concerned are listed below:

Autochorous species: their diaspores do not possess a particular pattern of dissemination. In this case the diaspores can be either ejected by the plant (ballochory), disseminated due to their weight (barochory) or very light (sclerochory).

Zoochorous species: their diaspores are dispersed by animal. Their diaspores can be fully or partially soft or fleshy (sarcochory). They can be spiny or have adhesive organs that allow them to stick on a transport agent (desmochorous);

Anemochorous species: they are wind dispersed species. Their seeds can be winged as samara (pterochorous). The dispersal organ can be silky or featherlike (pogonochorous)

4.5 Data analysis

4.5.1 Data processing

Data collected were entered in Excel sheets. Two data matrices were created and named main matrix and second matrix.

The main matrix concerns floristic data with samples (fallows) in rows and species in columns. At the intersection of a row and column, a mean Braun Blanquet index was assigned to the species.

The second matrix concerns environmental variables with variables in column and samples (fallows) in rows. At the intersection of a column and a row is the value of the variable for the sample (fallow). The environmental variables are:

- Age of the fallow
- Number of species
- Canopy closure
- Latitude
- Longitude
- Precipitation
- Vegetation around the fallow

The vegetation around the fallow is thought to play an important role in the reconstitution of the fallow. It was ranked in the following categories:

1: forest. This concern cases where the surroundings of the fallow is made of mature forest with tall and big trees

2: *Chromolaena odorata* thicket or fallow. The surrounding in this case is made of thickets of *Chromolaena odorata*. *Chromolaena odorata* is therefore the most abundant and dominant plant species in the fallow.

3: forest regrowth or young secondary forest. It is made of shrubs and trees amongst which are *Rauvolfia vomitoria, Bridelia micrantha, Musanga cecropioides* or *Trema orientalis* as examples. In some cases, the understory is made of *Selaginella myosorus* or *Marantaceae* and *Zingiberaceae*

4: Forest and fallow. This concerns fallows which are taken into “sandwich” between forest and a fallow. The fallow can belong to the two previous categories (*Chromolaena odorata*) dominant or abundant, forest regrowth or young secondary forest.

Previous vegetation

This is all about the type of vegetation existing before farming. Farm could be created by cutting down:

1: a mature forest. This is a forest with tall and big trees. The canopy is dense and close with discontinuous strata.

2: forest regrowth and secondary forest. This is forest recovering from disturbance. The height of trees is not so important and does not exceed 15 m. The specific composition is mostly made of pioneer trees and other light demanding species. The understory is dense due to the low coverage of the canopy.

3: fallow. It is more or less similar to the previous case. However, there is a minor difference in the sense that some species are dominant: cases of *Chromolaena odorata, Pteridium aquilinum* or *Selaginella myosorus.*

- Soil texture

A scale of soil texture was established grouping them in three main categories: sandy, silty and clayed. Therefore, under sandy were grouped sandy sandy, silty sandy and clayed sandy. That is exactly the same for the two other categories (silty for sandy silty, silty silty and clayed silty and clayed for sandy clayed, silty clayed then clayed clayed).

- Region

It is about the geographic area where the sample was done.

4.5.2 Multivariate analyses

Multivariate analyses comprise both ordination and classification analyses

A constant value of 1 was added to cover abundance value of the floristic data, followed by a log transformation. This exercise aims to reduce the gap between cover-abundance classes. The two matrices were then imported in PC-ORD 5.0 for both ordination and classification analyses.

4.5.2.1 Ordination

This is the process that enables to detect amongst the environmental variables, those who have a significant influence on the floristic composition. Many ordination methods such as the Correspondence Analysis (CA) (Hirschfield 1935; Roux & Roux 1967), Principal Component Analysis (PCA) (Hotelling 1933; Goodall 1954), Nonmetric Multidimensional Scaling (NMS) (Shepard 1962, Kruskal 1964) had been developed and used in the field of ecology.

The limit of the Correspondence Analysis led to its improvement. Therefore the Detrended Correspondence Analysis (DCA) (Hill 1979a, Hill & Gauch 1980) came out and had been widely used in the field of ecology just as NMS (McCune et al. 2002). For the present study, an NMS ordination was carried out. This ordination is becoming more popular in the study of ecological communities. Contrary to some ordinations such as PCA, CA and CCA which require an assumption before carrying out the analysis, NMS has many advantages (McCune et al. 2002, Bouxin, 2004). The ordination method used in this study was NMS. Prior to this operation and following the principles of this method, a DCA was first performed to have the sample and species scores which were further used for NMS. The set up parameters of the NMS were: 250 iterations, 30 runs with real data, 249 runs with randomized data and with Sørensen distance measure.

4.5.2.2 Classification

The classification analysis aims to gather relevés into vegetation groups. The pattern of grouping takes into consideration the similarity between samples. In other words, samples with more similar floristic composition will tend to belong to the same vegetation unit.

There are many types of vegetation classification such as the Two Way Indicator Species Analysis or TWINSPAN (Hill 1979b; Gauch 1982; McCune et al. 2002) Cluster Analysis (McCune et al. 2002). The most common and widely used is the Cluster Analysis which is preferred to Twinspan.

In the current study, a cluster analysis was performed using Sørensen or Bray-Curtis as distance measure, Flexible Beta as linkage method and -0.25 as Flexible Beta value. The graph of the analysis was drawn automatically by the computer programme PC-ORD 5.0 (McCune & Mefford 2006). The maximum number of groups chosen was 8 in order to avoid having groups not well represented in terms of number of relevés. Beyond this number there are some groups made only with 2 plots; below 8, some groups are so large in terms of number of samples.

After the cluster analysis, a categorical variable was defined as group and was included in the second matrix. This refers to the vegetation unit (group) to which the sample belongs;

4.5.2.3 Diagnostic species and fidelity measures

The main concern in vegetation study is to define and name plant communities at the light of diagnostic or character species. During many decades, some authors such as Schnell (1952), Gérard (1960), Aubréville (1965) and Letouzey (1968, 1985) characterized vegetation by the most abundant and common species found in the sample area. Thanks to recent developments of computer software integrating lot of statistic methods, it becomes easy to assign a fidelity value to each species (Brueldheide, 2000, Sokal & Rohlf 1995, and Dufrêne & Legendre 1997). Out of the different fidelity measures existing in the study of ecological communities in the indicator values (IndVal) of Dufrêne and Legendre (1997) is most popular and was used in the current study. This index is available in PC-ORD 5.0 package which was used in this work. PC-ORD has the advantage that apart from performing the indicator species analysis, it carries out the Monte Carlo test. The utility of the Monte Carlo test is that it indicates to which vegetation group the species can be considered as character species. On the same time, the p values generated during the Monte Carlo test helps to choose the good diagnostic species of the vegetation community.

4.5.2.4 Diversity indices and other structural parameters

Other statistical analyses (ANOVA, Post hoc tests, LSD, correlations) were carried out using the PASW 18.0 package.

Some diversity indices and quantitative parameters were calculated and included in the second matrix of environmental variables. It is the case of:

Species richness is the total number of species per plot. It is determined by counting the number of species recorded during the floristic inventory

Shannon index (H') is calculated by the following formula $H' = -p_i \ln p_i$ where pi is the proportion of the abundance cover of each species and ln the logarithm at base "e" (Kent & Cooker 1992);

Simpson diversity index (D') is the measure of the probability that 2 chosen individuals belong to 2 different species. It follows the relation

$$D' = 1 - D$$

where

$$D = \sum Ni(Ni - 1)/N(N - 1)$$

In the formula of D, Ni is the number of individuals of specie "i" and N the total number of individuals.

The Simpson diversity index D'ranks from 0 (low diversity) to 1 (high diversity).

Pielou's evenness (EQ): this is the ratio of the Shannon diversity index over the maximum diversity and is calculated as follows: $EQ = H'/\ln S$ where S is the total number of species of the fallow (Kent & Cooker 1992);

Basal area of a fallow: this is the total sum of cross section of all individuals of all species of at least 5 cm dbh. The basal area S_i of species "i" is calculated as follows:

$$S_i = \frac{Di^2}{4} \times \pi \text{ where D is the dbh of species "i"}$$

Relative dominance (Do.r): It is the ratio of the basal area of species 'i' (Si) by the total basal area of all species (ST) times 100.

$$Do.r = \frac{Si}{ST} \times 100$$

Relative density (De.r) is the ratio of the number of individuals of species 'i' (Ni) to the total number of individuals of all species (N) times 100.

$$De.r = \frac{Ni}{N} \times 100$$

Relative frequency of a species. The frequency F_i of species “i”, is the total number of relevés in which species “i” is present times 100 and all divided by the total number of relevés. The ratio of this number to the sum of frequencies (F) of all species times 100 is the relative frequency (F.r).

$$F.r = \frac{Fi}{F} \times 100$$

Importance Value Index (IVI) (Curtis & McIntosh 1951) is the sum of relative density, relative frequency and relative dominance.

$$I.V.I = De.r + F.r + Do.r$$

Relative diversity (Di.r) is the ratio of the number of species (si) in a family to the total number of species (S) of all families multiply by 100.

$$Di.r = \frac{si}{S} \times 100$$

The species with the highest **I**VI in a vegetation unit is considered as leading dominant species for that vegetation unit. Another s index called Family Importance Value was defined by Mori et al. (1983) to assess the ecological importance of tree and shrub individuals in a plant community. Thus, FIV is calculated at plant family level as follows:

$$F.I.V = Di.r + De.r + Do.r$$

These indices help to assess the ecological importance of a species or family.

Proportion of trees. This concerns the individuals of more than 20 cm dbh and a height beyond 10 m. It’s all about number of species having trees individuals over the total number of species;

Proportion of shrubs. It is close to the previous. It takes into account individuals of less than 10 m high.

Proportion of climbers. This encompasses woody and herbaceous climbers.

Proportion of individuals. It takes into account percentage of tree and shrub individuals having (at least 5 cm dbh) of each sample over the total number of individual recorded for the entire data set.

The species richness, Shannon index, Pielou evenness, basal area, proportion of trees, herbs and climbers were afterwards included in the second matrix.

4.5.5.5 Ecological behaviour and forest types

The ecological behaviour in question refers to the guild category of different species recorded in this work. It concerns the response of the species seedlings to light and their capacity to grow under forest canopy. The classification by Hawthorne & Abu-Juan (1995) is adopted in the present study. These authors recognize three categories of plants:

The pioneers or weed trees which require light (canopy opening) for seed germination and growth of their seedlings. They are fast growing and short-lived species which die after some years. They are never found in the canopy mature forest;

The non pioneers light demander species are species which need light (canopy opening) for the germination of their seeds and their individuals are part of the canopy of mature forest;

The shade bearers or non pioneer shade bearers; their seeds germinate in the understory of mature forest where their seedlings grow normally. Many species of forest canopy belong to this group. They have a long lifespan and are called stationary species (van Steenis 1958)

Each species is assigned a forest type to which it is confined. The typology adopted follows Lebrun & Gilbert (1954) and Letouzey (1985): evergreen forest (coastal forest, biafrean forest, Atlantic forest and Congolese forest), semi deciduous forest, secondary forests and swamp forests. Another category, concerning forest species with large range was added Mosango & Lejoly (1987, 1990).

Chapter 5: Results of ordination and classification analyses

5.1 Ordination analysis

The nonmetric multidimensional scaling (NMS or NMSD) was used as ordination method and the following results were obtained: the number of dimension is 3; the final stress after the last run is 16.6 and the p value is equal to 0.004.

This analysis helped to see the distribution of plots into the different vegetation groups and to detect the ecological factors controlling floristic data. These factors can be either categorical or quantitative.

5.1.1 Importance of environmental factors

Many factors govern floristic data of the samples. The most important factors are presented in Figure 5.1 as arrows originating from a centroid. The graph is based on the ordination sample scores. The main factors are precipitation, age, canopy coverage, species richness, basal area, proportion of herbs, individuals and climbers. The results of the correlation analysis (tab. 5.1) help to understand the relationship between variables and samples as they (samples) are plotted on the ordination graph.

On the first axis (tab. 5.1), a strong positive correlation with precipitations and proportion of herbs is visible. The linear correlation coefficient of Pearson (r) is 0.65 for precipitations and 0.69 for proportions of herbs. Other variables are negatively correlated with the second matrix. They include canopy closure (-0.69), age (-0.67), proportions of woody species (-0.61) and individuals (-0.56), the basal area (-0.47) and species richness (-0.45) with its related indices (Shannon -0.62, evenness of Pielou -0.61). The rank correlation coefficient of Kendall (tau) is high for precipitations (0.53), followed by proportion of herbs (0.49). For other variables this coefficient is negative but in absolute value, they can be ranked as follows: age>canopy>proportion of woody species>Shannon index>basal area>proportion of individuals>Pielou evenness>species richness>proportion of trees. The first axis then opposes on one side precipitation and proportion of herbs with the other variables named above as it is well indicated on figure 5.1.

Although there is a correlation between floristic data and precipitations, we do not consider it because for the precipitations, only two values were available: 2797 mm for all villages situated near the coast or between Campo and Nko’elon and 1690 mm for those around Nyabessan.

Table 5.1 Results of correlation with second matrix on the three first axes

	Axis		
	1	2	3
Age	-0.67	0.19	0.04
Latitude	-0.24	0.05	0.24
Longitude	0.03	0.08	0.07
Species	-0.45	0.19	-0.07
Shannon	-0.62	0.28	-0.11
Pielou	-0.61	0.27	-0.13
Trees	-0.39	0.24	-0.15
Precipitation	0.65	0.47	0.21
Canopy	-0.69	0.46	-0.01
Basal area	-0.47	0.37	-0.10
Woody	-0.61	0.21	-0.01
Herbs	0.69	-0.31	-0.00
Climbers	-0.03	0.13	0.03
Individuals	-0.56	0.45	-0.12

On the second axis, the situation is different. The only negative correlation of r is with proportion of herbs (-0.31) while the highest positive correlation concerns precipitation (0.47), canopy closure percentage (0.46) and proportion of individuals and basal area (-0.37). Concerning the rank coefficient of Kendall tau, precipitation has the highest absolute value (0.37), followed by proportion of individuals (0.35), the basal area (0.34) and the canopy closure (0.33).

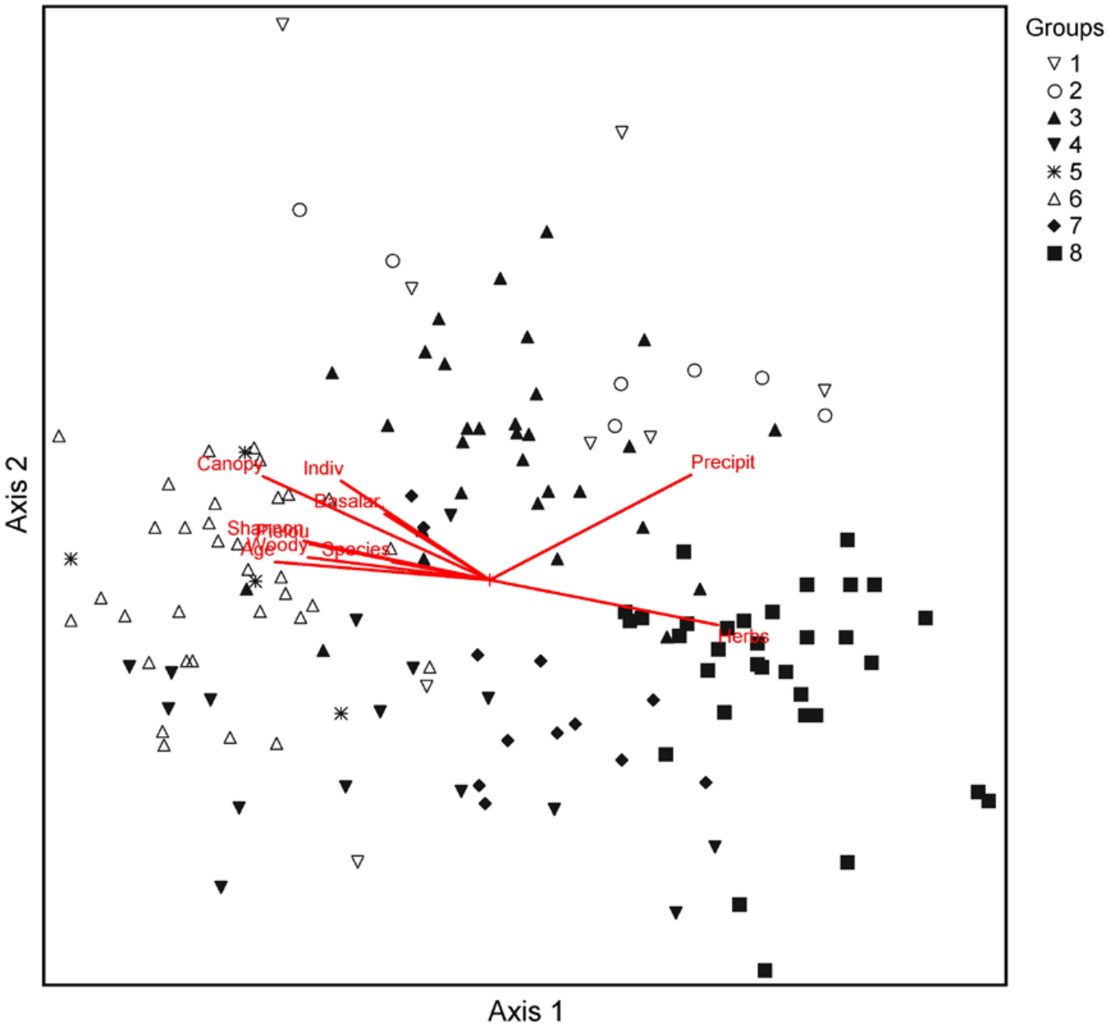
There is no real strong variable expressed on the third axis.

5.1.2 Vegetation groups

A maximum of eight vegetation groups (fig. 5.1) were distinguished in the present study. The different steps and factors controlling the discrimination of the groups will be treated in paragraph 5.2 (classification analysis). In the following, group will be abbreviated as G with e.g. group 1 as G1.

The arrows show the quantitative factors governing the discrimination of the groups such as:

- Species richness: it is high in groups on the left of the graph (G1-G3) and low in groups on the right (G7, G8); in between are groups with average richness; all plots near axis 1 (plots 2, 4, 5, 6, 137 and 138) are poor in species;
- Age: G5, G7 and G8 are made of young fallows while the others such as G1, G2 and G3 comprise a good number of old fallows;
- Canopy closure: the canopy is widely open for plots in G5, G7 and G8 while in groups of old fallows, it is becoming close;
- Proportion of herbs: this factor is high in G7 and G8 and low in G2 and G3;
- Basal area: it is low in groups on the right side of the graph (G5, G7 and G8) and high on the left (G1, G2 and G3) with intermediate situation for the groups in the middle.



A

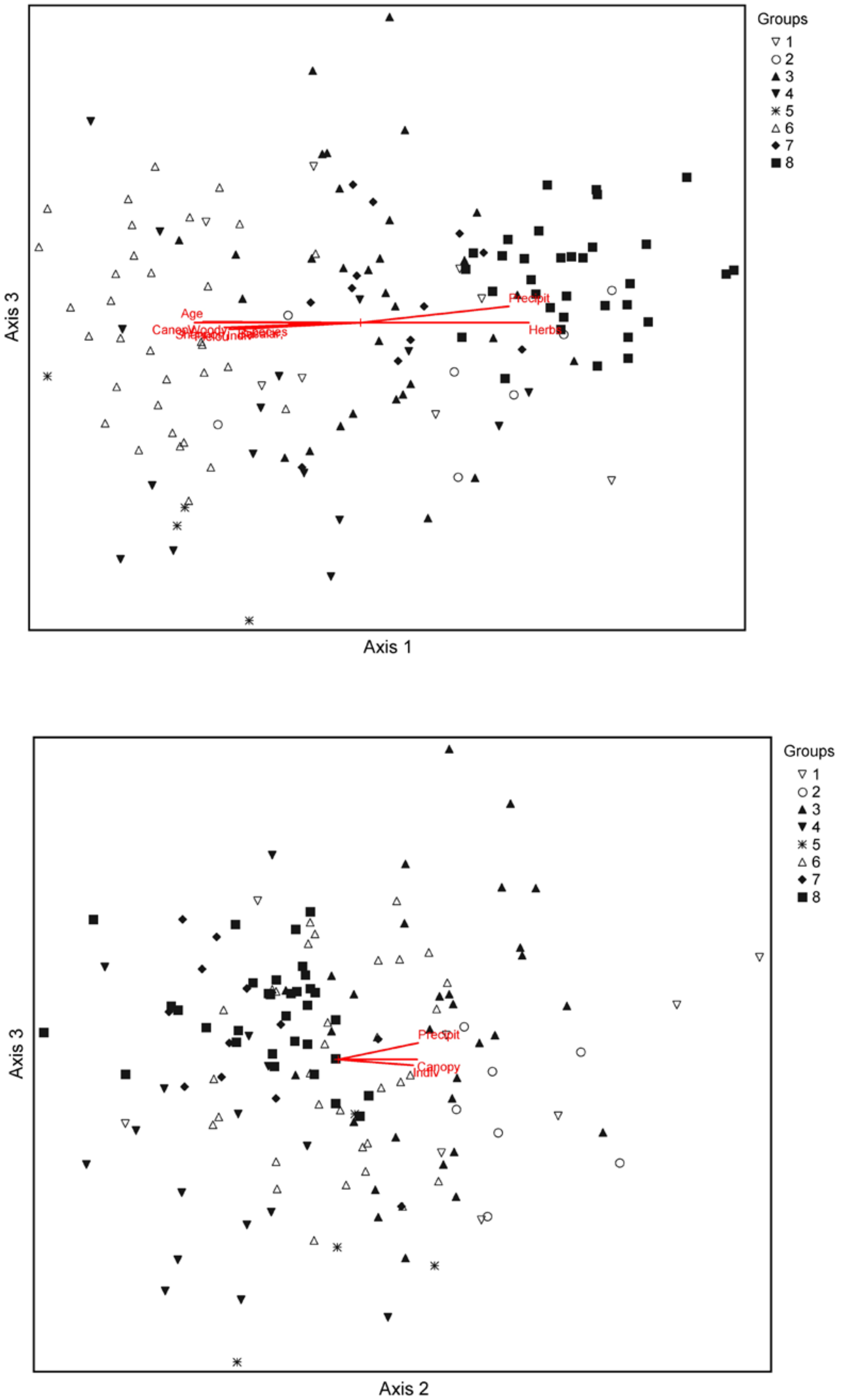


Figure 5.1: Ordination of vegetation groups along the first three axes.

5.1.3 Categorial factors

The categorical factors are vegetation type cleared before the last farming, vegetation around the fallows, number of farming cycles in the same plot and soil. These factors could not be quantified but their influence on the succession is certain.

5.1.3.1 Previous vegetation type

The previous vegetation type refers to the vegetation that was cleared before the last farming from which the studied fallow developed. The ordination graph of the previous vegetation (fig. 5.2) shows a spatial plotting of samples similar to that of the vegetation groups. The position of each sample in both graphs is exactly the same. It is obvious (tab. 5.2) that the previous vegetation was made in majority by thickets of *Chromolaena odorata* in G7 (81.3% of fallows versus 15) and G8 (68.75% of fallows).

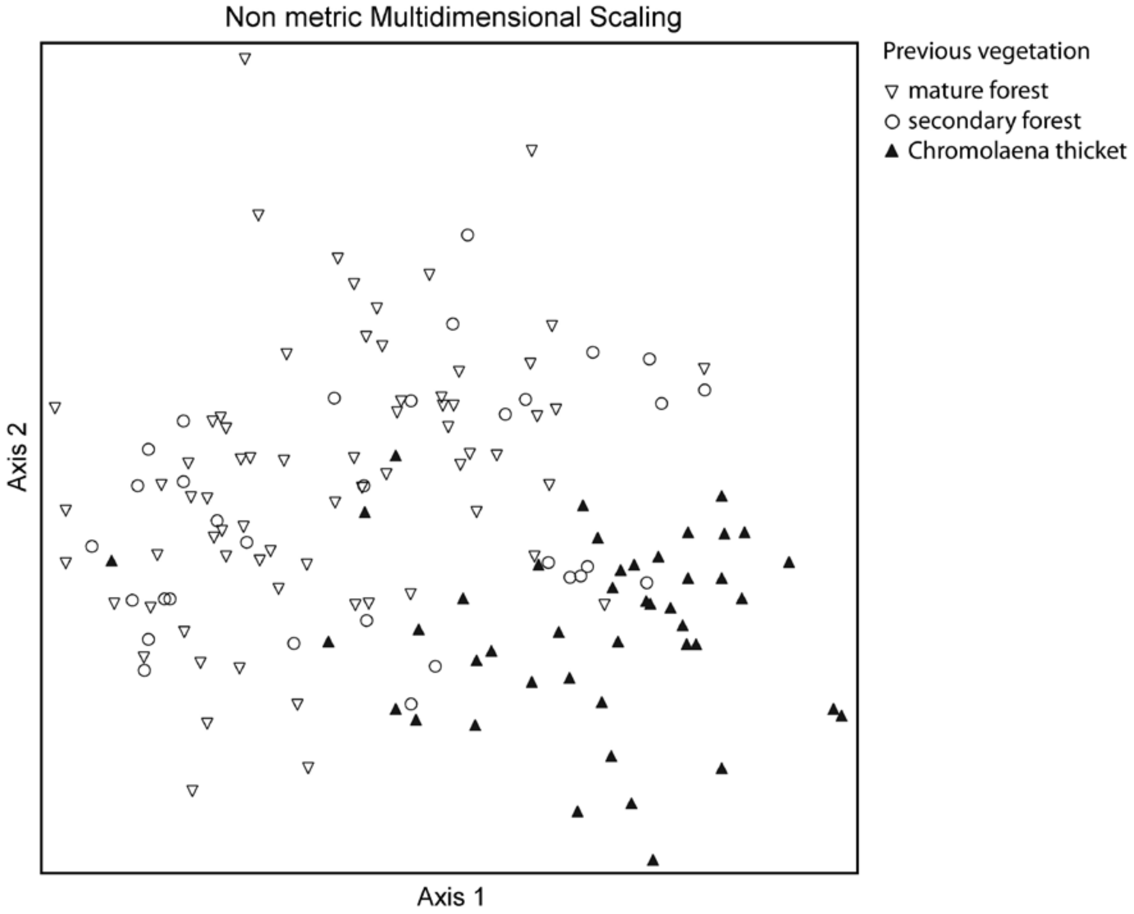


Figure 5.2: Ordination graph of previous vegetation type

All fallows of G3 and G6 were developed from fields created by clearing mature forest. In G5, 71.44% of its fallows derived from secondary forest, 14.28% from mature forest and

14.28% from *Chromolaena* thickets. In the cases of G1, G2 and G4, the majority of their fallows (62.5 to 74.07%) were made up from fields created after cutting mature forest. Very few were established on former thickets of *Chromolaena odorata* (7.40 to 8.33%).

5.1.1.2 Vegetation around fallows

Vegetation around fallows was of four types (fig 4.3): mature forest (1), secondary forest (2), *Chromolaena* thicket (3), forest and *Chromolaena* thickets (4) bordering the fallow.

All these types were observed in G2, G4, G7 and G8 (tab. 5.3) but with different proportions. Fallows bordered by forest and *Chromolaena* thicket were absent in G1, G3, G5 and G6. They represented 2.5% in G2, 9.37% in G7 and 6.25% in G8. G3 and G6 were found exclusively (100%) in a mature forest environment. Five groups (G2, G4, G5, G7 and G8) had fallows in the *Chromolaena* environment but in G5 and G7 the majority plots (43% and 56.2% respectively) were found in this vegetation type. On the opposite, G1, G3 and G6 had no fallow neighbored by *Chromolaena.* The highest number of fallows in secondary forest was observed for G2 (50%) and G8 (68.7%).

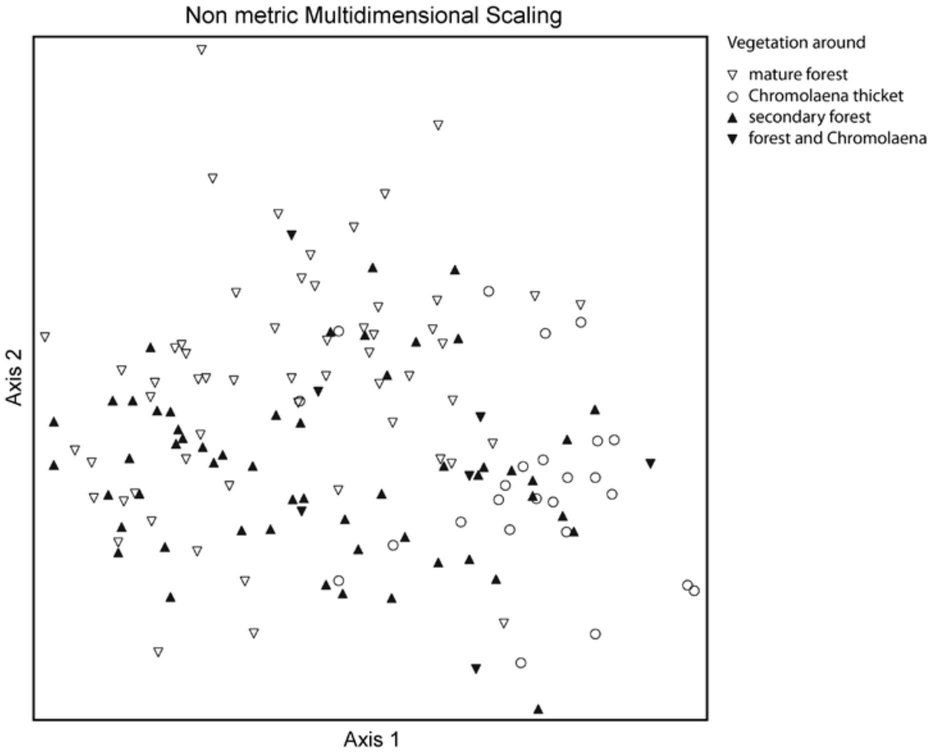


Figure 5.3: Ordination graph showing types of surrounding vegetation

Table 5.2: Proportion of previous vegetation types in the different vegetation groups

Groups	Mature forest	Secondary forest	*Chromolaena* thickets
1	66.7	25	8.3
2	62.5	30	7.5
3	100	0	0
4	74.1	18.5	7.4
5	14.3	71.4	14.3
6	100	0	0
7	3.1	15.6	81.3
8	18.8	12.5	68.7

Table 5.3: Proportion of vegetation types around the fallows

Groups	Mature forest	Secondary forest	*Chromolaena* thickets	Forest and *Chromolaena*
1	50	50	0	0
2	45	50	2.5	2.5
3	100	0	0	0
4	63	26	4	7
5	28.5	28.5	43	0
6	100	0	0	0
7	6.2	28.2	56.2	9.4
8	12.5	68.7	12.5	6.3

5.1.1.3 Number of farming cycles in the plots

The number of farming cycles refers to the number of times the same plot had been farmed before letting it rest as fallow. This could be one, two, multiple or in some cases unknown (fig. 5.4). Once again, the spatial distribution of sample distribution in this graph is similar to that of figure 5.1.

From the diagram, it is clear that many dark squares representing multiple farming cycles are concentrated on the lower right side. This part of the diagram represents groups 7 and 8.

Details on the situation in each group are presented on Table 5.3. It is obvious that G7 and G8 comprise fallows that had been regularly disturbed by multiple farming cycles with respectively 78.1% and 50% of plots in that category.

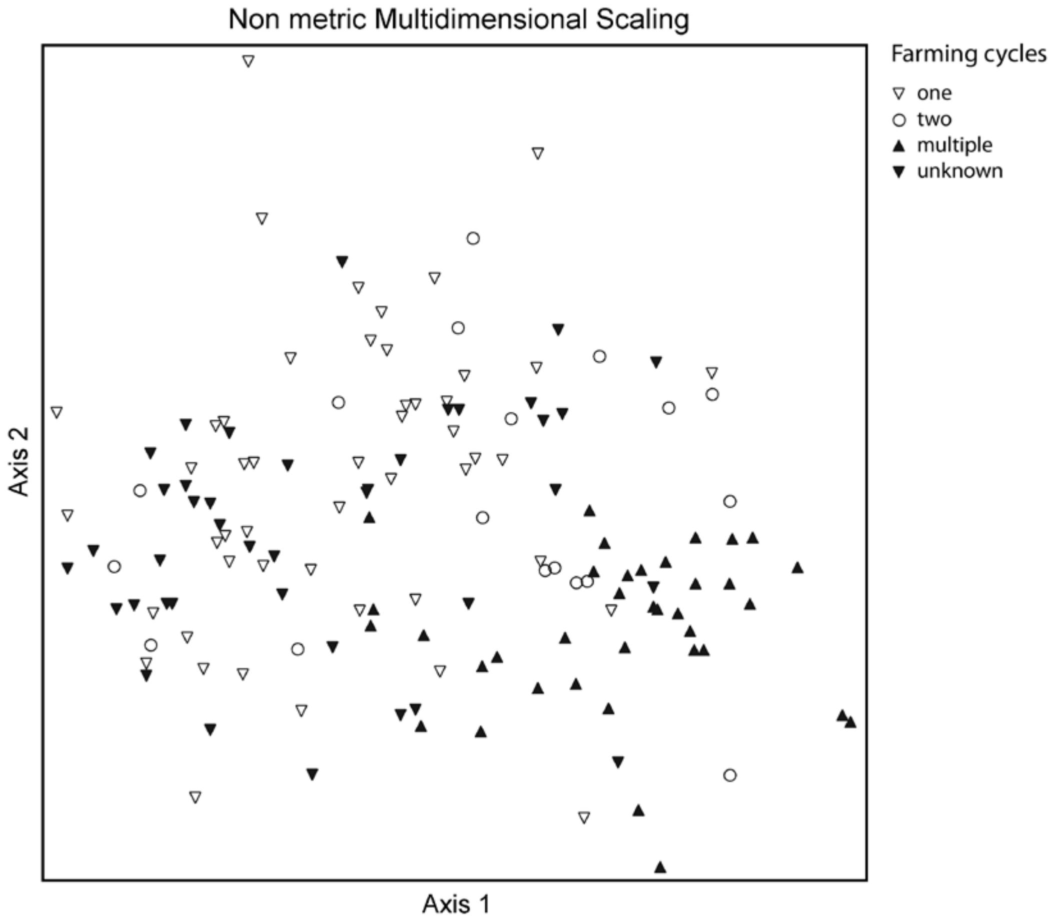


Figure 5.4: Ordination graph showing the number of farming cycles of plots

Group 5 comes in third position with 14.3% of its plots being derived from fields which had been farmed many times. The majority of plots (42.8%) forming this group (G5) were found in fields which had been farmed twice while for 28.6%, the number of previous farming could not be determined.

5.1.1.4 Type of soil

The type of soil concerns the texture of the soil on which each plot was demarcated. The ordination graph (fig. 5.5) shows the type of soil of each plot and group.

No group entirely consists of fallows established on only one type of soil (tab. 5.5). There are always at least two types of soil present. As for the other categorical variables presented before, each vegetation group has a preference for a particular type of soil. Thus, the majority of fallows from G1, G2 and G8 grow on clayey soil. 58.3 % of fallows of G1, 52.5 % of G2 and 43.8% are found on clayey soil.

Table 5.4: Number of farming cycles of the fields

Groups	Once	Twice	Multiple	Unknown
1	50	16.7	0	33.3
2	37.5	5	7.5	50
3	50	0	0	50
4	59.3	22.2	0	18.5
5	0	42.9	14.2	42.9
6	83.3	0	0	16.7
7	3.1	15.7	78.1	3.1
8	25	0	50	25

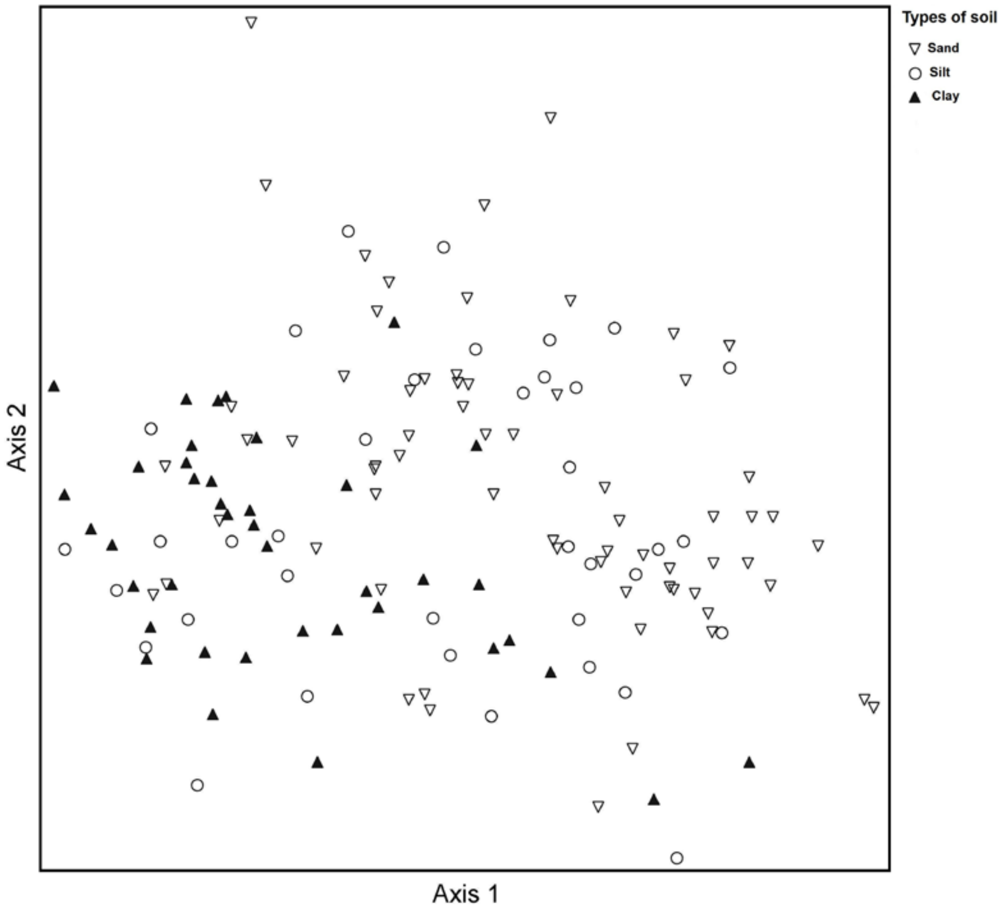


Figure 5.5: Ordination graph of soil texture

Sandy soil is substrate of 70.4% of the fallows of G4, 83.3% of G6 and 68.8% of G7. The majority of fallows on silty soil belongs to those of G3 (50%) and G5 (57.1%).

Table 5.5: Distribution of types of soil in different vegetation groups

Groups	Sandy soil	Silty soil	Clayey soil
1	16.7	25	58.3
2	25	22.5	52.5
3	25	50	25
4	70.4	26	3.6
5	43	57	0
6	83.3	0	16.7
7	68.8	25	6.2
8	31	25	44

5.2 Classification analysis

In the present study, the classification analysis helped to discriminate a maximum of eight vegetation groups (fig. 5.6). Beyond this number of eight, some groups were made only of 3 relevés and were could not be representative for any discussion.

The first division in the set of 144 relevés splits them into two main groups A and B. This division is based on the intensity of disturbance expressed by the canopy closure of the fallows. Group A is made of 48 frequently disturbed fallows with poor canopy coverage while group B is composed of 96 less disturbed fallows where there is a low to good canopy closure. Fallows in A developed in majority from fields where there had been multiple faming cycles while in B, the number of farming cycles does not exceed two.

The second division occurs within the set of less disturbed relevés of group B and gives two subsets of relevés of unequal size: 40 relevés in subset B_1 and 56 relevés in subset B_2. $B_1$is made of relatively young fallows with a mean age of is 8.1± 6.3 years. The mean age of fallows forming the subset B_2 is 17± 9.9 years, showing that it is made of relatively old fallows.

The third division occurs in subset B_1 and releases G6 which is a group of six relevés. The remaining relevés after the extraction of G6 in B1 form B'_1 which has 34 relevés. In subset B_1, the discrimination of G6 consisted in isolating old fallows from young ones. These fallows of G6 are ecologically found in periodically flooded areas. This is a group of relatively old fallows preferring sandy soil located in coastal area. Age of fallows varies from 12 to 23 years the mean being 17.3 ± 4 years. They developed from farms created by clearing mature forest (tab. 5.1). The vegetation type around all the fallows (tab. 5.2) is exclusively mature forest while for more than 80 %, there had been only one farming cycle (tab. 5.3).

The fourth division occurs in the set of 48 relevés (main group A) extracted from the first division. This set of 48 relevés is known as resulting from regularly disturbed fallows. The fourth division splits the 48 relevés into two subsets: 32 relevés for G7 and 16 relevés for G8. Group 8 has the smallest mean age 2.9 ± 1.5 years while versus 3 ± 1.2 years in group 7. The fourth division is based on the physiognomic and structural aspect of the vegetation around the fallows which were either thickets of *Chromolaena odorata* (poor canopy closure and poor number of tree and shrub individuals in G7) or secondary forest (increase of canopy closure and presence of tree and shrub individuals in G8) in most of the cases. The two groups are made of young fallows and their age does not exceed 6 year. They were former fields of *Manihot esculenta*, *Dioscorea rotundata*, *Arachis hypogaea* and *Cucumeropsis mannii.* These fallows are dominated by *Chromolalaena odorata* a Neotropical plant that has invaded many regions in tropical areas.

The previous vegetation for the majority of the fallows was *Chromolaena* thickets (tab. 5.1). They are developed from fields which were farmed many times and their surrounding vegetation was mostly dense thickets of *Chromolaena odorata* or secondary forest.

The fifth division takes places in the remaining 34 relevés of B'_1 and releases two groups G4 with 27 relevés and G5 with 7. G4 developed from former fields of *Musa paradisiaca* and *Cucumeropsis mannii* created by clearing mature or secondary forest. This previous vegetation type represents 92.6% of the fallows belonging to this group (tab. 5.1). The surrounding vegetation was for 89 % of fallows either a mature or secondary forest (tab. 5.2) while for 81.5% of them, it was the first or second time they were farmed (tab. 5.3). Age of fallows stretches from 2 to 23 years with a mean of 7.4 ± 5.3 years. The proportion of woody species is 52.4 ± 8.2%.

Group 5 is composed of 7 relevés of which 85.6% of fallows were developed from fields created by clearing mature or secondary forest (tab. 5.1). 57% of them are related to forest environment (tab. 5.2). The fields were farmed twice for 42.9% of fallows, many times in 14.2% and unknown for 42.9%. G5 is a group of former cassava fields with time since abandonment less than 5 years.

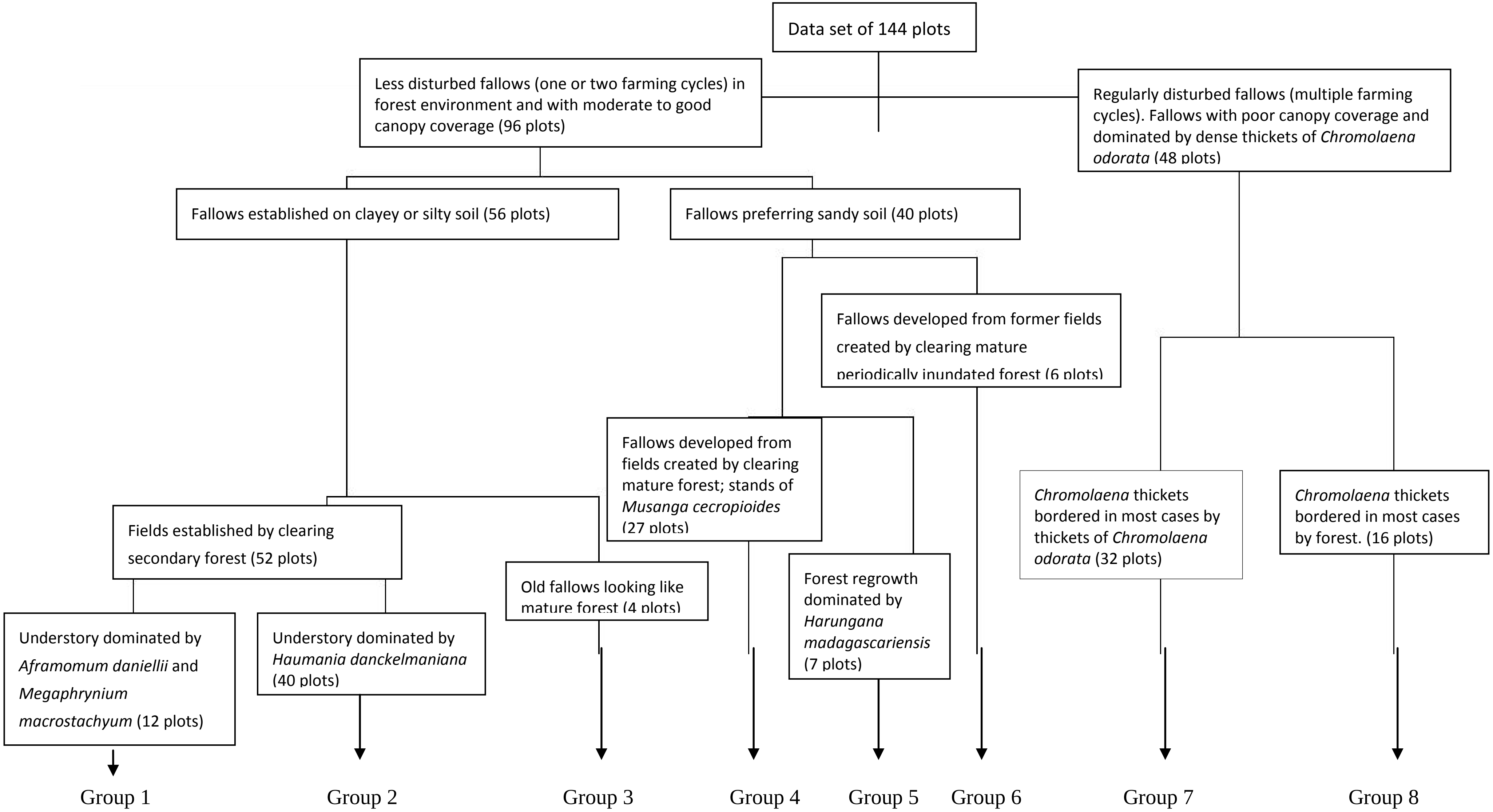


Figure 5.6 Classification tree and vegetation groups during forest recovery

The sixth division affects the subset of B_2 made of 56 plots which was obtained after the second division. This division generates a small set of 4 relevés (G3) originating from old fallows for 75% of them and another subset of 52 relevés. All the fallows are in a forest environment and emanate from fields created at the expense of mature forest. There had been only one farming cycle for 50% of the fallows. The number of agricultural cycles is unknown for the remaining 50%.

The last division occurs in remaining 52 relevés and splits them into 2 groups of unequal size regarding the number of plots. The groups are G1with 12 relevés and G2 composed of 40 all originating from fields created by clearing either mature or secondary forest in more than 90% of fallows (tab. 5.1). The surrounding vegetation can be mature or secondary forest, situation concerning all fallows of G1 and 95% of fallows in G2 (tab. 5.2). These two groups are made of relevés preferring clayey soil. This type of soil concerns 58.3% of plots in G1 and 52.5% in G2.The number of farming cycles is either one, two or unknown. Only 7.5% of fallows belonging to G2 were farmed many times.

Chapter 6: Phytosociological study of succession

In the present chapter, the eight vegetation groups distinguished in chapter five are described. Each group is studied in detail with focus on the statistics of the different quantitative variables presented in table 6.1.

In the previous chapter after the first division based on the intensity of disturbance, two main groups of relevés were distinguished: regularly disturbed and less disturbed fallows.

6.1 Regularly disturbed fallows or *Chromolaena* thickets

6.1.1 Environmental factors

Chromolaena thickets form dense vegetation that can reach a maximum height of 5 m and below their canopy, herbs and seedlings of forest tree species are growing. This growth is fast when a gap is created in the *Chromolaena* canopy. Numerous weeds and remains of some food crops such as *Manihot esculenta*, *Musa paradisiaca* and *Xanthosoma sagittifolia* are growing in the thickets.

The majority of these thickets (68.7%) develop from fallows that had been farmed many times. Fields from which these fallows originated were created by clearing dense thickets of *Chromolaena* (77.1%), secondary forest (14.6%) and mature forest (8.3%). The immediate environment surrounding these thickets is diverse and mature forest (8.3%), secondary forest (41.7%), and *Chromolaena* thicket (41.7%), or a combination of forest and *Chromolaena* thicket (8.3%). These stands of *Chromolaena odorata* occur in the entire the study area. Therefore, one can conclude that they are neither influenced by precipitation regime nor soil type.

6.1.2 Physiognomy and structure

This vegetation type is represented by 48 relevés of young fallows aged from six months to six years with a mean of 3.0± 1.3 years. In contrast to mature forests with tall trees forming a continuous cover, *Chromolaena* thickets have a scattered canopy. In many plots, there was no other vegetation layer above the canopy of *Chromolaena*. The canopy coverage reaches from 0 to 30% with a mean of 5.8± 9.1%. In 50% of relevés, no tree was found (tab.6.1).

Trees and shrubs are rare in these fallows. Some shrubs recorded during the study were resprouts developing from stumps of trees that had been fallen down when creating the field.

In the dense thickets of *Chromolaena odorata*, the proportions of woody and herb species were representing more than 75% of the total flora. The proportion of woody plants stretches between 22.6 and 94.4% with a mean of 44.4%± 12.1%, herbaceous species from 13.7 to

54.1% with a mean of 33.1%±10.8, and climbers represent 8 to 37% of species in the plots with a mean of 22.4± 6.8.

Table 6.1: Mean and standard deviation of some structural parameters of the vegetation groups

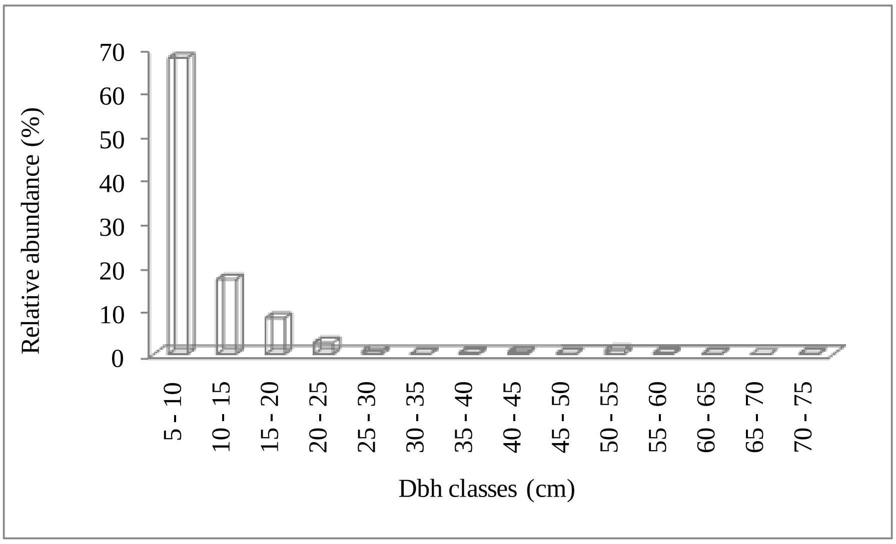
Groups	Tr	Can	B. ar.	Wdy	Hbs	Clim.	Ind.
1 Mean	51.0	42.0	20.8	55.8	22.4	21.6	0.7
Standard deviation	23.1	13.5	16.5	8.1	7.8	6.1	0.3
2 Mean	49.7	47.1	17.5	58.6	18.3	23.0	0.9
Standard deviation	14.5	15.7	12.5	7.8	5.5	6.0	0.3
3 Mean	55.6	56.2	20.6	66.5	16.1	17.2	1.0
Standard deviation	12.9	4.7	9.9	4.4	2.5	5.8	0.1
4 Mean	47.0	41.3	21.6	52.4	25.0	22.4	0.9
Standard deviation	16.8	18.9	13.9	8.2	8.1	4.9	0.5
5 Mean	46.1	16.7	6.2	49.5	27.3	23.0	0.4
Standard deviation	29.6	16.4	4.5	8.9	6.8	5.1	0.4
6 Mean	42.2	55.0	23.2	57.2	18.4	24.2	1.2
Standard deviation	6.9	15.8	13.1	5.4	8.8	5.6	0.2
7 Mean	26.7	3.8	2.1	43.2	35.5	21.2	0.2
Standard deviation	29.5	7.8	2.8	13.2	11.3	7.4	0.3
8 Mean	29.4	9.6	5.4	46.8	28.3	24.7	0.3
Standard deviation	29.3	10.4	4.9	9.3	8.1	4.8	0.3
Chromolaena thickets together							
Mean	27.6	5.8	3.2	44.4	33.1	22.4	0.2
Standard deviation	29.1	9.1	3.9	12.1	10.8	6.8	0.3

Legend: Tr: proportion of trees; Ca: Canopy cover (%); B. ar.: Basal area; Wdy: Proportion of woody; Hb: Proportion of herbs; Clim: Proportion of climbers; Ind.: Proportion of individuals

A total of 518 individuals of trees and shrubs of at least 5 cm dbh belonging to 72 species were counted in the relevés of *Chromolaena* thickets (Annex 1.1). The shrub stratum is well diverse with 66 species (91.6%) reaching a maximum height of 6 - 7 m. 483 of these individuals (93.2%) are shrubs and their dbh does not exceed 20 cm (fig. 6.1).

The individuals of the shrub layer are sparsely distributed, making this stratum difficult to be highlighted. The most abundant species shrubs are forest pioneers (tab.6.2).

Anthocleista schweinfurthii, Macaranga hurifolia and *Musanga cecropioides* have both high abundance and dominance. *Rauvolfia vomitoria, Myrianthus arboreus* and *Trema orientalis* are abundant but not dominant. *Harungana madagascariensis* and *Margaritaria discoidea* are not abundant but show a high dominance (tab.6.2).



`Figure 6.1: Distribution of tree and shrub individuals according to dbh in` *`Chromolaena`* `thickets`

The lower tree stratum has a total of 25 individuals belonging to 12 species and their height does not exceed 12 m and their dbh ranks from 20 to 50 cm. Each species is represented by a single stem in this vegetation layer, except *Elaeis guineensis, Musanga cecropioides* and *Pycnanthus angolensis* which have five individuals each and are the most dominant.

Table 6.2 Abundant and dominant species in the shrub stratum

Species	Relative abundance (%)	Relative dominance (%)
Anthocleista schweinfurthii	12.6	10.5
Macaranga hurifolia	9.5	6.4
Musanga cecropioides	9.1	9.9
Rauvolfia vomitoria	6.8	2.6
Myrianthus arboreus	6.4	3.3
Trema orientalis	4.3	3.2
Harungana madagascariensis	3.1	8.8
Margaritaria discoidea	1.9	7.2

The medium tree stratum has 8 species and 9 individuals. In this stratum, the largest tree is an individual of *Coelocaryon preussii* which has a dbh of 73.8 cm and a relative dominance of 17.8%.

The basal area is equal to zero in eight plots and less than one m² per ha in 10 other plots. The mean value of the basal area is 3.2± 3.9 m² per ha and the highest is 15.1m² per ha (relevé 96).

Table 6.3: Mean cover, relative frequency and indicator value of key species of *Chromolaena* thickets

Species	Mean cover	Rel. Freq	IndVal	p
Chromolaena odorata	49.6	100.0	55.1	0.001
Stachytarpheta cayennensis	0.2	41.6	33.8	0.004
Asystasia gangetica	0.25	50.0	30.7	0.006
Phyllanthus amarus	0.2	56.2	29.0	0.01
Triumfetta cordifolia	0.4	37.5	36.9	0.013
Fimbristylis hispidula	0.09	18.7	28.1	0.022
Axonopus compressus	0.1	39.5	21.4	0.03
Pteridium aquilinum	3.0	21.8	21.8	0.053
Oxalis barrelieri	0.1	29.1	17.0	0.099
Paspalum conjugatum	0.1	33.3	14.4	0.162
Alchornea cordifolia	4.1	84.3	22.0	0.434
Anthocleista schweinfurthii	1.3	71.8	9.0	-
Ipomoea involucrata	2.6	79.1	13.0	-
Manihot esculenta	0.9	66.6	18.0	-
Nephrolepis biserrata	1.5	75.0	4.0	-
Selaginella myosorus	4.2	40.6	7.0	-

6.1.3 Phytosociological characterization of *Chromolaena* thickets

6.1.3.1 Species cover and constancy degree

Species cover in the thickets shows a high variability. The majority of the species (97.6%) have a mean cover of less than 1%. *Chromolaena odorata* is the species with the highest cover. The mean cover of the remaining species varies between 1% and 4.2% in table 6.3.

79.2% of all species recorded are rare and found only in few relevés while very few (2.8%) are found in several relevés. *Chromolaena odorata* is the only species with a frequency of 100%.

6.1.3.2 Diagnostic species

Chromolaena odorata has the highest indicator value, 55.1 with a p-value of 0.001 (tab. 6.3). *Asystasia gangetica, Axonopus compressus, Fimbristylis hispidula* and *Stachytarpheta cayennensis* have good indicator and p-values. With *C. odorata* they represent the diagnostic species of the thickets. The table shows that frequent species are not necessarily indicator species. Character species are not automatically the most common or dominant species (Chytrý et al. 2002). For instance *Alchornea cordifolia, Anthocleista schweinfurthii, Nephrolepis biserrata, Pteridium aquilinum* and *Selaginella myosorus* are not character species although they have a good presence degree. Many of the diagnostic species are ruderal species or weeds.

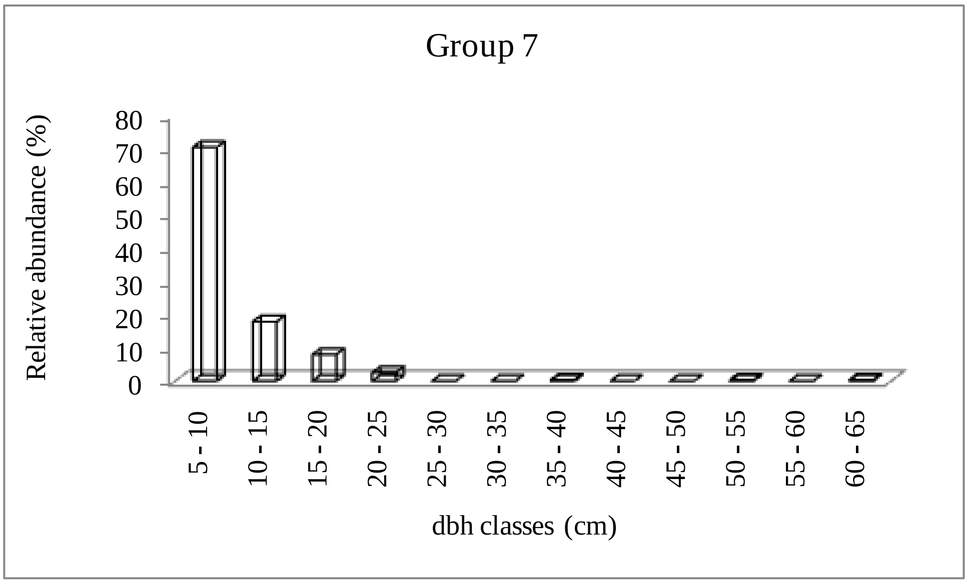
6.1.3.3 Existence of vegetation subunits in the *Chromolaena* thickets

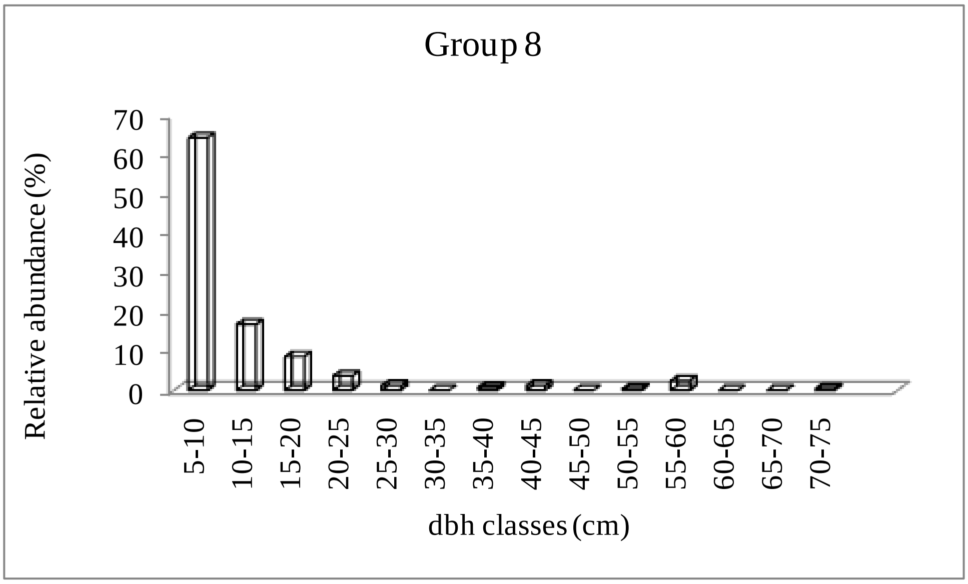
The *Chromolaena* thickets can be divided into two subgroups as already mentioned in chapter 5. The fourth division in chapter five splits the set of 48 relevés constituting the *Chromolaena* thickets into two groups, 7 and 8. This division is based on the canopy cover. Group 7 has a mean canopy cover of 3.8% versus 9.6% for group 8 (tab.6.1). Structural factors including the proportion of woody species, herbs and climbers, oppose the two subgroups. The mean of the proportion of herbs is higher in group 7 (35.5%) than in group 8 (28.3%). However, the proportion of woody species is higher in group 8 (46.8%) than in group 7 (43.2%) and a similar tendency can be observed for canopy cover (9.6 in group 8 and 3.8% in group 7), basal area (5.4% in group 8 versus 2.1% in group 7) and proportion of climbers (24.7% in group 8 and 21.2% in group 7).

6.1.3.3.1 Structural evidence of two groups in the thickets

The main difference between the two subgroups is of structural nature (annex 1.2 and 1.3). The number of tree and shrub individuals with a dbh of at least five cm is higher in group 7 (273) than in group 8 (244). However, the number of fallows is not the same in the two groups. Therefore the density of trees and shrubs of not less than 5 cm dbh is 263 stems per ha in group 7 and 469 stems per ha in group 8.

The difference between the two groups is also expressed in the distribution of tree and shrub individuals according to dbh as shown in figure 6.3.





`Figuress 6.3: Dbh classes of trees and shrubs in` *`Chromolaena`* `groups`

Dbh classes between 5 and 20 cm show almost the same trend in the two subgroups (fig. 5.3). The dbh classes 25-30 cm, 30-35 cm, 40-45 cm and 55-60 cm do not have any individual in group 7 while they are represented in group 8 where the largest tree has a dbh of 73.8 cm.

The other structural factor separating the two groups is the basal area. In group 7, the total basal area of trees and shrubs recorded is 2.6 m² per ha while it is 9.5 m² per ha in group 8, being almost four times higher than in group 7.

6.1.3.3.2 Categorial environmental factors

The other differences between the two vegetation groups concern environmental factors (previous vegetation, vegetation around the thickets, farming cycles and soil types). These factors have been presented in the previous chapter.

Mature forest was the previous vegetation for 3.1% of the fallows in group 7 and 18.8% in group 8. In 15.6% of the plots in group 7, the previous vegetation was a secondary forest versus 12.5% in group 8.

Mature forest is the vegetation around 6.2% of the fallows in group 7 and 12.5% of the fallows in group 8. Secondary forest is bordering 28.1% of the fallows in group 7 and 68.7% in group 8. In 56.2% of the fallows in group 7, the surrounding vegetation consists of *Chromolaena* thickets versus only 12.5% in group 8. In group 7, 9.4% of the fallows and 6.2% in group 8 are bordered by forest on one side and *Chromolaena* thickets on the other.

Farming cycles: There had been only one farming cycle for 3.1% of the fallows in group 7 and 25% of the fallows in group. In group 7 some fallows (15.7%) had been farmed twice. Multiple farming cycles had taken place in 78.1% of the fallows in group 7 and in 50% in group 8. The number of farming cycles was unknown for 3.1% of the fallows in group 7 versus 25% in group 8.

The majority of the fallows (68.8%) in group 7 are found on sandy soil while in group 8 many fallows (44%) are established on clayey soil (tab.6.5).

6.1.3.3.3 Diagnostic species

Apart from *Chromolaena odorata* which is the most dominant species in the thickets, all diagnostic species shown in table 6.3 characterize only one of the two groups distinguished in these thickets. Some of the indicator species are not indicated in this table.

For group 7 the diagnostic species include *Asystasia gangetica*, *Axonopus compressus, Fimbristylis hispidula, Phyllanthus amarus* and *Stachytarpheta cayennensis*. The highest values are observed for *Stachytarpheta cayennensis* (33.8) and *Asystasia gangetica* (30.7). In group 8, the diagnostic species comprise *Celosia trigyna*, *Clerodendrum buchholzianum, Cyperus diffusus, Dioscorea bulbifera, Lygodium smithianum, Piper umbellatum, Trema orientalis*, *Triumfetta cordifolia* and *Xanthosoma sagittifolia.* The most important indicator values we calculated are for *Triumfetta cordifolia* (36.9), *Trema orientalis* 27.6) and *Celosia trigyna* (27.5).

6.2 Less disturbed fallows

Plant communities or vegetation groups (group 1 to group 6) represented by 96 relevés are found on the left side of the classification tree (fig. 6.2). These groups comprise fallows established on all types of soil and are situated all over the research area. They can be named as:

- Group 1 with *Myrianthus arboreus* in the tree layer and *Aframomum daniellii* and *Megaphrynium macrostachyum* in the understory

- Group 2 with *Macaranga barteri* and *Haumania danckelmaniana*;
- Group 3 with *Dichostemma glaucescens* and *Laccosperma secundiflorum*;
- Group 4 with *Funtumia elastica, Rauvolfia macrophylla* and *Jateorhiza macrantha*;
- Group 5 with *Harungana madagascariensis, Selaginella myosorus* and *Ipomoea involucrata*;
- Group 6 with *Xylopia aethiopica*.

6.2.1 Group with *Myrianthus arboreus, Aframomum daniellii* and Megaphrynium *macrostachyum* (group 1)

6.2.1.1 Categorial environmental factors

Group 1 is represented by 12 fallows of different ages. Their ages range from 3 to 35 years with a mean of 16.5± 9.6 (tab.6.1). This group was found in forest environment and established on all types of soil (tab. 5.5) but with preference for clayey soils (58.3%). For 91.1% of the fallows (tab. 5.2), the previous vegetation was mature (66.7%) or secondary forest (25%). The remaining 8.3% developed from plots created by clearing *Chromolaena* thickets.

Half of these fallows were surrounded by mature forest and the remaining by secondary forest (tab. 5.3). *Chromolaena* thickets were not found in the vicinity.

In group 1, no agricultural activity had been carried out in 50% of the plots versus one farming cycle in 16.7%. The number of farming cycles was unknown for 33.3% of the plots.

6.2.1.2 Physiognomy and structure

The vegetation type in group 1 is a secondary forest with tall trees reaching a height of 25 m. These fallows were found in the Nyabessan – Ma'an area. The canopy coverage is average to medium. Values of canopy closure rank from 30 to 65% with a mean of 42.0± 13.5%. The proportion of climbers is between 12.9 and 33.3% with a mean of 21.6± 6.7% and herbs represent 9.8 to 33.8% with a mean of 22.4± 7.8%. Trees and shrubs represent almost half of all species in this stage of forest recovery. Their individuals are spatially distributed according to the herb, shrub and tree strata.

The herb stratum can reach 3 to 4 m with tall stems of Zingiberaceae represented by *Aframomum daniellii*. *Aframomum daniellii* and *Megaphrynium macrostachyum* are dominant in the herb layer and leave only little space to other species. Other herbaceous species become important where there is an opening in the tree layer. In such conditions, species like *Acroceras zizanioides, Centothecca lappacea, Pollia condensata* and *Palisota* spp. can be found.

The species diversity is high in the shrub and the tree strata. A total of 363 tree and shrub individuals of not less than 5 cm dbh belonging to 72 species were recorded (annex 1.4).

Out of the 72 species, 67 (93%) are represented in the shrub stratum with a height of about 6 m and a dbh not exceeding 20 cm. This stratum comprises species such as *Callichilia bequaertii, Milletia macrophylla, Schumanniophyton magnificum* and *Microbesmis puberula*. Table 6.4 shows that the most abundant and dominant species are forest pioneers. Individuals of this stratum are the most abundant on the graph showing the distribution of tree and shrub individuals according to their dbh (fig. 6.4).

The tree stratum has 31 species with 56 individuals. The majority of these species (77.4%) and individuals (85.7%) are found in the lower tree stratum with heights between 15 and 18 m while their dbh does not exceed 50 cm. Most abundant species are *Anthocleista schweinfurthii, Bridelia micrantha* and *Musanga cecropioides,* all of them forest pioneers. Both the medium and upper tree strata are poor in species and individuals. None of the species is abundant, each species only represented by one individual. The largest tree both in height and girth is *Piptadeniastrum africanum,* which is a non pioneer light demanding species, with a height of ca 30 m and the only species with a dbh greater than 100 cm (dbh of 120 cm above large buttresses). This tree was spared by the farmer during clearing.

The 363 individuals of trees and shrubs recorded in the fallows of this vegetation group yielded a basal area of 22.2 m² per ha and a density of 756 stems per ha.

6.2.1.3 Species cover and constancy degree

In group 1, the following species have a mean cover greater than 1%: *Aframomum daniellii, Anthocleista schweinfurthii, Berlinia auriculata, Haumania danckelmaniana, Megaphrynium macrostachyum, Musanga cecropioides* and *Myrianthus arboreus.*

Myrianthus arboreus with a mean cover of 10.7% is the most dominant species (tab. 6.5). Its height can reach 8 m. It is also the most frequent species being present in all 12 relevés of this vegetation group. Beside *Myrianthus arboreus,* Marantaceae and Zingiberaceae are also abundant with species such as *Aframomum daniellii, Haumania danckelmaniana* and *Megaphrynium macrostachyum.* Most of the species are rare in the plots and their constancy degree is I which is the well represented on figure 6.6. The graph of the constancy degree shows that few species have a high frequency or a constancy degree of V.

Table 6.4: Abundant and dominant species in the shrub (S), lower (L) and medium tree strata of group 1

Relative abundance (%)	Relative dominance (%)					
	Strata			Strata		
Species	S	L	M	S	L	M
Myrianthus arboreus	20.1	0	0	19.7	0	0
Aidia micrantha	6.0	0	0	7.6	0	0
Tabernaemontana crassa	3.8	0	0	4.0	0	0
Milletia macrophylla	3.5	0	0	2.2	0	0
Macaranga hurifolia	3.5	6.25	0	5.8	10.8	0
Ficus exasperata	2.7	4.1	0	5.1	6.6	0
Terminalia superba	3.3	0	12.5	4.8	0	14.6
Musanga cecropioides	1.3	18.7	12.5	4.1	21.5	9.6
Bridelia micrantha	1.6	10.4	0	1.5	11.4	0
Anthocleista schweinfurthii	0.8	10.4	0	0.8	6.7	0
Pycnanthus angolensis	0.2	0	12.5	0.8	0	19.2

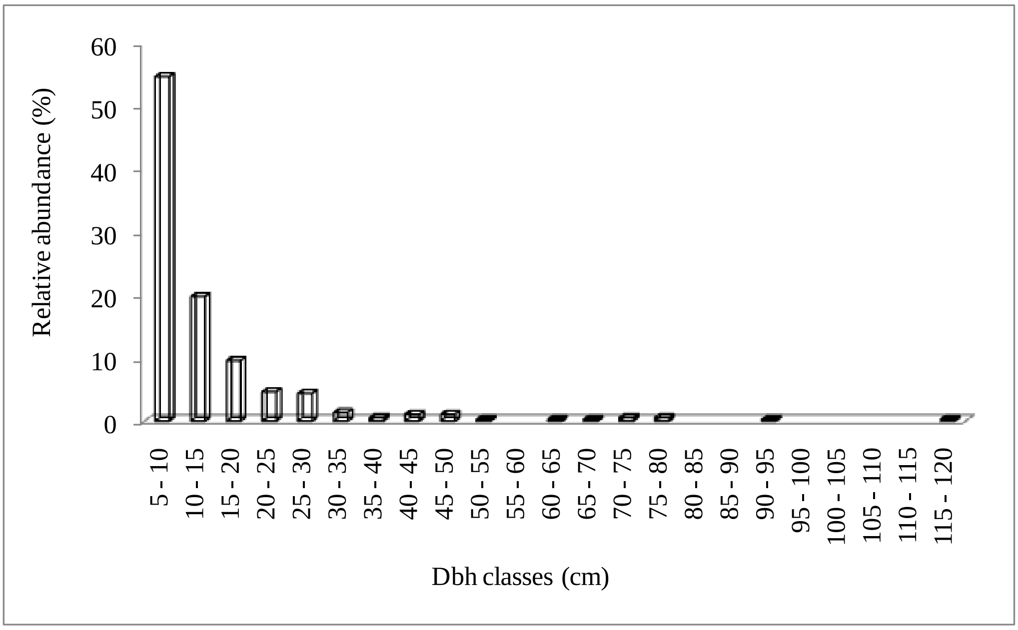


Figure 6.4: Dbh classes of tree and shrub individuals in group 1

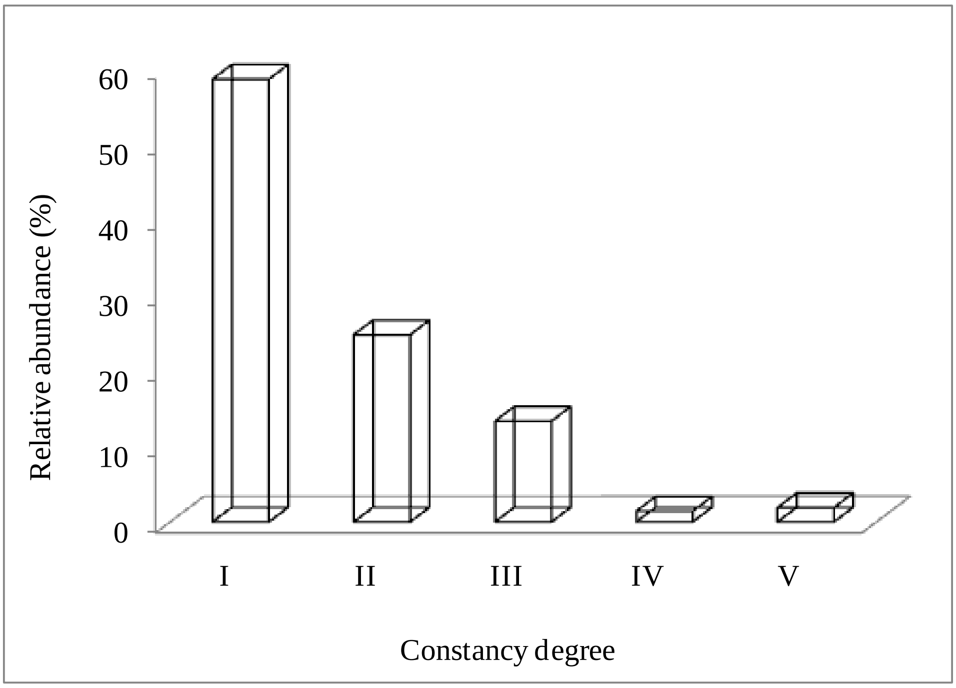


Figure 6.5: Histogram of constancy degree of group 1

Table 6.5: Relative frequency, mean cover, indicator and p values of some key species of group 1

Species	Relative frequency	Mean cover	Indicator value	p
Myrianthus arboreus	100	10.7	85.5	0.003
Aframomum daniellii	91.6	4.08	43.5	0.005
Haumania danckelmaniana	83.3	1.62	19	
Megaphrynium macrostachyum	58.3	3.9	30.7	0.016
Terminalia superba	41.6	0.41	26.7	0.038
Callichilia bequaertii	41.6	0.20	21.3	0.061
Olyra latifolia	58.3	0.29	32.2	0.011
Musanga cecropioides	58.3	1.5	4	

Table 6.5 shows that *Myrianthus arboreus, Aframomum daniellii, Megaphrynium macrostachyum* and *Olyra latifolia* have high indicator values between 30 and 85%. Because of their low p value, they are best regarded as diagnostic species of this vegetation group.

6.2.2 Group with *Macaranga barteri* and *Haumania danckelmaniana* (group 2)

6.2.2.1 Categorial environmental factors

Group 2 is represented by 40 relevés and found in localities situated between Nyabessan and Bitoto, an area under low precipitations around 1690 mm.

Most of the fallows were found on clayey soils (58.3%), less often on silty soils (25%) and sandy soils (16.7%).

Plots on which these fallows developed had been created by clearing mature forest (62.5% of cases), secondary forest (30%) and *Chromolaena* thickets (7.5%). 37.5% had been cultivated only once, 5% twice and 7.5% for more than 2 times. For 50% the farmers could not indicate the number of farming cycles. These fallows are found in a forest environment. Their surrounding was a mature forest for 45%, a secondary forest for 50% and *Chromolaena* thickets for 2.5%. The remaining 2.5% of the fallows were bordered by forest on one side and *Chromolaena* thickets on the other.

6.2.2.2 Physiognomy and structure

These fallows are of different age and 27 of them are more than 10 years old, 35 years being the maximum age. The mean age for this group is 17.5±9.9 years. This plant community is a secondary forest with moderately closed canopy where tall trees can reach a height of 25 to 30 m. The maximum canopy coverage is 75% and the minimum 12% with a mean of 47.1±15.7%.

Climbers represent 11-38% of the species found in this group with a mean of 23±6%. Herbs constitute 8 to 28% of the species with a mean of 18±5.5%. Woody species are represented with 35 to 75.6% and higher than 50% in 87.5% of the relevés with a of 58.6±7.8%.

In vertical direction, there are four main strata and the first one is formed by herbs. Herbs species are sparsely distributed in the forest. *Adiantum vogelii, Guaduella densiflora, Olyra latifolia* and *Aframomum* spp grow on the forest floor. Within canopy gaps, the diversity of herbs increases. The maximum height of this stratum coincides with that of tall stems of *Aframomum daniellii* and *A. subsericeum* and can reach 4 m. *Megaphrynium macrostachyum* is often dominant in the understory of some fallows, but less than in group 1.

In the shrub stratum (S), some individuals reach 7 m height. With up to 130 species, diversity is high. In this stratum, some species like *Alsodeiopsis mannii, Angylocalyx oligophylla, Lasianthera africana* and *Vismia guineensis* are represented by individuals of less than 5 cm dbh (annex 1.5). Out of the 1526 individuals counted in the plots of this group, 1262 (82.6%) are shrubs among which *Myrianthus arboreus, Macaranga barteri, M. hurifolia, Musanga cecropioides* and *Oncoba glauca* are the most abundant (tab.6.6). They are also the most dominant species. In figure 6.6, individuals of this vegetation stratum which dbh of 5 to 20 cm, are well represented.

In the tree stratum consisting of individuals of more than 20 cm dbh, 60 species are present with a total of 264 individuals. The lower stratum (L) where trees are 16 to 18 m high with their dbh not exceeding 50 cm is well diverse and 227 individuals belonging to 53 species are found in this stratum.

Table 6.6: Abundant and dominant species in group 2

	Relative abundance (%)			Relative dominance (%)		
	Strata			Strata		
Species	S	L	M	S	L	M
Musanga cecropioides	4.5	32.6	22.2	6.1	41.4	17.4
Margaritaria discoidea	2.2	3.5	2.7	2.4	4.0	3.9
Macaranga barteri	5.7	3.9	2.7	6.9	3.9	2.7
Aidia micrantha	3.3	3.5	2.7	4.4	3.0	2
Coelocaryon preussii	2.7	1.3	2.7	2.2	0.7	1.6
Elaeis guineensis	0.3	3.5	13.9	1.1	2.5	12.8
Macaranga hurifolia	7	7.9	0	9.7	6.1	0
Funtumia elastica	3.8	2.2	0	4.6	1.9	0
Anthocleista schweinfurthii	3.7	6.6	0	3.4	5.4	0
Anthonotha macrophylla	2.4	0.4	0	1.2	0.4	0
Canarium schweinfurthii	2.4	0.4	0	1.5	0.4	0
Tabernaemontana crassa	2.3	0.8	0	2.1	0.5	0
Xylopia aethiopica	2.2	0.8	0	2	1.1	0
Tetrochidium didymostemon	2	0.4	0	1.9	0.2	0
Myrianthus arboreus	4.2	0	0	2.6	0	0
Oncoba glauca	6.3	0	0	7	0	0

Legend: S: Shrub stratum; L: lower tree stratum; M: medium tree stratum

Table 6.6 shows that the most abundant and dominant species is *Musanga cecropioides* with a relative abundance of 32.6% and a relative dominance of 41.4%. Also important species are *Macaranga barteri, M. hurifolia, Margaritaria discoidea* and *Anthocleista schweinfurtii.* In the medium tree stratum (M), 36 individuals belonging to 23 species were recorded and some individuals can reach a height of 25 m high. The most abundant and dominant species is *Musanga cecropioides. Elaeis guineensis* which is not indicated in table 6.6 has a relative abundance of 13.9% and a relative dominance of 12.8%.

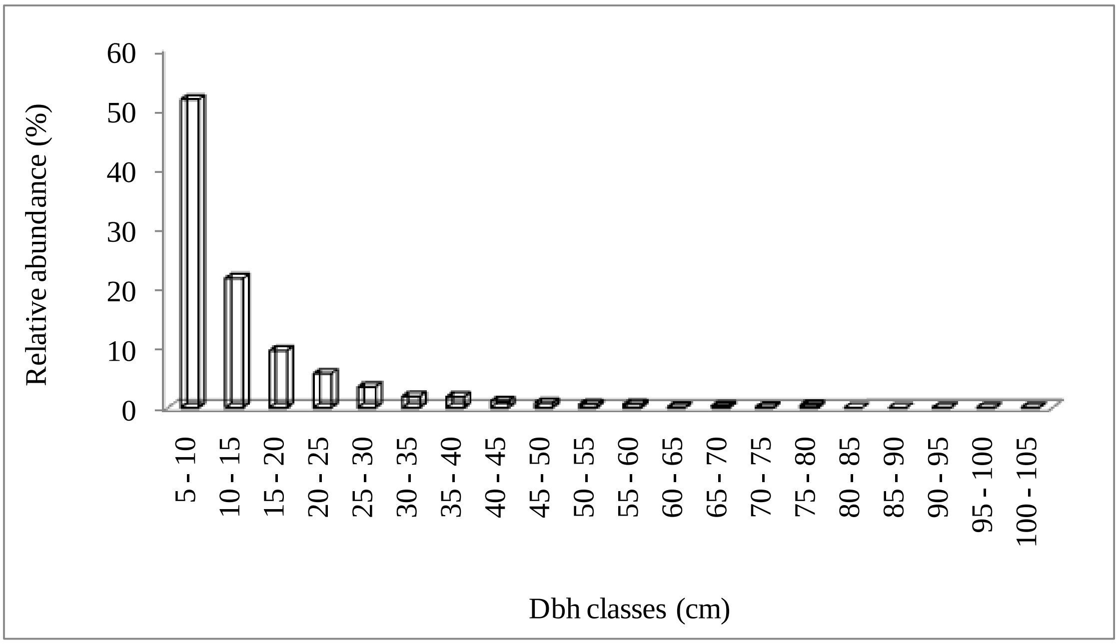


Figure 6.6: Dbh classes of shrubs and tree individuals in group 2.

The upper tree stratum rising up to 30 m high consists of a single individual of *Milicia excelsa* with a dbh of 101.2 cm found in only one relevé. This stratum is poor both in species and individuals.

The main physiognomic character of this group is the dominance of the understory by *Haumania danckelmaniana* which climbs on the trunks of trees and reaches heights of 5-6 m. It is the most important species of the vine synusiae. Other climber species are *Adenia cissampeloides, A. mannii, Artabotrys pierranus, Dalbergia grandibracteata* and *Dichapetalum* spp.

The 1526 tree and shrub individuals of the 40 relevés of this group yield a total basal area of 25.6 m² per hectare and a density of 954 stems per ha.

6.2.2.3 Species cover and presence degree

Out of the 437 species recorded for this group, only eight species show a mean cover of 1% with *Haumania danckelmaniana* having the highest value of 9% (tab. 6.7) followed by *Musanga cecropioides* (7.6%) and *Megaphrynium macrostachyum* (4.6%). *Pycnanthus angolensis, Alchornea floribunda, Bertiera aequatorialis* and *Macaranga barteri* have a low mean cover despite their high frequency. 98.1% of the species have a mean cover of less than 1%. The relative frequency is high (82.5) for *Haumania danckelmaniana* which is found in 33 of the 40 relevés. No species reaches a frequency of 100%. Other frequent species (tab. 6.7) are *Pycnanthus angolensis, Elaeis guineensis, Alchornea floribunda, Macaranga barteri, Bertiera aequatorialis* and *Musanga cecropioides,* and most of them are forest pioneers.

Table 6.7: Relative frequency, mean cover, indicator and p values of some key species in group 2

Species	Relative frequency	Mean cover	Indicator value	p value
Haumania danckelmaniana	82.5	9.0	65.3	0.001
Macaranga barteri	60.0	1.5	44.2	0.012
Alchornea floribunda	67.5	0.4	27.5	0.019
Bertiera aequatorialis	62.5	0.3	22.9	0.034
Musanga cecropioides	62.5	7.6	24.0	-
Megaphrynium macrostachyum	52.5	4.6	26.0	-
Macaranga hurifolia	57.5	3.3	22.0	-
Aframomum daniellii	57.5	2.8	25.0	-
Elaeis guineensis	70.0	2.3	10.0	-
Anthocleista schweinfurthii	47.5	2.0	5.0	-
Pycnanthus angolensis	80.0	0.46	16.0	-

The relative frequency is high (82.5) for *Haumania danckelmaniana* which is found in 33 of the 40 relevés. No species reaches a frequency of 100%. Other frequent species (tab. 6.7) are *Pycnanthus angolensis, Elaeis guineensis, Alchornea floribunda, Macaranga barteri, Bertiera aequatorialis* and *Musanga cecropioides*, and most of them are forest pioneers.

The constancy histogram (fig. 6.7) shows that more than 70% of the species are rare in the relevés (constancy degree of I) while only few of them are frequent (constancy degree of V).

Haumania danckelmaniana has the highest indicator value of 65.3 followed by *Macaranga barteri, Alchornea floribunda, Megaphrynium macrostachyus* and *Musanga cecropioides.* However, the p value is lower than 0.05 for *Haumania danckelmaniana, Macaranga barteri, Alchornea floribunda* and *Bertiera aequatorialis* which are therefore the indicator species for this vegetation group.

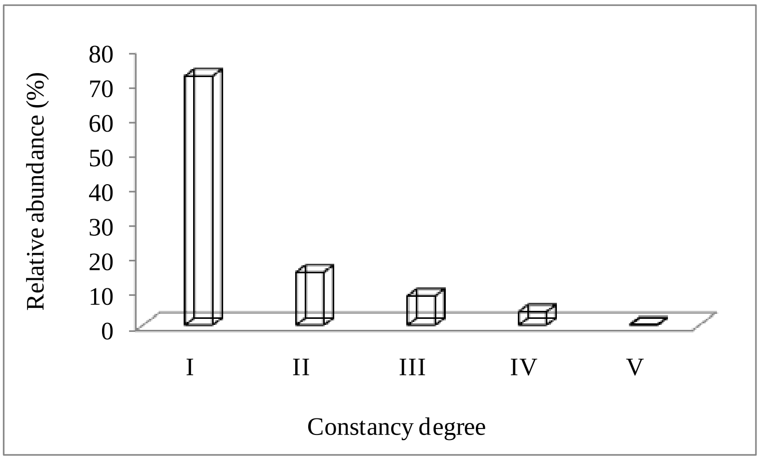


Figure 6.7: Histogram constancy degree of group 2

6.2.3 Group with *Dichostemma glaucescens, Podococcus barteri* and *Laccosperma secundiflorum* (group 3)

6.2.3.1 Environmental factors

Group 3 is represented by 4 relevés (R_{27}, R_{76}, R_{109} and R_{141}) and easily identifiable on the first two axes of the ordination graph (fig. 5.1). One was found on sandy soil, two on silty soils and one on clayey soil.

All relevés represent fallows that had been created by clearing mature forest. In two cases there had been only one farming cycle while for the two other plots the number of farming cycles was not indicated by the informants. These fallows are exclusively surrounded by mature forest.

6.2.3.2 Physiognomy and structure

Regarding the mean age, this group is the oldest of the eight groups discriminated in this study. Apart from R_{141} which is 6 years old, the others (R_{27}, R_{76} and R_{109}) are more than 10 years old. The mean age is 19.5± 13.3 years. The canopy closure stretches between 50 and 60% with a mean of 56.2± 4.7%. The heights of the tallest trees range between 25 and 30 m. The vegetation in these fallows is either a swamp forest (R_{27} and R141) or a periodically flooded forest (R_{76} and R_{109}).

The proportion of herbs is between 12.9 to 18.9% with a mean of 16.17±2.57% which is the lowest compared to that of the other groups. Woody plants comprise between 66.1 and 71.8% of all the species recorded with a mean of 66.5± 4.4%. Climber species have a proportion between 13.7 and 23.4% and a mean of 17.2± 5.8%.

Four different strata are found. The herb stratum is not species rich as in the other groups previously studied. The tallest species are *Aframomum danielli* and *A. subsericeum* with a maximum height of 4 m. Herbs are sparsely distributed on the forest floor.

The shrub stratum shows a high diversity with more than 50 species some of which, such as *Rinorea campoensis, Tricalysia gossweileri* and *Cola caricaefolia* have low dbh.

In the four relevés forming this group, 173 individuals of trees and shrubs of at least 5 cm dbh belonging to 56 species were counted of which 49 (87.5%) had 143 individuals (82.6%) in the shrub stratum (annex 1.6). Their dbh stretches between 5 and 20 cm and the graph of dbh classes (fig. 5.8) shows that they are well represented. In this layer *Dichostemma glaucescens, Tabernaemontana crassa, Macaranga hurifolia, Albizia zygia Uapaca guineensis* and *Strombosia grandifolia* are either abundant, dominant or both.

Table 6.8: Abundant and dominant species in group 3

The lower tree stratum has low diversity compared to the shrub layer. It is formed of 27 individuals of only 16 species, some of which like *Aidia micrantha, Albizia adianthifolia,* *Dichostemma glaucescens, Macaranga hurifolia* and *Tetrochidium didymostemon* are also present in the shrub layer. Apart from *Aidia micrantha* and *Musanga cecropioides,* all the species in this stratum are represented by one (nine species) or two individuals (five species). There is no real abundant species in this stratum. *Aidia micrantha* with five individuals (18.5%) and *Musanga cecropioides* with three (11.1%) are the most dominant species (tab. 6.8) with a relative dominance of 21.8% for *A. micrantha* and 19.4% for *M. cecropioides*.

The medium tree layer is poorly represented and consists of three individuals of three species which are *Celtis tessmannii, Pycnanthus angolensis* and *Ricinodendron heudelotii.* The largest tree species is *Pycnanthus angolensis* with a dbh of 82 cm.

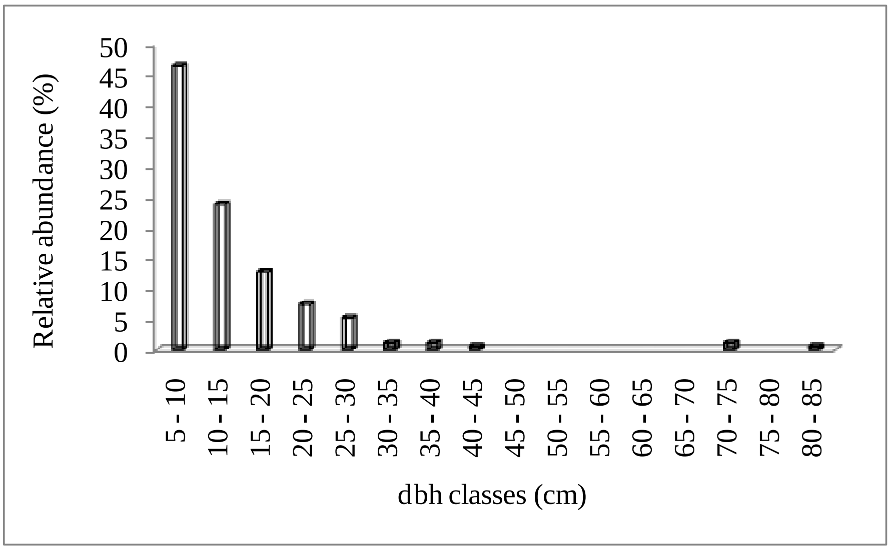


Figure 6.8: Dbh classes of tree and shrub individuals in group 3

An upper tree stratum does not exist.

The total of 173 shrub and tree individual yielded a total basal area of 35.13 m² per ha and account for a density of 1081 stems per ha.

The climber synusia is stretching between the four strata with the rattan *Laccosperma secundiflorum* as the most dominant climber species that reaches the canopy.

6.2.3.3 Species cover and presence degree

Out of the 163 species, only 11 have (Table 6.9) a mean cover higher or equal to 1%. *Macaranga hurifolia* (9.5%), *Dichostemma glaucescens* (6%), *Raphia monbuttorum* (4.5%), *Laccosperma secundiflorum* (4.1%), *Aidia micrantha* (3.9%), *Ricinodendron heudelotii* (3.9%) and *Scaphopetalum thonnerii* (3.9%) show high mean covers. *Haumania danckelmaniana, Podococcus barteri, Pycnanthus angolensis and Tabernaemontana crassa* have a mean cover ranking from 1 to 1.5%.

Table 6.9: Mean cover, relative frequency, indicator value and p-value of some key species of group 3

Species	Mean cover	Relative frequency,	IndVal	p
Macaranga hurifolia	9.5	50	6	–
Dichostemma glaucescens	6	100	98.2	0.001
Raphia monbuttorum	4.5	50	31.3	0.023
Laccosperma secundiflorum	4.1	100	87.5	0.001
Aidia micrantha	3.8	50	22	0.04
Ricinodendron heudelotii	3.9	50	48.1	0.002
Scaphopetalum thonneri	3.9	50	39.1	0.01
Pycnanthus angolensis	1.5	50	34.7	0.007
Tabernaemontana crassa	1.1	100	70.1	0.001
Haumania danckelmaniana	1	75	2	–
Podococcus barteri	1	75	64.9	0.002
Uapaca guineensis	0.5	100	46.3	0.002
Oxyanthus gracilis	0.2	50	50	0.002
Lomariopsis guineensis	0.3	75	57	0.001
Calpocalyx heitzii	0.3	75	49.7	0.001
Cola acuminata	0.9	50	44.9	0.002
Trichoscypha acuminata	0.2	50	39.2	0.001
Napolaeona vogelii	0.4	75	33.1	0.007
Antidesma membranacea	0.4	75	30	0.011
Mapania macrantha	0.2	50	29.6	0.008
Trichilia rubescens	0.4	75	27.9	0.015
Penianthus longifolius	0.2	50	26	0.011

Species with a relative frequency less than 20% (fig. 5.9) and thus a presence degree of I are absent because of the small number of relevé. 102 species (62.5%) are present in one relevé representing a relative frequency of 25%: their constancy degree is II and they are considered as rare in the relevés. 42 species (25.7%) are present in two relevés, their relative frequency is 50% and their constancy degree III. Fifteen species (9.2%) are present in three relevés which corresponds to a relative frequency of 75% and constancy degree of IV. Four species are present in all relevés: their relative frequency is 100% and the constancy degree V.

6.2.3.4 Indicator values and diagnostic species

In this group, the indicator values are high for 95 species and $p<0.05$ for 44 of these species. This is due to the fact that this vegetation group is made of old fallows and most of these species with high IndVal and good p values are not found in other groups.

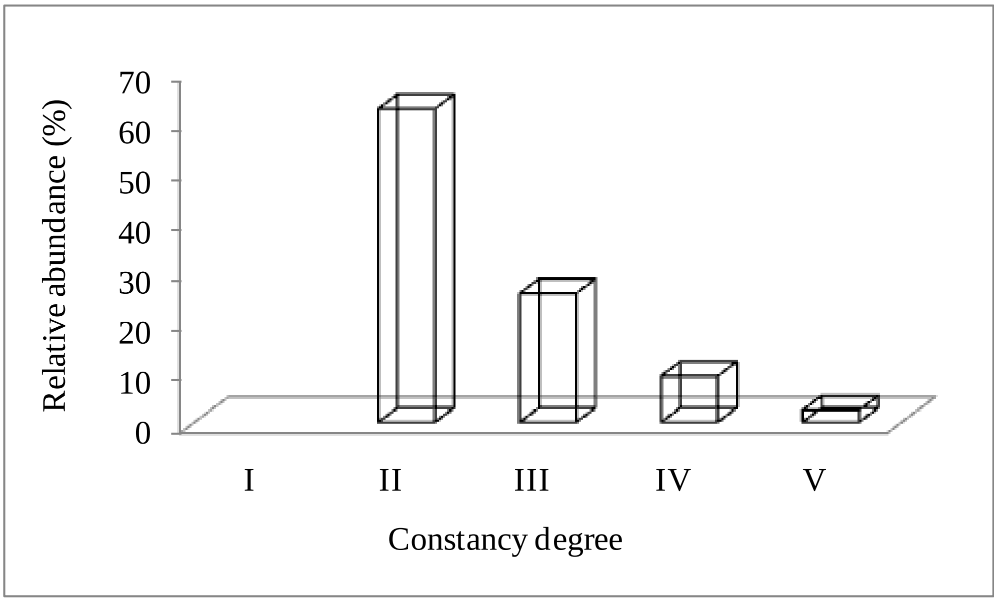


Figure 6.9: Histogram of constancy degree of group 3

They therefore contribute in isolating these relevés from the others. However, about 20 of them (tab.6.9) have an indicator value large or equal to 30 and we selected the diagnostic species are selected amongst this set. The top five species with both high indicator value and low p-values are *Dichostemma glaucescens, Laccosperma secundiflorum, Tabernaemontana crassa, Podococcus barteri,* and *Lomariopsis guineensis.* Apart from *Tabernaemontana crassa*, most of them are belong to mature forest.

6.2.4 Group with *Funtumia elastica, Rauvolfia macrophylla* and *Jateorhiza macrantha* (group 4)

6.2.4.1 Environmental factors

Group 4 is a set of 27 relevés on fallows of which the majority (92.6%) are under high precipitations because they are situated in the coastal area.

70.4% of these fallows are established on sandy soils, 26% are on silty soils and 3.6% on clayey soils. These fallows are less disturbed because there had been only one farming cycle in 59.3% and two in 22.2%. No fallow had been farmed more than twice, but the number of farming cycles was unknown in 18.5%.

These fallows were located in a forest environment. They were surrounded exclusively by mature forest in 63% and by secondary forest in 26%. For 4% the surrounding vegetation is a thicket of *Chromolaena odorata*. 7% of the fallows were bordered on one side by mature forests and by *Chromolaena* thicket on the other.

The history of the fallows reveals that 74.1% of them were created by clearing mature forest and 18.5% from secondary forest. Only 7.4% of the fallows developed at the detriment of *Chromolaena* thickets.

6.2.4.2 Physiognomy and structure

Six of the 27 fallows in this group are more than 10 years old. The youngest are 2 years old while the oldest is 23 meaning that the age of the fallows stretches from 2 to23 years with a mean of 7.4±5.4 years.

Canopy closure is variable and quite low for some relevés (R_{56}, R_{63} and R_{70}) with values less than 20%. In other relevés, the values are high and reach 70 and 75% (R_{34} and R_{66}). The mean canopy closure is 41.3±18.9%. This variability of canopy closure has a consequence on the different types of plants in the fallows. Thus, the proportion of herbs varies from 12.3% to 37.3% with a mean of 25.0±8.1%. Woody species represent between 37.3 and 68.4% of the entire flora with a mean of 52.4±4.5%. The proportion of climbers varies from 11.3 to 34.0% with a mean of 22.4±4.9%.

The spatial distribution of the species in the fallows helps to distinguish the herb, shrub, lower and medium tree strata.

On the forest floor, herbs are sparsely growing and no species is particularly abundant. However, it happens that *Selaginella myosorus*, *Nephrolepis biserrata* and *Chromolaena odorata* can be locally abundant. The maximum height of the herb stratum coincides with that of tall herbs like *Aframomum daniellii, A. subsericeum* and *Chromolaena odorata* and reaches 4 m.

The shrub stratum is well represented both in species and individuals and its maximal height is around 6 m. In this vegetation layer some species like *Carpolobia alba, Rinorea campoensis, Rauvolfia mannii* and *Bertiera aequatorialis* are represented by individuals of less than 5 cm dbh. In the 27 relevés of this group, 932 shrub and tree individuals of 91 species were recorded and their dbh was between 5 and 20 cm (annex 1.7). 769 of these 932 individuals (82.5%) were shrubs belonging to 83 species and are well represented on figure 6.10. The most abundant and dominant species in this stratum are forest pioneer including *Musanga cecropioides*, *Macaranga hurifolia*, *Funtumia elastica* and *Harungana madagascariensis* (tab.6.10).

The tree layer consists of individuals of more than 20 cm dbh and hosts 27 species with a total of 163 individuals. The lower tree stratum (L) has only 23 species with152 individuals up to

12 m high. The most abundant and dominant species at this level (tab.6.10) are *Musanga cecropioides, Elaeis guineensis, Macaranga cecropioides, Spathodea campanulata* and *Raphia mombuttorum.* Apart from *Raphia monbuttorum* all species in this stratum are forest pioneer species which are almost the same as in the shrub stratum.

Table 6.10: Abundant and dominant species in group 4

	Relative abundance (%)			Relative dominance (%)		
Species	S	L	M	S	L	M
Elaeis guineensis	0.3	7.2	20	1.2	14	23.4
Musanga cecropioides	23	58	0	35.8	49	0
Macaranga hurifolia	17.9	5.9	0	16.1	5.6	0
Funtumia elastica	5.6	2	0	3.5	1.8	0
Ficus exasperata	3.4	1.3	0	2.9	0.7	0
Calpocalyx heitzii	0.1	1.3	20	0.1	2.4	15.8
Albizia adianthifolia	0	0	10	0	0	11.2
Dacrydes edulis	0.1	0	10	0.1	0	8.0
Eribroma oblongum	0.2	0.7	10	0.9	0.4	9.5
Irvingia gabonensis	0	0	10	0	0	11.1
Pycnanthus angolensis	0.2	0	10	0.4	0	12.1
Treculia cf. *obovoidea*	0	0.7	10	0	0.4	8
Rauvolfia vomitoria	2.7	0	0	1.3	0	0
Xylopia aethiopica	0.2	3.9	0	0.1	3.8	0
Bridelia micrantha	2.1	1.3	0	2.6	1.3	0
Spathodea campanulata	1.8	3.3	0	2.2	2.9	0
Anthocleista schweinfurthii	1.1	3.3	0	1.2	1.9	0

The medium tree stratum (M) is poorly represented with eight species and 10 individuals. Apart from *Calpocalyx heitzii and Elaeis guineensis* which have each two individuals in this vegetation layer, others are only represented by a single stem. None of the species is abundant. Three species have a relative dominance lower than 10%, (*Calpocalyx heitzii* (8.0%), *Dacryodes edulis* (8.0%) and *Eribroma oblongum* (9.5%)) while the five others have each a relative dominance larger to 10%, the highest value being that of *Elaeis guineensis* (23.4%).

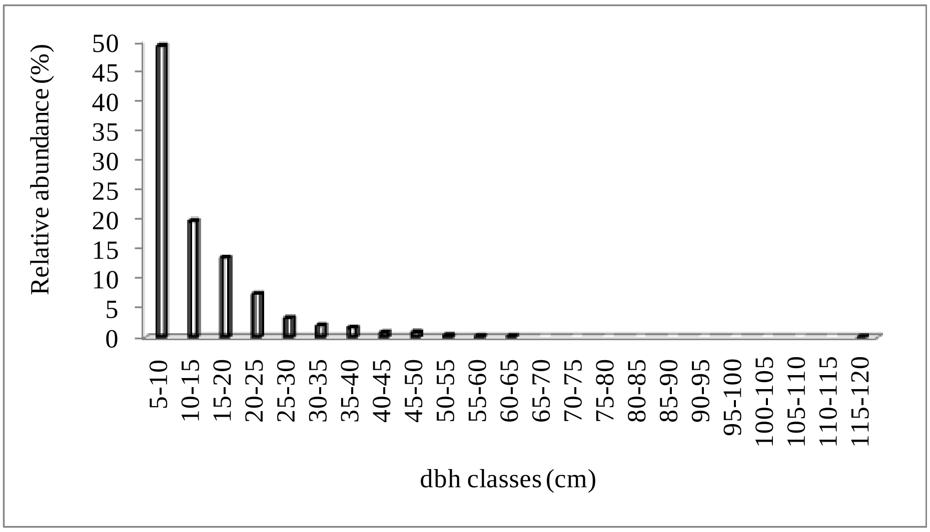


Figure 6.10: Distribution of tree and shrub individuals according to dbh classes in group 4

In the upper tree stratum there is only one individual of *Irvingia gabonensis* with a dbh of 120 cm and a height of 30 m. The total basal area is 19.78 m^2 per ha for a density of 896 stems per ha.

Climbers **(***Artabotrys pierreanus, Chassalia cristata, Cissus dinklagei* or *Tetracera alnifolia* **)** link the different strata.

6.2.4.3 Species cover and constancy degree

Only 11 species (3%) have a mean cover greater or equal to 1% (tab.6.11). *Musanga cecropioides* has the highest mean cover (10.9%)), followed by *Chromolaena odorata* (5.5%), *Nephrolepis biserrata* (4.4%), *Macaranga hurifolia* (4%) and *Duparquetia orchidacea* (2.7%). Each of the remaining 354 species (97%) has a mean cover less than 1%. Some species like *Napolaeona vogelii, Carica papaya, Chassalia bipindensis, Cola chlamydantha* and *Croton oligandrus* which are rare and just present in the relevés have a mean cover almost equal to zero.

However, when considering the frequency of the species, 70.9% of them are rare in the relevés. They have a presence degree of I and their frequency does not exceed 20% i.e. that they occur in a maximum of 5 relevés. The constancy histogram (fig. 5.9) shows that few species have high frequencies. None of the species has a relative frequency of 100%. The most frequent species with a constancy degree of V are *Nephrolepis biserrata* (92.6%), *Lasianthera africana* (88.9%), *Macaranga hurifolia* (85.2%), *Milletia macrophylla* (85.2%) and *Elaeis guineensis* (81.5%).

Table 6.11: Mean cover, relative frequency, indicator and p values of some key species of group 4

Species	Mean cover	Relative frequency	IndVal	p
Musanga cecropioides	10.9	66.7	31	0.055
Chromolaena odorata	5.5	55.6	-	-
Nephrolepis biserrata	4.4	92.6	-	-
Macaranga hurifolia	4.0	85.2	-	-
Duparquetia orchidacea	2.7	40.7	31.1	0.079
Lasianthera africana	0.5	88.9	23.6	0.034
Elaeis guineensis	1.31	81.5	8.6	0.68
Desmodium adscendens	0.4	77.8	-	-
Jateorhiza macrantha	0.6	77.8	38.9	0.007
Funtumia elastica	0.7	63	35.7	0.029
Bridelia micrantha	0.4	66.7	22.8	0.039
Leptoderris oxytropis	0.3	51.9	23.9	0.04
Rauvolfia macrophylla	0.2	48.1	31.7	0.013

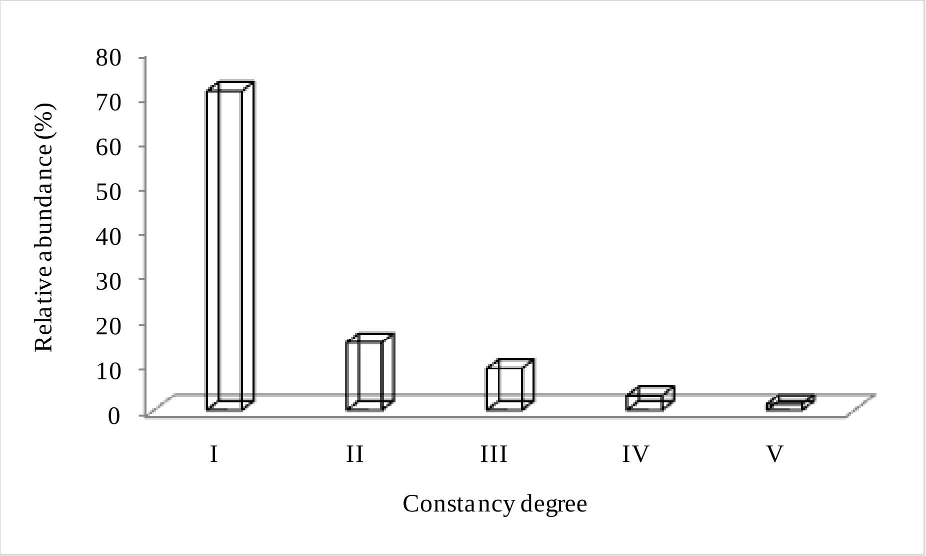


Figure 6.11: Histogram of constancy degree of group 4

6.2.4.4 Indicator values and diagnostic species

Twelve species have an indicator value larger or equal to 20. On the basis of the results of the Monte Carlo test (tab. 6.11), only 6 of them can be considered as indicator species of this group: *Bridelia micrantha, Funtumia elastica, Jateorhiza macrantha, Lasianthera africana, Leptoderris oxytropis* and *Rauvolfia macrophylla*.

6.2.5 Group with *Harungana madagascariensis, Selaginella myosorus* and *Ipomoea involucrata* (group 5)

6.2.5.1 Environmental factors

This is a group of seven relevés emanating from fallows established on sandy (43%) and silty soils (57%).

Fields from which these fallows developed had been created by clearing mature (14. 3%) and secondary forest (71.4%). In some cases (14.3%) a *Chromolaena* thicket had been the former vegetation. Most of these fallows (57%) are found in forest environment while 43% are surrounded by *Chromolaena* thicket.

There had been two farming cycles for 42.9% of the plots. Multiple farming cycles had taken place in 14.2% of the fallows while in the remaining 42.9%, the number of farming cycles could not be determined.

6.2.5.2 Physiognomy and structure

The relevés of this group are from fallows aged from 1 to 8 years with a mean of 3.2±2.2 years. The canopy closure is poor and stretches from 2 to 40% with a mean of 16.7±16.4%. It is equal to zero in fallow R_{23} at Tondefoum near Campo.

This group has the third highest proportion of herbs after groups 7 and 8, with values of 20 to 41.8% and a mean of 27.3±6.8%. The lowest value (20%) is found in R_{19} which has a canopy closure of 40% while the value 41.8 is found in fallow R_{23} that has a canopy closure of 0%. Woody plants represent between 32.7 to 58.4% of all species recorded in these fallows. Their mean proportion is 49.5±8.9%. The lowest proportion is found in fallow R_{23} that has a canopy closure of 0%. The highest value (58.4%) is met in R_{18} and R_{20} with respectively 5 and 10% as canopy closure.

Climbers represent between 14.6 and 28.7% of the total flora of this group. The mean proportion of climbers of 23.0±5.1% is the third highest value within the eight groups discriminated in the present study.

Four strata can be distinguished: herb, shrub, lower and medium tree strata.

The herb stratum is well represented. Few species are abundant and dominant in some fallows, including:

- *Selaginella myosorus* which forms small mats dominating R_{18} and R_{19}. It is also abundant in R_{23} and R_{18}.
- *Ipomoea involucrata* is abundant in $R_{18,}$ R_{20} and R_{23}. This creeping species covers the floor and often climbs on shrubs such as *Manihot esculenta, Harungana madagascariensis* or *Alchornea cordifolia.*
- *Nephrolepis biserrata* is often locally abundant in fallows but does not form stands.

The shrub stratum is diverse and its maximum height coincides with that of *Harungana madagascariensis* at about 5 m. Individuals belonging to this stratum have a dbh of 5 to 20 cm and are well represented than individuals of other vegetation layers (fig. 5.12).

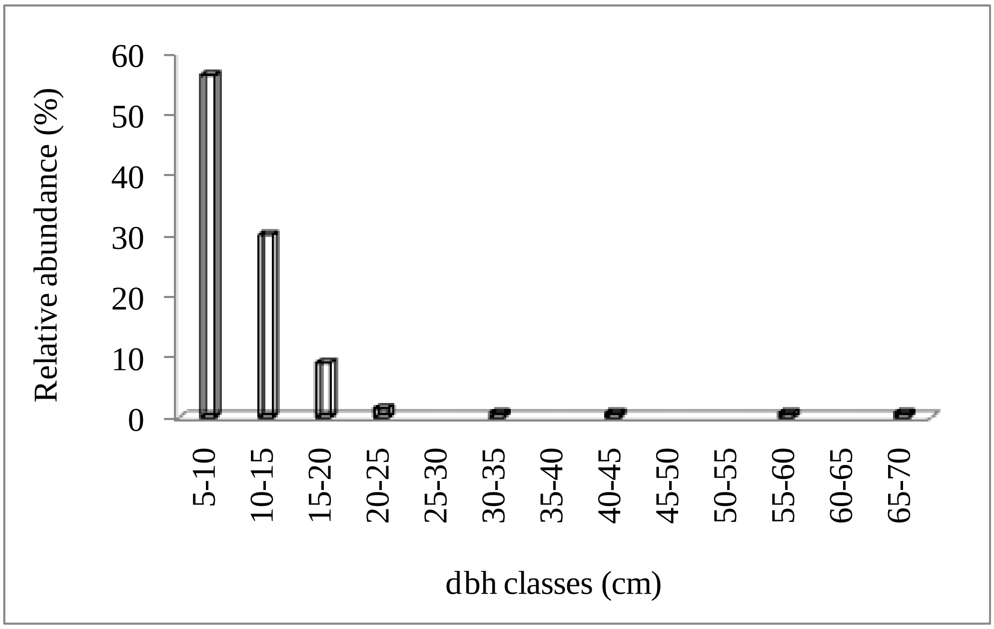


Figure 6.12: Distribution of tree and shrub individuals of group 5 according to dbh classes

In the seven plots of this group, 133 trees and shrub individuals of at least 5 cm dbh were recorded and 127 of them (95.5%) are shrubs belonging to 23 species (annex 1.8). However, only few species are both abundant and dominant in this stratum (tab. 6.12). Most of them are forest pioneer like *Macaranga hurifolia, Harungana madagascariensis, Anthocleista schweinfurthii* and *Musanga cecropioides*.

The tree stratum is poorly represented and comprises only five species and six individuals. The biggest tree is an individual of *Pycnanthus angolensis* with a dbh of 61 cm. None of the species is abundant in this vegetation layer where each is represented only by a single individual except for *Musanga cecropioides* with two.

The 133 shrub and tree individuals recorded in this vegetation unit account for a basal area of 6.7 m^2 per and a density of 475 stems per ha.

Table 6.12: Abundant and dominant species in the shrub (S), lower (L) and medium (M) strata in group 5

	Relative abundance (%)			Relative dominance (%)		
	Strata			Strata		
Species	S	L	M	S	L	M
Macaranga hurifolia	34.6	0	0	38.1	0	0
Harungana madagascariensis	20	0	0	21.7	0	0
Musanga cecropioides	6.3	50	0	11.6	26.4	0
Anthocleista schweinfurthii	6.3	0	0	8.7	0	0
Erythrophloeum ivorensis	4.7	0	0	3.5	0	0
Canarium schweinfurthii	3.9	0	0	2.1	0	0
Rauvolfia vomitoria	3.9	0	0	1.9	0	0
Maesopsis eminii	3.1	0	0	1.2	0	0
Coelocaryon preussii	0	25	0	0	29.4	0
Mangifera foetida	0	25	0	0	44.2	0
Raphia monbuttorum	0	0	50	0	0	41.1
Pycnanthus angolensis	0	0	50	0	0	58.9

6.2.5.3 Species cover and presence degree

12 species (7.7%) have a mean cover larger or equal to 1% (tab. 6.13). The species with the highest values of mean cover are *Selaginella myosorus, Harungana madagascariensis Ipomoea involucrata* and *Macaranga hurifolia.* Their mean cover is greater than 10%. The mean cover is less than 1% for 92.3% of species. They are just present in relevés or occur once with a low cover.

Out of the 155 species constituting this group, 67 (43.2%) are present in only one relevé and their constancy degree is I. This constancy degree is the most important one in terms of species abundance (fig. 6.13). Other species like *Axonopus compressus, Stachytarpheta cayennensis, Sterculia tragacantha* or *Paspalum conjugatum* belong to this constancy category species. Eight species *Anchomanes difformis, Anthonotha macrophylla, Costus afer, Harungana madagascariensis, Ipomoea involucrata, Manihot esculenta, Selaginella myosorus* and *Tristemma camerooniana* occur in all relevés and have a relative frequency of 100%. Their presence degree just like that of five other species is V. The L shape of the constancy histogram is characteristic of homogeneous plant communities.

Table 6.13: Mean cover, relative frequency, indicator and p-values of some key species in group 5

Species	Mean cover	Relative frequency	IndVal	p value
Selaginella myosorus	26.2	100	76.7	0.001
Harungana madagascariensis	19.5	100	89.6	0.001
Ipomoea involucrata	13.4	100	64.3	0.001
Macaranga hurifolia	12.7	85.7	42.3	0.016
Dalbergia hostilis	0.1	28.6	25.8	0.008
Setaria megaphylla	0.1	28.6	25.8	0.011
Chromolaena odorata	9.2	71.4	-	-
Anthonotha macrophylla	6.1	100	-	-
Nephrolepis biserrata	5.2	85.7	-	-
Scleria boivinii	3.9	85.7	57.8	0.001
Sabicea pilosa	0.6	57.1	32.5	0.005
Ipomoea alba	0.1	28.6	28.6	0.005
Manihot esculenta	3.2	100	64.3	0.003
Tristemma camerooniana	0.5	100	41.2	0.001
Anchomanes difformis	0.5	100	27	0.016
Costus afer	0.5	100	-	-
Pueraria phaselioides	2.1	14.3	13.2	0.213
Alchornea cordifolia	1.8	85.7	-	-
Musanga cecropioides	1.0	14.3	-	-

6.2.5.4 Indicator values and diagnostic species

Seventeen species of this group have an indicator value equal or larger than 20. They might be regarded as diagnostic species of this vegetation group. Results of the Monte Carlo test with focus on the p values show that there are 12 diagnostic species (tab.6.13). *Selaginella myosorus, Harungana madagascariensis, Scleria boivinii* and *Ipomoea involucrata* show the highest indicator values and lowest p values. *Manihot esculenta* which has good IndVal and p value is excluded from the diagnostic species list because it is a food crop.

The first five species mentioned above occur in other groups, but in group 5 their cover and frequencies are important. They characterize young fallows on sandy soils where there had been low disturbance.

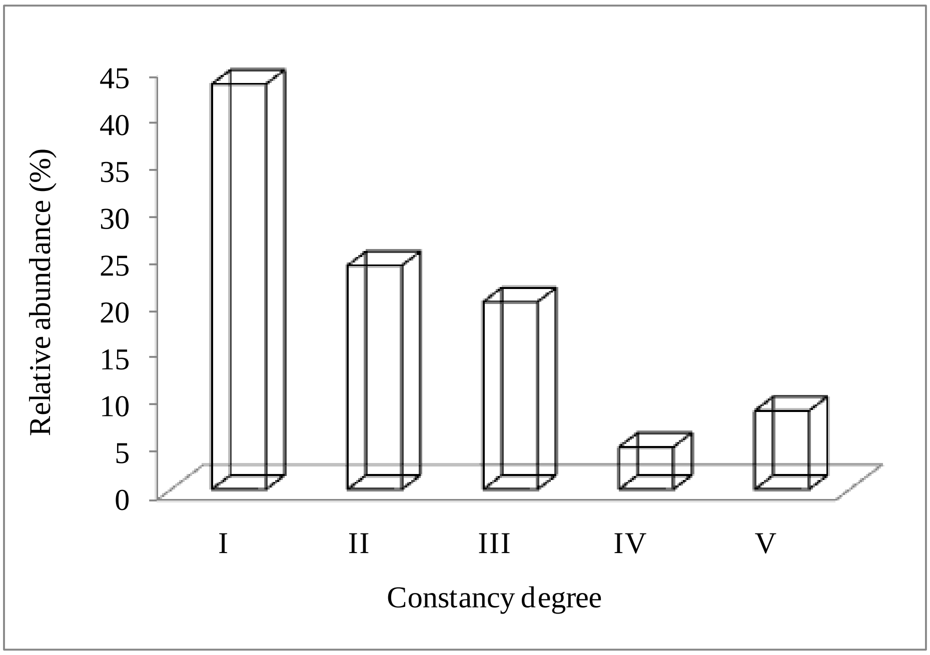


Figure 6.13: Histogram of constancy degree of group 5

6.2.6 Group with *Xylopia aethiopica* (group 6)

6.2.6.1 Environmental factors

This group is represented by six relevés taken on fallows, five of them (83.3%) on sandy soil, one (16.7%) on clayey soil. The majority of them are located in the coastal area under high precipitation.

The fallows developed from fields in a forest environment. All of them are surrounded by mature forest which is the vegetation type from which they were created like in group 3. The history of the fallows reveals that 83.3% of these fields were cultivated only once. For the rest, the number of farming cycles could not be determined.

6.2.6.2 Physiognomy and structure

The fallows in this group are older than 10 years (12 and 23) with a mean of 17.3±4.0 years.

The canopy closure varies from 25 to 70% with a mean of 55±15.8%. The lowest value is observed in fallow R_{32} and the highest in R_{30}. There is also a high variation in types of plants. Thus, herbs represent between 7.1 to 32.6% of all the species recorded. The mean in this case is 18.4±8.8%. 48.6 to 64.2% of the flora consists of woody plant and the mean is 57.2±5.4%.

Climbers are less represented. Their proportion falls within 13 and 28.5% while the mean is 24.2±5.6%.

Like in the other groups, herb, shrub and tree strata are developed in the fallows of this group. The herb stratum can reach a height of 4 to 5 m because of the presence of tall herbs such *Aframomum daniellii* and *Chromolaena odorata*. In this herb layer some species like *Nephrolepis biserrata* are often locally abundant. There are also seedlings and saplings of some forest trees and shrubs amongst which *Hymenostegia afzelii, Xylopia aethiopica* are the most common.

A total of 331 tree and shrub individuals of at least 5 cm dbh belonging to 46 species were counted (annex 1.9). Out of this number, 289 were found as shrubs with dbh not exceeding 20 cm. Their maximum height is 7 m. They are the well represented dbh classes on figure 6.12. This stratum is more diverse and some species do not have individuals up to 5 cm dbh. This is the case with *Bertiera aequatorialis, Chazaliella sciadephora, Trichilia rubescens* and *Voacanga africana.* Individuals of this stratum with dbh standing between 5 and 20 cm are the most abundant (fig. 6.14). Some species like *Anthonotha macrophylla* and *Xylopia aethiopica* are better represented in this stratum than in others both by their abundance and dominance (tab. 6.14).

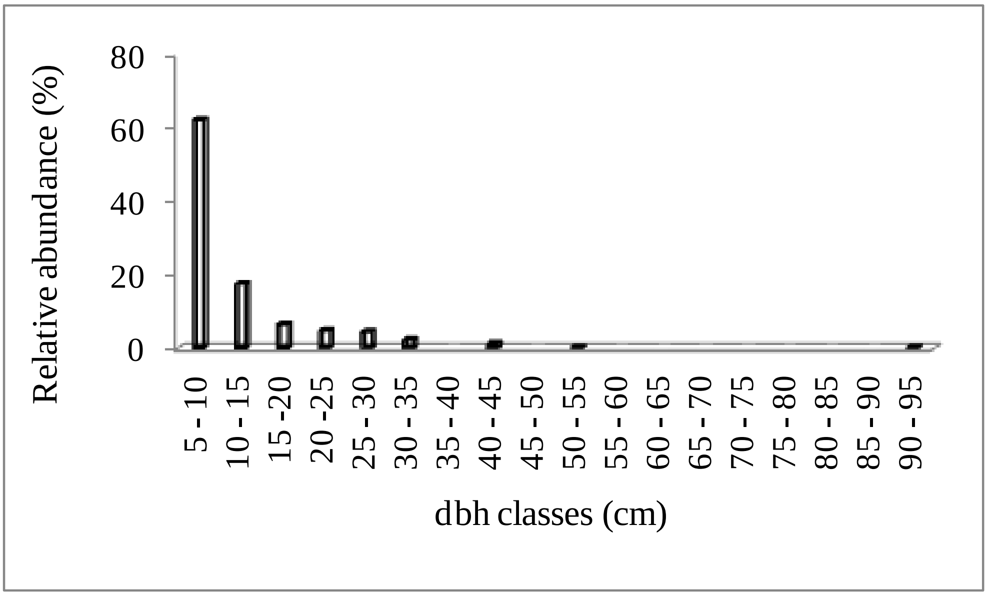


Figure 6.14: Distribution of tree and shrub individuals according to dbh classes

In the tree stratum, only 11 species are present for a total of 42 individuals. It is especially the lower tree stratum that is well represented with 10 species and 40 stems. Tree individuals of this stratum do not exceed 50 cm dbh. Once more, *Xylopia aethiopica* is the most abundant and dominant species in this vegetation layer. It is represented by 23 stems with a relative abundance of 57.5% and a relative dominance of 51.2%.

The medium tree stratum is almost absent. Two species are found in this stratum with one individual each. They are *Sacoglottis gabonensis* and *Anthocleista schweinfurthii.*

The total basal area of all individuals recorded in this group is equal to 23.4 m² per ha and the density is 1379 stems per ha.

Between the different strata, climbers are found and some of their individuals reach the canopy. They comprise *Sherbounia zenkeri, Leptoderris oxytropis* and *Landolphia landolphioides.*

Table 6.14: Abundant and dominant species in the shrub (S), lower (L) and medium (M) strata in group 6

	Relative abundance (%)			Relative dominance (%)		
	Strata			Strata		
Species	S	L	M	S	L	M
Xylopia aethiopica	6.5	57.5	0	12.9	51.2	0
Anthonotha macrophylla	34.6	0	0	32.6	0	0
Musanga cecropioides	3.8	0	0	5.9	0	0
Anthocleista schweinfurthii	2.0	10	50	4.8	12.4	25
Harungana madagascariensis	2.0	0	0	1.0	0	0
Spathodea campanulata	4.8	0	0	3.5	0	0
Macaranga barteri	4.5	0	0	5.2	0	0
Lophira alata	1.0	7.5	0	1.4	9.3	0
Calpocalyx heitzii	0	2.5	0	0	6.7	0
Hymenostegia afzelii	1.3	10	0	0.6	9.5	0
Alstonia boonei	0.3	2.5	0	0.2	5.9	0
Ongokea gore	0	2.5	0	0	4.9	0
Leonardoxa africana	3.8	0	0	3.6	0	0

6.2.6.3 Mean cover and presence degree

Out of the 143 species recorded in this group, five (3.5%) have a mean cover equal or greater than 1% (tab.6.15). *Nephrolepis biserrata* has the highest value (16.5%), followed by *Alchornea cordifolia* (10.5%), *Xylopia aethiopica* (9.4%), *Anthonotha macrophylla* (9.2%), and *Macaranga barteri* (2.2%). The remaining 138 species have a low mean cover, in some cases less than 0.1% as is the case of *Desmodium adscendens, Asystasia gangetica, Irvingia gabonensis* and *Leea guineensis*.

There is no species with a relative frequency of 100%. The highest frequency of 83.3% is found for *Elaeis guineensis, Tetracera alnifolia* and *Xylopia aethiopica* and their constancy degree is V (tab.6.15). Figure (6.15) shows that species found in only one relevé represent almost 60% of the total number of species. The constancy histogram has the same L shape as that of the other groups.

Table 6.15: Mean cover, relative frequency, indicator and p values of some key species of group 6

Species	Mean cover	Relative frequency	IndVal	p value
Nephrolepis biserrata	16.8	66.7	-	-
Alchornea cordifolia	10.5	33.3	-	-
Xylopia aethiopica	9.4	83.3	78.7	0.001
Anthonotha macrophylla	9.2	50	-	-
Macaranga barteri	2.2	16.7	-	-
Elaeis guineensis	0.4	83.3	-	-
Tetracera alnifolia	0.4	83.3	21.3	0.05
Ampelocissus bombycina	0.3	66.7	-	-
Anchomanes difformis	0.3	66.7	-	-
Eremospatha wendlandiana	0.2	50	50	0.001
Sacoglottis gabonensis	0.3	66.7	41.3	0.002
Angylocalyx oligophylla	0.3	66.7	40.7	0.003
Gaertnera longevaginalis	0.1	33.3	33.3	0.004
Hymenostegia afzelii	0.6	50	33.3	0.002
Symphonia globulifera	0.5	33.3	24	0.023
Diospyros conocarpa	0.1	33.3	21.9	0.026
Garcinia mannii	0.01	33.3	23.3	0.011
Psydrax subcordata	0.1	33.3	20.9	0.029

6.2.6.4 Indicator value and diagnostic species

Eleven species of this group have an IndVal equal or greater than 20 at $p < 0.05$ (tab.6.15). They are then considered as diagnostic species of this group. However, *Xylopia aethiopica* has the highest indicator value, a good mean cover and lowest p value. Its relative dominance and frequency are high in the strata where they are found. It is found in all vegetation layers of the fallows. For these reasons this species is regarded best to be used to name this group. Other diagnostic species have weak or poor cover, frequency and average indicator value.

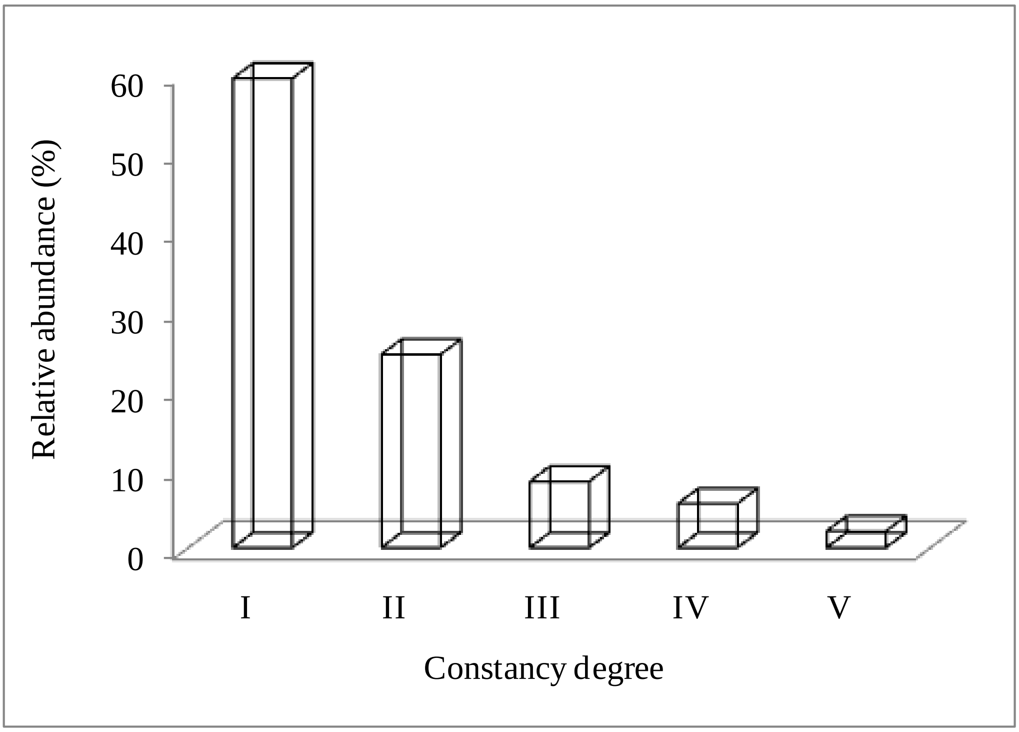


Figure 6.15: Histogram of constancy degree of group 6

Chapter 7: Floristic and ecological patterns of forest recovery during succession

In the 144 plots demarcated in this study, 605 species belonging to 424 genera and 104 families were recorded. These species comprise flowering plants (dicotyledons and monocotyledons) and ferns. There are 493 dicotyledons, 90 monocotyledons, one gymnosperm and 21 ferns. One tree species could not be identified neither at family nor generic level because it was more than 16 m tall and the high density of vines covering its branches and leaves could not allow identifying it. Peculiarities of each vegetation group are emphasized.

7.1 Floristic analysis of succession

7.1.1 Frequently disturbed fallows

The frequently disturbed fallows form groups 7 and 8 which are dominated by thickets of *Chromolaena odorata.* They comprise a total of 48 fallows not more than to 6 years old.

7.1.1 Diversity and floristic composition

7.1.1.1 Diversity

In the 48 fallows, 389 species (305 dicotyledons, 63 monocotyledons, 19 ferns and 1 gymnosperm) belonging to 87 families and 288 genera have been recorded. There is a variation of diversity indices in the groups forming the *Chromolaena* thickets (tab. 7.1).

Species richness varies from 13 (plot 137 at Ipono; G7) to 85 (plot 98 at Nsebito; G8). Plot 137 is located in the coastal area at Ipono on sandy acidic soil with coarse grains of sand where nutrients are easily washed out and fertility is low. In this plot, *Pteridium aquilinum* was the most dominant species with a Braun- Blanquet cover-abundance index of 4 while that of *Chromolaena odorata* was 3. Thus, very few species are found in fallows of this area. The vegetation around this fallow was made of a dense thicket of *Chromolaena odorata* mixed up with *Pteridium aquilinum*. In this fallow, remains of *Manihot esculenta* were present. Very often, under the thickets of *Chromolaena odorata,* no plant was growing.

The highest species richness (85 species) was observed for plot 98 in G8 (at Nsebito) a two-year old fallow with numerous young individuals of *Macaranga barteri* and *Chromolaena odorata* which showed a cover of only 15%. However, many seedlings were present in the fallow. The low coverage of *Chromolaena odorata* gave the opportunity to other species to establish in the fallow.

Table 7.1: Variation of diversity indices in the fallows of the different vegetation groups

	Vegetation groups							
Diversity indices	1	2	3	4	5	6	7	8
Species richness (S)								
Total	210	437	163	365	155	143	298	308
Max.	68	120	64	95	66	47	72	85
Min.	26	46	58	38	41	28	13	35
Mean	48.3	73.8	62	64.5	52.4	39	14.1	13.6
Std. Dev.	14.0	16.7	2.8	12.7	10.5	7.3	14.1	13.6
Shannon index (H)								
Max.	4.1	4.5	3.9	4.4	3.9	3.7	4.1	4.2
Min.	2.8	3.5	3.8	3.2	3.2	3.0	2.2	3.5
Mean	3.5	4.0	3.8	3.9	3.5	3.4	3.4	3.9
Std. Dev.	0.3	0.2	0.0	0.2	0.2	0.2	0.5	0.2
Simpson index (D’)								
Max.	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Min.	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.9
Mean	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Std. Dev.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Equitability of Pielou (E)								
Max.	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Min.	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.9
Mean	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Std. Dev.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0

The vegetation around this fallow consisted of mature and secondary forests, providers of diaspores that enrich the flora of the plot which developed from a field that had been farmed only once and that had been created by clearing a mature forest.

The mean species richness per plot was 51.9±17.2.

Values of the Shannon diversity index (H) fluctuate from 2.0 to 4.2. The lowest value 2.0 was observed in plot 137 (G7) a three-year old fallow at Ipono on the coast the highest value 4.2 in plot 98 (G8).

The Simpson diversity index stretches from 0.7 to 0.9 and the lowest value was stated in plot 5 (G7), a six-year old fallow dominated by a dense *Chromolaena* thicket. The highest value (0.9) was calculated for plot 104 (G8), a two-year old fallow at Nsebito.

The Pielou evenness (E) varies more or less like the species richness and the Shannon diversity index. The lowest value (0.7) was found for a three-year old fallow (plot 137, G7) at Ipono in Campo area while plot 4 (G8) in the Ma'an area exhibits the highest value (0.9).

Finally fallows belonging to G8 showed the highest values while plots of G7 have the lowest.

7.1.1.2 Floristic composition

7.1.1.2.1 Well represented and important families

Out of the 87 families, three of them are represented with more than 20 genera (tab. 7.2). The Rubiaceae and Leguminosae have the same number of genera (27) while at species level, Rubiaceae rank first with 45 species followed by Leguminosae which have 37 species.

Table 7.2 Families with high generic and species diversities in *Chromolaena* thickets

Families	N.G	%	N.S	%	G.Q.
Rubiaceae	27	9.3	45	11.5	1.6
Leguminosae	27	9.3	37	9.5	1.3
Euphorbiaceae	23	7.9	32	8.2	1.4
Apocynaceae	11	3.8	13	3.3	1.2
Compositae	10	3.4	12	3.3	1.2
Graminae	10	3.4	13	3.3	1.3
Menispermaceae	8	2.7	9	2.3	1.1
Annonaceae	7	2.4	7	1.8	1
Commelinaceae	6	2.1	10	2.5	1.6
Sterculiaceae	5	1.7	10	2.5	2
Moraceae	3	1.04	10	2.5	3.3

In third position come the Euphorbiaceae with 23 genera and 32 species. Other families with high generic and/or specific diversity are the Apocynaceae, Asteraceae and Poaceae. They all have almost the same generic and specific diversities. The number of genera is 11 for the Apocynaceae and 12 for the Asteraceae and the Poaceae. At species level, apart from the Asteraceae which are represented by 12 species, the Apocynaceae and the Poaceae exhibit each 13 species. Other well diverse families are the Commelinaceae, the Sterculiaceae and the

Moraceae which possess each 10 species but with only 6 genera for the Commelinaceae, 5 for the Sterculiaceae and 3 for the last family the Moraceae.

With respect to the values of the Family important Index (F.I.V), five families have a value of F.I.V of at least 20% (tab. 7.3).

Once more, the Leguminosae have the highest value (39.7%), followed by Euphorbiaceae (38.2%).

Table 7.3: Important plant families in the *Chromolaena* thickets

Families	R. Div.	R. Dom.	R. Freq.	F.I.V
Leguminosae	15.6	11.1	13	39.7
Euphorbiaceae	15.2	11	12	38.2
Loganiaceae	2.2	11.2	10.3	23.7
Cecropiaceae	3.2	12.1	6.6	21.9
Arecaceae	2.2	14	4.2	20.4
Myristicaceae	3.2	10	5	18.2
Moraceae	8.8	3.2	6	18
Rubiaceae	6.3	3	4.8	14.1
Apocynaceae	5.6	2.6	5.2	13.4
Sterculiaceae	3.2	4.5	3	10.7

Their high values are due to their diversity. Each of these families has a relative diversity of at least 15%. The other families are the Loganiaceae, the Cecropiaceae and the Arecaceae. The importance of the Loganiaceae comes from the frequency and size of individuals of *Anthocleista schweinfurthii*, the only species of this family present in the shrub and tree layers. This species is a forest pioneer common just as *Musanga cecropioides* which belongs but to the family of Cecropiaceae. For the Arecaceae, the presence of spared individuals of *Elaeis guineensis,* the oil palm tree explains their importance. Some individuals were left behind during clearing by farmers. The Rubiaceae, despite their large diversity, are not represented by individuals of large dbh.

7.1.1.2.2 Well represented genera

Considering the 389 species and 288 genera, the Jaccard's generic quotient is 1.3, meaning in theory that each genus is represented by 1.3 species. Few of the most represented families show high values of this quotient (tab. 7.2). The Moraceae exhibit a high value of 3.3, followed by the Sterculiaceae 2 and the Commelinaceae and the Rubiaceae 1.6 each. It means that many families are represented by a number of genera which is almost equal to that of the species.

Most of the genera (224 genera or 77.7%) are monospecific. Despite the low diversity of these genera, some of them are structurally more interesting. The genus *Chromolaena* has only one species which however has the highest coverage in the community. It produces large quantities of wind dispersed seeds which colonize open areas. *Musanga* is a monospecific genus with *Musanga cecropioides.* This forest pioneer tree is one of the most abundant species in the shrub and tree strata with a relative abundance of 9.5%. Other genera with one species but with abundant individuals are *Anthocleista, Harungana, Myrianthus, Pycnanthus* and *Trema*.

There are 43 genera (14.9%) represented each by two species which are herbaceous, climbers, shrubs, and trees. Only seven genera have individuals of not less than 5 cm dbh and account for a total of 113 individuals and the most important contributors are *Rauvolfia* (37), *Myrianthus* (31) and *Albizia* (23).

11 genera are represented each by three species but their contribution to the shrub stratum is very weak. Only three of them *Psychotria, Vernonia* and *Xylopia* have stems of at least 5 cm dbh and the biggest (*Vernonia frondosa*) is 31 cm in girth. The three genera have in total eight individuals in the shrub layer and are not present in the other upper strata.

The genera *Cissus, Cyperus, Dichapetalum, Macaranga, Milletia* and *Palisota* have four species each. All species of *Cissus, Dichapetalum* and one species of *Milletia* (*Milletia hypolampra*) are climbers while those of *Cyperus* and *Palisota* are herbs. The remaining three species of *Milletia* and all species of *Macaranga* are woody erect plants. They are found in the shrub and tree strata with 63 individuals representing a relative abundance of 12.1%, the most important contributors being: *Macaranga hurifolia* (46), *M. monandra* (4), *Milletia macrophylla* (1) and *M. mannii* (4).

Dioscorea and *Bertiera* are well diverse since each of the two genera has five species in the thickets. While all *Dioscorea* species are climbers, those of *Bertiera* (except *B. bracteolata* a climber) are shrubs with low dbh. None of them could reach a diameter of 5 cm.

Genera with high specific diversity are *Cola* and *Ficus* with six species each. All species of *Cola* are small shrubs of dbh less than 5 cm. The genus *Ficus* represented by *Ficus exasperata*, *F. mucuso* and *F. sur* with 23 individuals

7.1.1.2.3 Peculiarities of each group

The predominance of *Chromolaena* in G7 and G8 does not mean that they have the same specific composition. Although they share most of the families, they are distinctly different at specific and generic levels.

A total of 217 species (55.7%) comprising 40 monocots, 167 dicots, 9 ferns and 1 gymnosperm are common to the two groups and this represents a Sørensen similarity of 71.6%.

There are 80 species in G7 which do not occur in any plot of G8 while 92 species in G8 are not present in G7. Despite this high similarity between the two groups, some general remarks can be made. Thus, 16 species or 20% of G7 not occurring in G8 are ruderal therophytes while only 5% of them in G8 are absent in G7. The majority of other species in G7 are fast growing pioneers, which need large quantity of light for their development. Three ferns species, *Lycopodium cernum, Ophioglosum reticulatum* and *Vittaria guineensis* occur in G7 and not in G8. It is also the case with *Persea americana, Gloriosa simplex* and *Eulophia euglossa. Dacryodes macrophylla, Laportea ovalifolia* and *Urera* sp. occur in G8 and not in G7. Some families are more diverse in one group than in the other and nine of them have a difference of at least 3 species from one group to another (tab. 7.4). The Leguminosae-Cesalpinioideae and Leguminosae-Papilionoideae are more diverse in G7 than G8 with respectively nine and 16 species versus five and 10. Also well diverse in G7 are the Asteraceae (12 species versus nine), the Cyperaceae (seven species versus four) and the Dioscoreaceae (five species versus two). On the contrary, the Annonaceae, Euphorbiaceae, Ochnaceae and the Rubiaceae are more diverse in G8 than in G7.

The two groups have in common 188 genera representing a Sørensen similarity of 86.24%. However, there are 45 genera belonging only in G7 while 56 others are represented exclusively in G8. The top 10 most diverse genera are the same for the two groups: *Bertiera, Cissus, Cola, Costus, Cyperus, Dichapetalum, Dioscorea, Ficus, Macaranga* and *Palisota*. Each of them is represented in any of the two groups by not less than 3 species. However, out of the four species of *Milletia*, only two occur in G8. These genera are rich in species of disturbed areas. The difference in the previous vegetation type and the surrounding of the fallows explain these differences. The multiple farming systems in G7 explain the high proportion of therophytes since burning favours their establishment. The forest environment of most of the fallows in G8

7.1.2 Less disturbed fallows

96 less disturbed fallows belonging to 6 vegetations groups (G1 to G6) were recorded with G4 and G5 which represent the young steps and groups 1, 2, 3 and 6 referring to relatively old stages of succession. The difference in their physiognomy is perceptible in their floristic diversity and composition

7.1.2.1 Diversity

The less disturbed fallows comprise a total of 557 species belonging to 100 families and 396 genera. Fallows composing each of the different vegetation groups are of various ages. On the basis of the mean age, they can be ordered as follows: 5<4<1<6<2<3 (where "< "means "is younger than"). The diversity indices show a variation from one group to another (tab. 7.1)

The species richness at group level ranges between 143 in G6 and 437 species in G2. Species richness varies also between plots of the same vegetation group. The other diversity indices like Shannon index, Pielou evenness, and Simpson index which depend on species richness vary more or less like specie richness.

In G1for example, the lowest species richness (26) was found in plot 8 which also has the lowest Shannon (2.8) and Simpson (0.91) diversity indices and Pielou evenness (0.86). Plot 8 is a nine-year old fallow made of few trees emerging from a thicket of Marantaceae and Zingiberaceae. This fallow was formerly a groundnut field and is located in the Ma'an area. The highest specie richness (68) in G1 is observed in plots 82 and 130 which are 10 years old each with tree density becoming more important. Plot 82 is from Ma'an area and has the highest Shannon (4.1) and Simpson (0.97) diversity indices and Pielou evenness (0.97). There is a large variation in species richness in this group since the mean is 48.3 and the standard deviation 14. For the other diversity indices, the variation is low. Thus the mean Shannon index is 3.5±0.3, 0.91±0.01 for Simpson index and 0.92±0.03 for Pielou evenness.

The lowest number of species (46) in G2 was observed in plot 118 at Ma'an village in a 6-year old fallow. This fallow is a former field created by clearing the mature forest for the first time. Plot 101 with 120 species is the richest among the 40 of this vegetation unit. It was also found in Ma'an area on a 24-year old fallow dominated by some forest pioneer tree species such as *Anthocleista schweinfurthii* and *Macaranga barteri* protruding from a network of stems of *Haumania danckemaniana.* This plot has also the highest Shannon diversity index of 4.5 while the lowest was observed in plot 68, a 17-year old fallow located at Afane-Essokie, at the East of Campo. Plot 111 has the lowest Simpson index of 0.94. This 10-year old fallow located in Ma'an area is a former field created by clearing a mature forest. The highest values of the Simpson index (0.98) and Pielou evenness (0.98) are observed in a five-year old fallow (plot 90) in Nyabessan area.

The mean species richness in G2 was 73.8±2.8, 4.0±0.07 for Shannon index, 0.97±0.0 for the Simpson index and 0.93±0.01 for Pielou evenness.

The four relevés forming G3 do not differ so much in terms of species richness. The highest specie richness (64) was observed in plots 27 and 76. Plot 27 which is a 11-year old fallow located in Campo area, has the highest Shannon index of 3.9 (just as plot 141) while plots 76 and 109 has the lowest value of 3.8 each. Plot 76 is a fallow of 26 years old located in Ma'an area. Plot 109, a 35-year old fallow located in Ma'an area has the lowest specie richness (58). The mean number of species is 67.0±7.0. The Pielou evenness is lowest in plot 76 and highest in plot 109. The mean value is 0.93±0.0. The Simpson diversity index is either 0.96 (plots 27 and 76) or 0.97 (plots 109 and 141). The mean is 0.94±0.04.

In G4 characterized by *Funtumia elastica, Rauvolfia macrophylla*, and *Jateorhiza macrantha* plot 46 which is a fallow of eight years old has the low values for the species number (38), the Shannon and Simpson diversity indices (3.2 and 0.94), and for the Pielou evenness (0.89). This plot is located at Nkoadjap in Campo area. Plot 60 which is a six-year old fallow from Afan-Essokie in Campo area has the highest values for species richness (95), Shannon index (4.4) and Simpson index (0.98). The highest value for Pielou evenness is observed in plot 34 a six-year old fallow in Campo area. The mean values for the diversity indices are: 64.5±2.7 for the species richness, 3.8±0.08 for the Shannon index, 0.92±0.01 for the Pielou evenness and 0.97±0.00 for the Simpson index.

In G5, plot 18 has the lowest values for all diversity indices. The values are 41 for the specie richness (like plot 20 which also had that value), 3.2 for the Shannon index, 0.93 for the Simpson index and 0.87 for the Pielou evenness. This plot is a fallow of two years old in Campo area on the coast. Plot 26 which is eight years old had the highest values for the specie richness (66 just like plot 28), the Shannon and Simpson indices (3.9 and 0.97), and the Pielou evenness (0.93).

The mean values for these diversity indices are 52.4±10.5 for the specie richness, 3.5±0.2 for the Shannon index, 0.95±0.01for the Simpson index, and 0.94±0.02 for the Pielou evenness.

The species richness in the last vegetation group characterized by *Xylopia aethiopica* is high in plot 58 with 47 species recorded. This plot also has the highest values for the Shannon and Simpson indices (3.9 and 0.97) and for the Pielou evenness (0.93). This plot is a 15-year old fallow located at Afan-Essokie at east of Campo with a close canopy. Inversely, plot 50 has the lowest values for all diversity indices: 28 for the specie richness, 3.0 and 0.92 respectively for the Shannon and Simpson index, and 0.91 for the Pielou evenness. This plot is a 12-year old fallow located at Nkoadjap, a village situated at the east of Campo in which *Psidium guajava* and *Anthonotha macrophylla* are abundant in the understory while in the tree layer, *Xylopia aethiopica* is the abundant and dominant species. The value of 0.91 for the Pielou evenness is also observed for plot 31 which is also from campo area. The mean values for the diversity indices are 39.6±7.3 for the specie richness, 3.4±0.2 and 0.94±0.01 for both the Shannon and Simpson indices respectively, and 0.92±0.02 for the Pielou evenness.

In these less disturbed fallows, the mean number of species per plot was 63.8±17.6.

7.1.2.2 Floristic composition

7.1.2.2.1 Generic diversity

The generic diversity concerns the number of genera per family. This number varies from 1 to 38 (tab. 7.4). Many families (38) are represented by one genus. Given that one genus corresponds to a relative abundance of 0.25%, the 38 families account for about 9.6% of all the genera recorded. Their generic quotient is equal to one. In other words, there are few families with high generic diversity.

There are seven families with at least 10 genera. Out of these families, the Rubiaceae come first with 38 genera (9.6%) followed by the Leguminosae with 35 genera (8.8%), and the Euphorbiaceae with 29 genera (7.3%). The three families account for 26% of all genera and each of them is represented by not less than 25 genera. The generic diversity of some families is between 10 and 20 genera: Annonaceae (16), Poaceae (13) Apocynaceae (11) and Acanthaceae (10) while 12 others are represented by not less than five genera.

7.1.2.2.2 Species diversity

The 557 species comprise 455 dicotyledons, 83 monocotyledons, 1 gymnosperm, and 18 ferns. Species diversity is analyzed at the level of families and genera.

Table 7.4: Families with high generic and species diversities in the less disturbed fallows

Families	N.G	%	N.S	%	G.Q.
Rubiaceae	38	9.6	67	12.0	1.7
Leguminosae	35	8.8	37	8	1.3
Euphorbiaceae	29	7.3	39	7	1.3
Annonaceae	16	4.0	19	3.4	1.2
Graminae	13	3.3	15	2.7	1.1
Apocynaceae	11	2.8	15	2.7	1.4
Acanthaceae	10	2.5	11	1.9	1.1
Meliaceae	9	2.3	11	1.9	1.2
Araceae	8	2.0	9	1.6	1.1
Marantaceae	7	1.8	7	1.2	1
Menispermaceae	7	1.8	8	1.4	1.1
Anacardiaceae	6	1.5	8	1.4	1.3
Compositae	6	1.5	7	1.2	1.1
Commelinaceae	6	1.5	11	1.9	1.8
Moraceae	6	1.5	11	1.9	1.8
Sapindaceae	6	1.5	9	1.6	1.5
Olacaceae	6	1.5	7	1.2	1.1
Palmae	6	1.5	7	1.2	1.1
Sterculiaceae	5	1.2	19	3.4	3.8
Ebenaceae	1	0.2	8	1.4	8

The most important families are once again those with high generic diversity (tab. 7.4) where the Rubiaceae come first with 67 species (12%) followed by Leguminosae with 45 species (8%) and Euphorbiaceae with 39 species (7%). Next with 19 species each (3.4%) are Annonaceae and Sterculiaceae while Apocynaceae and Poaceae comprise 15 species each (2.7%). This list of families with high species diversity can be completed by Acanthaceae, Commelinaceae, Meliaceae and Moraceae which have 11 species each.

The Ebenaceae, despite their low generic diversity are represented by many species. This family is represented only by the genus *Diospyros* and eight species that give it the high generic quotient of eight. Beside the Ebenaceae, the Dioscoreaceae also have one genus (*Dioscorea*) and five species for a generic quotient of five. Another example is the Dracaenaceae. This family is represented only by the genus *Dracaena* which has four species.

Other such as Gnetaceae, Humiriaceae, Lepidobotryaceae and Tecophyllaceae are represented by one genus and one species.

At generic level, species diversity varies between 1 and 13 (tab. 7.5). Most of the genera (302 in total or 76.3%) represented in the fallows are monospecific. They belong to many families and some of these genera are: *Anonidium, Dichostemma, Harungana* and *Tridemostemon*. Their generic quotient is equal to one.

As the number of species per genus increases, the corresponding number of genera decreases. Seven genera are the most diverse. *Cola* comes first with a diversity of 13 species mainly found in the understory of the fallows as is the case with *Cola caricaefolia, C. digitata* and *C.marsupium* which are characteristics of the Atlantic forest of Cameroon (Letouzey 1985). The generic quotient of *Cola* is 13. After *Cola, Diospyros* comes in the second position with eight species confined in the shrub stratum. Some of these species like *D. zenkeri, D. cinnabarina, D. conocarpa* are typical of the Atlantic forest of Cameroon (Letouzey 1985). The five genera *Bertiera, Chassalia, Dioscorea, Palisota* and *Rothmannia* have five species each and a generic quotient of five.

7.1.2.2.3 Variation of the floristic composition of the different vegetation groups

7.1.2.2.3.1 At family level

The number of families per vegetation group stretches from 59 (G3) to 89 (G2). The two values concern vegetation groups related to less disturbed fallows. 81% of plant families recorded are present in more than four vegetation groups (relative frequency > 50%). Thus about 40% of these families are present in all vegetation groups and very few of them are found in only one group.

The diversity of some families is important and almost constant in the different vegetation groups invariantly to whether the fallows are regularly disturbed or not. These families have high generic and species diversity and the top five of them are the Rubiaceae, Leguminosae, Euphorbiaceae, Apocynaceae and the Commelinaceae.

The variation of the floristic composition can be analyzed on the presence/absence basis. Five families comprising Colchicaceae, Loranthaceae, Malvaceae, Ophioglossaceae and Vittariaceae are present only in the *Chromolaena* thickets. Apart from Malvaceae which are represented by two species and three occurrences in the entire set of relevés, each of these families is represented by one species and with one occurrence. In contrast, 16 families among which the Chrysobalanaceae, Ebenaceae, Monimiaceae, Sapotaceae and the Tecophyllaceae are exclusive to the less disturbed fallows. Most of their species are forest shade tolerant that can only grow under the canopy of forest trees and require a high humid understory for their growth and development.

7.1.2.2.3.2 Most important plant families

With respect to the values of FIV (tab. 7.5), the Euphorbiaceae and the Leguminosae are the only families which exhibit values of at least 20% in each vegetation group. They are followed by the Cecropiaceae which have high values in four groups and the Myristicaceae in two groups. The other families of the table have a FIV of 20% or more only in one group. The Rubiaceae, despite their high species and generic diversities, have a low FIV because most of their species have small dbh. They are so common in the understory.

Table 7.5: FIV of the most important families in the less disturbed fallows

	Vegetation groups					
Families	1	2	3	4	5	6
Euphorbiaceae	40.2	45.3	59	40.5	50	21
Cecropiaceae	27.8	33	17.3	45.9	23.7	7.9
Leguminosae	43.1	35.6	42	32.4	45.5	62
Myristicaceae	18	10	27.2	7.4	34	5.4
Apocynaceae	21.3	15	16	17.1	15.2	15.2
Moraceae	18.3	14	7.3	19.1	14.3	9
Rubiaceae	13.5	21	16.4	12.7	10.3	10.5
Annonaceae	7.2	8.7	3.7	9.7	0	39.4
Loganiaceae	6.1	7.6	0	7	14.7	21

7.1.2.2.3.3 At generic and specie levels

A total of 136 genera occurring in the less disturbed fallows are absent in the *Chromolaena* thickets. 33 of them are herbaceous species while the remaining 103 are woody species.

From one group to another the generic diversity changes as do the most diverse genera. Five genera are the most diverse in the different vegetation groups. The genus *Cola* has a maximum of eight species in G2 and 5 species in G3. In both cases, the highest diversity is met in the less disturbed fallows. With respect to the large size of their seeds, their dispersal can be done only by mammals especially primates. In Cameroon, some of the *Cola* species (*C. pachycarpa, C.lepidota, C. rostrata*) are locally called “monkey Cola”. They have edible sweet fleshy seed-coat. The ebony genus *Diospyros* is represented by seven species in G4 (where many fallows were stands of *Musanga cecropioides* often mixed with *Macaranga hurifolia* and four species in G6 which is made of old fallows. The genus *Ficus* is the most diverse in G1 with four species. *Cnestis* and 11 other genera are each represented by 2 species in G5. Out of the eight groups, the highest generic diversity is low in G5.

Some genera and the related species are present in particular vegetation types. These species can be characteristic of forests growing on hydromorphic soils like *Hallea ciliata, Spondianthus preussii* and *Symphonia globulifera* which are found exclusively in G6. They can also be species that are normally found in old forests of tierra firme: *Ongokea gore, Gilbertiodendron brachystegioides, Pavetta camerooniana* and *Psydrax palma*.

7.2 Auto ecological characters

7.2.1 Guild category

Three main guild categories were distinguished: non pioneer light demanding (npld), pioneer (pi) and shade tolerant (sb) species. Pioneer and non pioneer light demanding species are well represented and they account in each group for more than 50% of the species recorded. Their large numbers is evidence that the process of forest recovery is still going on. The proportion of non pioneer light demanding species is almost constant in different vegetation groups and ranges between 20 and 25%. Pioneer species come first in G1, G4, G7 and G8, and their proportion stretches between 26.9% in old fallows of G3 and 45.9% in young fallows of G7 (fig. 6.2). If cross checked with canopy, one realizes that the high percentage of pioneer species coincides with wide opening of the canopy. As the canopy closes up, their proportion decreases and shade tolerant species become more abundant. It means that the low proportion of pioneer species matches the high proportion of shade tolerant and high canopy closure as are the case in G3 and G6. In G5, despite the young age of the fallows, shade tolerant species represent 41.3% of all the species followed by forest pioneers. The abundance of shade tolerant can be explained by the forest environment of the fallows of this group.

7.2.2 Phytogeographic types of distribution

There are eleven phytogeographic types of distribution, one unknown and some introduced species (Figure 6.3). Species confined to the Guineo-Congolian Centre of endemism (White 1983) are well represented. The species concerned are endemic to Cameroon (Cam), Lower Guinea (LG), Upper Guinea (G) and Guinea Congolian (CG) areas. In each vegetation group, these four types represent at least 65.1% of all phytogeographic types distinguished. However, out of these four types, the typical Guineo-Congolian species are the most abundant contributing at least for 50% of the total.

Other phytogeographic types also represented are:

The Tropical Africa (Trop. Afr.) type which concerns species widely distributed in Africa and their proportion stands between a minimum of 16.2% in G2 to a maximum of 20.6% in G5.

The Pantropical (Pan) and Paleotropical (Pal) species which are found in tropical areas of different continents (Africa, America, and Asia). The phytogeographic types related to species distributed in Africa and Asia (A-As), Africa and America (Aam) and America (AM) are rarely present and their percentages are low as is the case with Cosmopolitan (Cos) and introduced (Introduced) species.

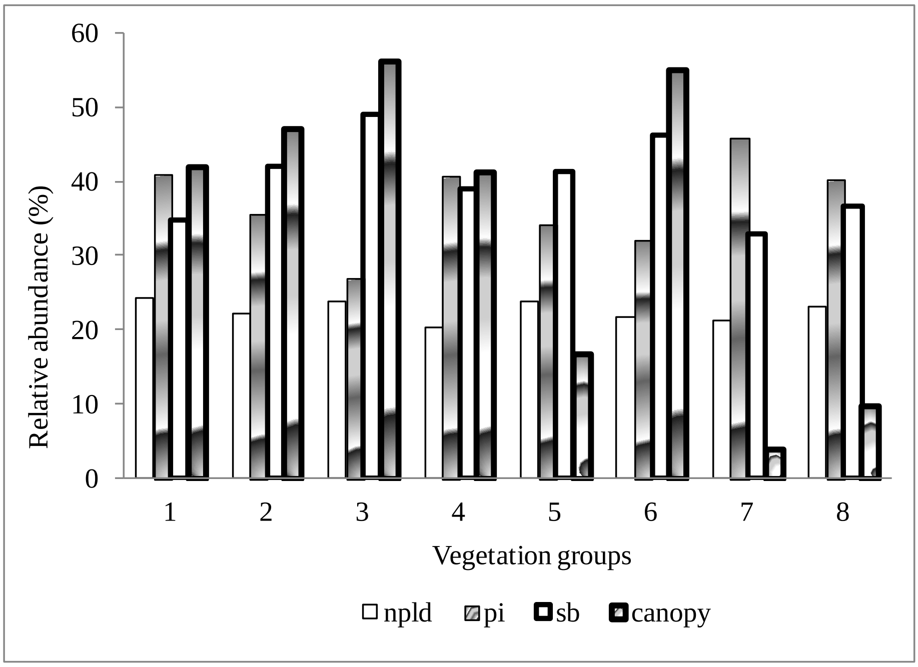


Figure 7.2: Proportions of guild categories species during succession

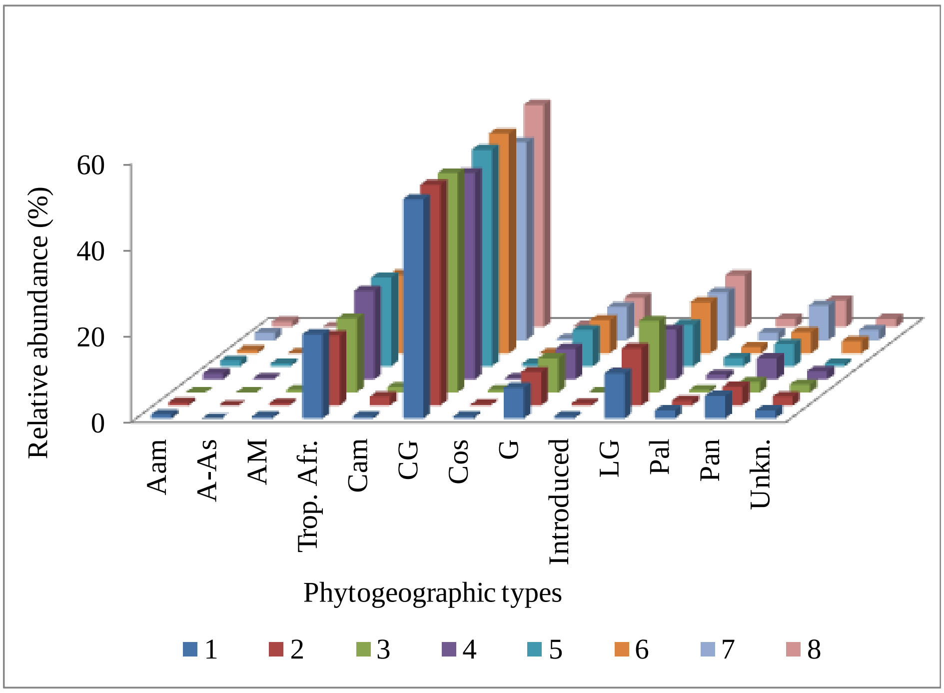
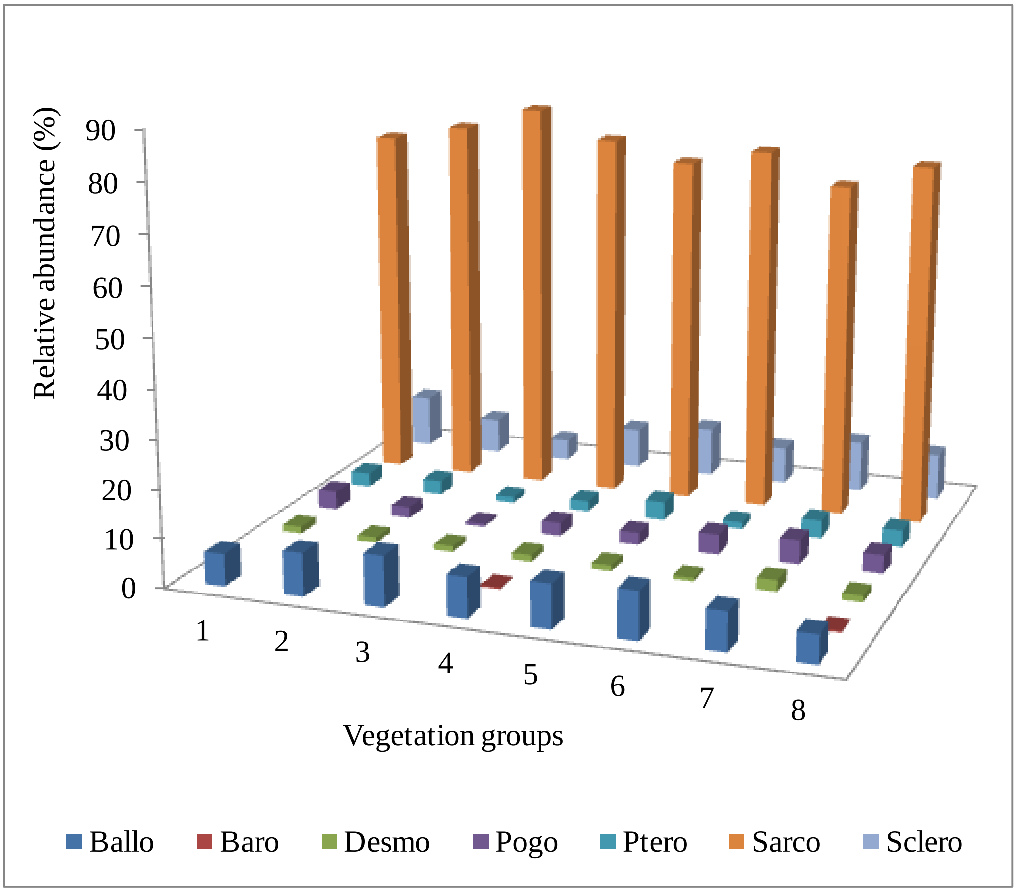


Figure 7.3: Different phytogeographic types

7.2.3 Types of seed dispersal

Seed dispersal by animals is predominant during succession (fig. 6.4). Most of the plant species in tropical forest produce fleshy fruits which attract many animals. Regardless the frequency of disturbance, sarcochory is well represented and constitutes more than 70% of the dispersal mean. The minimum value 70.1% is observed in G7 which had undergone many farming cycles whereas the maximum 82.2% is met in G3 that comprises old and less disturbed fallows. The other zoochorous type of seed dispersal desmochory, concerns not more than 2.3% of species and this maximum value is observed in G7. The successive burning coupled with the multiple farming cycles in the fallows of this group had favoured weed infestation with ruderal species being the most abundant. For example among these weeds, species like *Mimosa pudica*, *Desmodium adscendens*, *Bidens pilosa* and even *Chromolaena odorata* are epizoochorous. In this case, their diaspores are endowed with spines or adhesive organs which enable them to stick to the body of animals and to be carried over long distance from the mother individual. Although the achenes of *Chromolaena odorata* are dispersed by wind, they can cling of bristles of mammals and be transported and dispersed further. Man can also disperse them.



`Figure 7.4: Types of seed dispersal of different vegetation groups`

The second main seed dispersal mode is autochory represented by three types: sclerochory (Sclero), ballochory (Ballo) and barochory (Baro). Of these three types, barochory is poorly observed and concerns two species: *Kigelia africana* in G4 and *Inga edulis* in G8.

The other two types can cover up to 10% of the species recorded in this study.

Wind dispersed seeds (Pterochory and Pogonochory) are also present but in low proportions compared to other types. The highest value of pogonochory is found in G7 due probably to the abundance of Asteraceae in this vegetation group.

7.2.4 Ecological forest types of species

Species recorded in this study belong to seven ecological forest types (fig. 6.5). The evergreen forest species (EV) had been divided into two sub categories composed of Atlantic forest species (Atl), which are evergreen forest species confined to forest covering the border of Atlantic between Cameroon, Equatorial Guinea, Nigeria and Gabon and the evergreen forest species (EF) not confined to the Atlantic sector.

In all vegetation groups, the most represented species are those of semi-deciduous (SD) forests. In each vegetation group, their proportion is the highest. Their relative abundance is between 34.6% in G6 and 46% in G1.

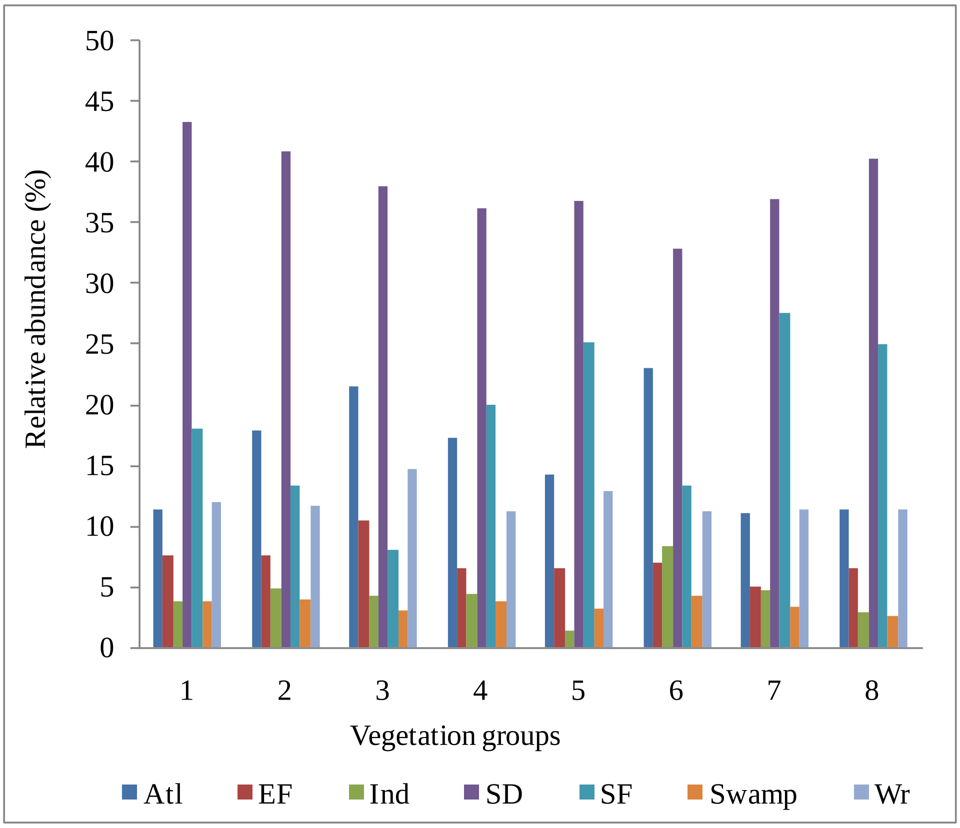


Figure 7.5: Variation of types of forest species during succession

Species of secondary forests (SF) are also well represented. Their proportion drops with the increase of fallow age during succession. In young fallows, the number of secondary forest species is higher than in old fallows. Thus their relative abundance ranges from 6.1% in G3 to 25.5% in G7. When compared to the curve of canopy closure during succession (fig. 6.1), it is obvious that as forest canopy is open, the proportion of secondary forest is high and when the canopy is close this proportion is low.

The evergreen forest species represent 15.7% in G7 made of heavily disturbed fallows and 30.6% in G3 where fallows are old of age where there had been only one farming cycle.

Within this category of evergreen forest species, those related to Atlantic forests (Atl) are well represented and follow the general trend of the main category. The lowest value is in G7 (11%) and the highest in G3 (20.8%). The general observation is that the proportion of semi-deciduous and that of evergreen forest species evolve inversely. As the proportion of semi-deciduous (SD) forest species increases, that of evergreen forest (EV) decreases.

Wide range forest species constitute 11.1% to almost 16% of all species recorded. Their proportion is more or less constant during succession and reaches 15.9% in G3.

Swamp forest species represent the last category of species distinguished in the vegetation groups. Their low proportion is due to the fact that the majority of plots were demarcated on terra firma. Only one non forest introduced species, *Annona muricata* was recorded in a plot at Afan-Essokie.

Chapter 8: Structural characteristics during succession

8.1 Influence of age on structural characteristics

7. 1.1 Physiognomy

The regularly disturbed fallows are physiognomically homogeneous as they are dominated by *Chromolaena* thickets. In some fallows a vegetation layer above these thickets is absent, but mostly shrub layer and some trees exist. Some of these shrubs and trees have developed from stumps and roots that had survived the clearing process.

In the less disturbed fallows, the vegetation is a secondary forest with different physiognomy. The structure of this vegetation depends on its age and on the type of soil. For example in young fallows established on sandy soils (G5), the vegetation is an open forest regrowth dominated by *Harungana madagascariensis*. These fallows which were former cassava fields have a dense understory where *Selaginella myosorus* and *Scleria boivinii* are often dominant. However, on clayey soils young fallows are generally dominated by forest tree pioneers, such as *Musanga cecropioides, Macaranga hurifolia, M. barteri* and *Funtumia elastica* (G4). In other fallows like in groups 1 and 2, the understory is dominated by species of the Marantaceae belonging to the genera *Haumania*, *Aframomum* and *Megaphrynium*. In groups 3 and 6 which represent relatively old fallows, the physiognomy is similar to that of mature forests. In these fallows, tree canopy creates shade and the understory is not as dense as in the other groups. From G5 (the youngest stand) to G3 (the oldest one), the change in forest structure is obvious.

8.1.2 Life forms in different vegetation groups

Phanerophytes are the most dominant life form during secondary succession. They account for not less than 60% of all life forms in each vegetation group (tab. 8.1). Within the phanerophytes, the nanophanerophytes are the most abundant since they comprise shrubs, saplings, seedlings and also sprouts of forest tree species. Beside the nanophanerophytes, micro and mesophanerophytes are represented by shrubs and smaller tree individuals while large trees which were spared during clearing represent the megaphanerophytes.

They are followed by erected chamephytes (6 to 8%) and the therophytes (4 to 7.5%). The different life forms are responsible of the physiognomy of the fallows. However, their contribution to the structure of the forest is not the same.

Some of the life forms mentioned above comprise climbing species: climbing chamephytes (Chc), climbing phanerophytes (Phgr).

Table 8.1 Different life forms during succession

Life forms	Vegetation groups							
	1	2	3	4	5	6	7	8
Chc	1.5	1.6	1.4	1.5	1.5	1.5	1.5	1.5
Chd	5.6	5.3	6.2	6.3	6.3	6.4	6.4	6.5
Ep	0.7	1.4	1.3	1.3	1.4	1.4	1.4	1.4
Gb	0.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Grh	3	4	3.6	3.6	3.7	3.7	3.7	3.7
Gt	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Hec	1.5	1.2	1.3	1.4	1.4	1.4	1.4	1.4
McPh	14.2	14.4	14.5	14	13.2	13.1	13	12.3
MgPh	0.4	0.2	1.6	1.6	1.6	1.6	1.7	1.7
MsPh	11	11	11.3	11	11	11	11	10.5
NnPh	38.3	44.0	41.4	42	42.2	42.1	42.3	43
Para	0	0	0.1	0.1	0.1	0.1	0.1	0.1
Phgr	15.4	12.1	10.4	10.5	11	11	11	11
Thc	3 1.4	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Thd	4.5	3	4.1	4.1	4.2	4.2	4.2	4.3

8.1.3 Age and recovery of structural characteristics

Age has an influence on the structural characteristics of the fallows: canopy closure, basal area, stems density, proportion of woody plants, trees and herbs. The variation of each of these characteristics according to age is expressed by its regression equation.

8.1.3.1 Age and proportion of climbers

Climbers were found in all vertical vegetation layers. In forest understory, most climbers are herbaceous, like *Momordica charantia, Adenia cissampeloides,* and *Kolobopetalum auriculatum,* while at the top of the trees *Combretum bracteatum,* and *Dolichos reflexa* were easily identifiable by the colour of their flowers. Other large climbers are *Neuropeltis acuminata, Cissus dinklagei* or *Tetracera alnifolia*. In the understory and lower tree stratum *Scleria boivinii, Selaginella myosorus,* and *Haumania danckelmaniana* are dominant.

The proportion of climbers does not significantly vary with age (fig. 8.1) of the fallows, as the correlation coefficient was weak (N = 144, r = -0.1 at p = 0.22>0.05 and the non linear regression shows that Y = -0.71log$_{10}$ (X) + 23.09 (with Y the proportion of climber species and X, age of the fallow) and the p-value of 0.22 is larger than 0.05.

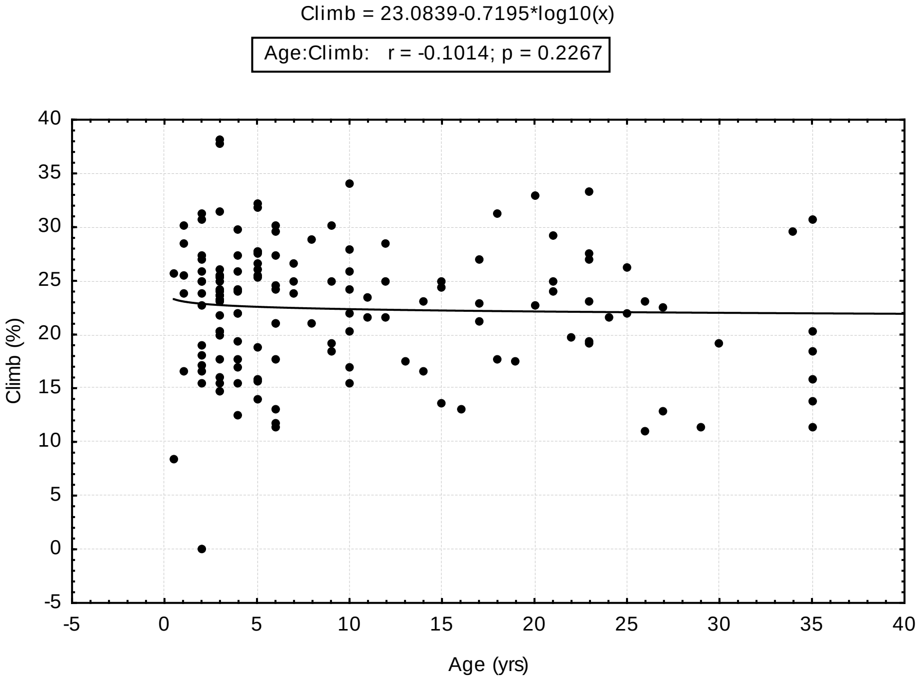


Figure 8.1 Variation of the proportion of climbers with age

The highest mean value of the proportion of climbers (24.7%) is observed in G8 while G3 has the lowest value (17.2%).

8.1.3.2 Age and proportion of herbs

In young fallows, ruderal herbs such as *Oxalis barrelieri*, *Oldenlandia lancifolia* or *Euphorbia hirta* are present. With increasing age, some forest herb species are found in the plots either growing on the forest floor or on dead trunks of trees in decomposition. *Palisota* spp., *Adiantum vogelii*, *Centothecca lappacea*, *Olyra latifolia* and *Pollia condensata* are the most common. However, other forest herbs like *Aframomum danielii* and *Megaphrynium macrostachyum* are dominant in the understory of the forest in groups 1 and 2 and reach a height of 3 m. Especially in old fallows on clayey soil they can form thickets. In vegetation groups developed from old fallows (groups 3 and 6), few herb species were found.

The height of some tall herb species like *Aframomum danielii* reached 3 m.

Time since abandonment influences the proportions of herbs in the fallows. A negative correlation exists between time since abandonment and proportion of herbs (N = 144, r = -0.5 at $p<0.05$ and Y = -14.74log$_{10}$(X) + 37.18). As for the climbers, high values of proportion of herbs were found mostly in young fallows while low values were observed in the old fallows (fig. 8.2).

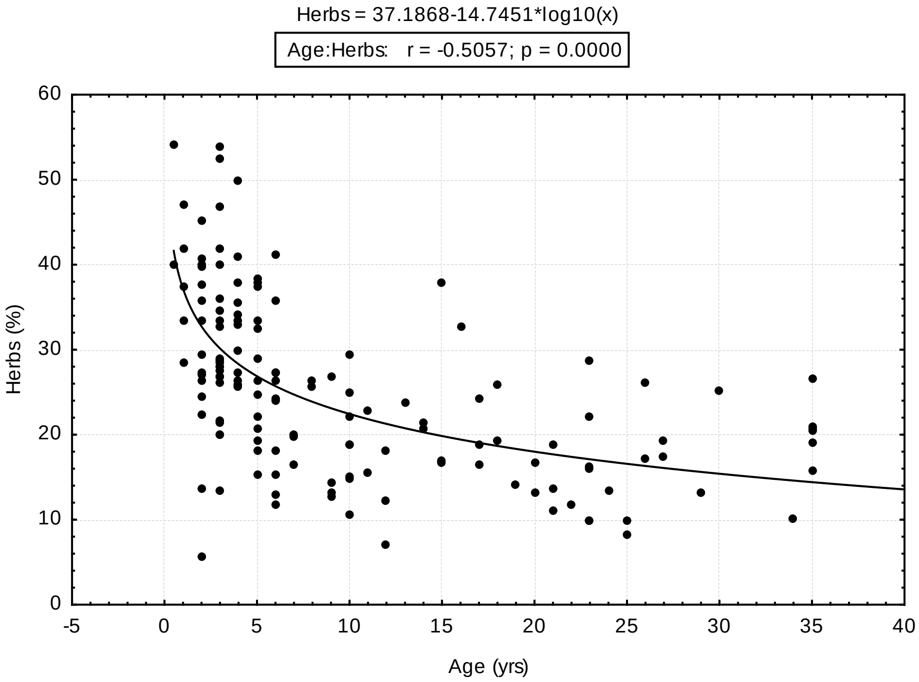


Figure 8.2: Variation of the proportion of herbs with age

At group level, G3 (old fallows) with 16.1% has the lowest proportion of herbs while the highest proportion 35.5% was found in G7 (young fallows).

8.1.3.3 Age and proportion of woody species

The proportion of woody plants increases with age of the fallows (fig. 8.3). Age and proportion of woody plants are positively correlated ($N = 144$, $r = 0.5$ at $p<0.05$ and $Y = 15.46 \log_{10}(X) + 39.72$).

Most of the woody plants found in the understory comprise shrubs and other individuals of less than 5cm dbh.

At vegetation stand level, the mean proportion of ligneous ranges from 43.2% in G7 to 66.5% in G3. These woody species are either represented by young individuals of large forest tree species (*Piptadeniastrum africanum* and *Lophira alata*) or individuals of shade tolerant species (*Cola cauliflora, Diospyros cinnabarina*).

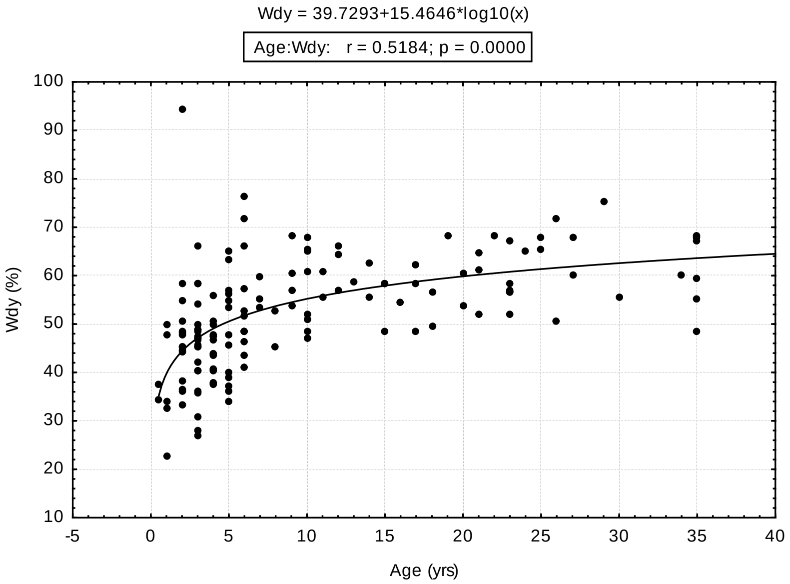


Figure 8.3: Variation of the proportion of woody plants with age of the fallows

8.1.3.4 Age and proportion of trees

A positive correlation exists between the proportion of trees and the age of the fallows (N = 144, r = 0.3 at $p<0.05$ and $Y = 21.69 \log_{10}(X) + 24.11$). Young fallows have low proportions of trees and old fallows have high ones (fig. 8.4).

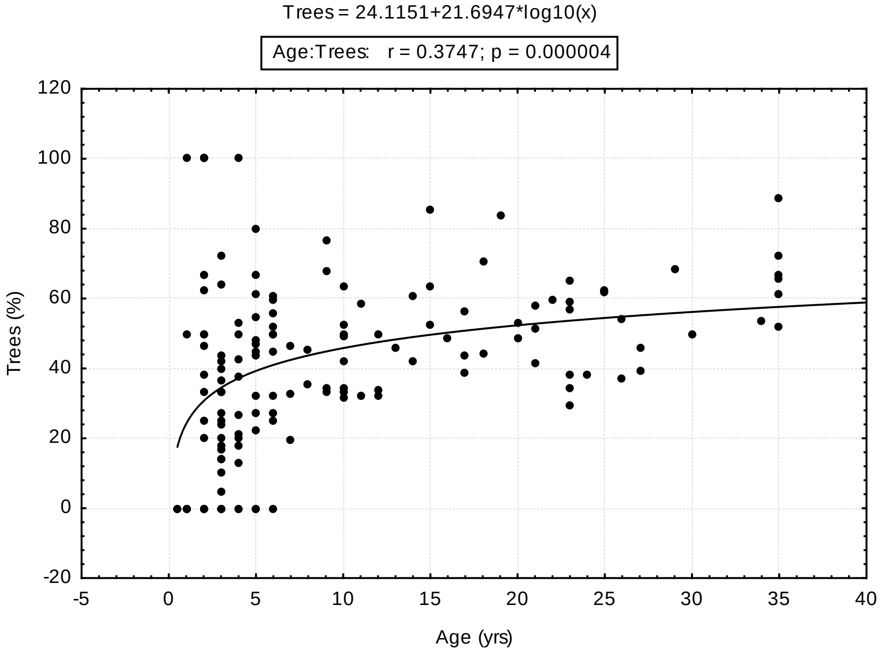


Figure 8.4: Variation of the proportion of trees with age

The proportion of trees per fallow ranged from 0 to 100%. Some plots in the *Chromolaena* thicket had no trees. At vegetation group level, G7 had the lowest proportion (26.7%) while the highest value (55.6%) was observed in G3. Tall trees included *Desbordesia glaucescens*, *Milicia excelsa* and *Petersianthus macrocarpus*.

8.1.3.5 Age and canopy closure

There was a strong positive correlation between age and canopy closure (N = 144, R = 0.69 at $p<0.05$ and $Y = 43.78 \log_{10}(X) + 13.32$). Low values of canopy were found in young fallows and highest values in old ones (fig. 8.5).

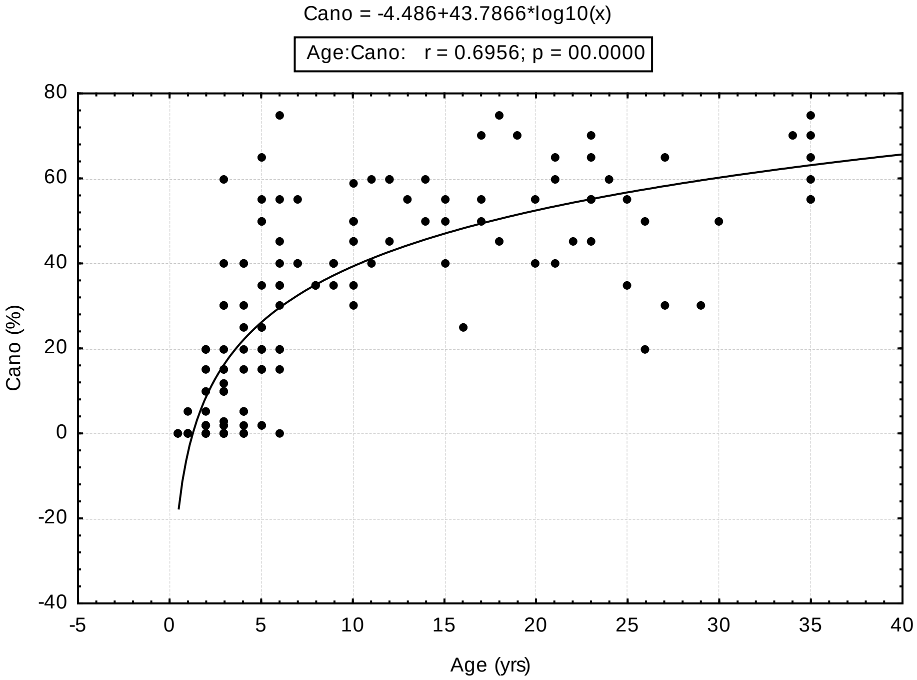


Figure 8.5 Variation of the canopy closure with age of the fallows

In some plots, the canopy closure was 0%, and could reach 75% in others. At the level of vegetation groups, G3 had the highest mean value (56.2%) because the fallows are old in age and consequently, the canopy closure is high. The lowest mean value of 3.8% was found in G7 where fallows are dense thickets of *Chromolaena odorata* with often neither tree nor shrub.

8.1.3.6 Age and basal area

During succession, the basal area increased with time since abandonment. The age of fallow was positively correlated (fig. 8.6) with the basal area (N = 144, r = 0.56 at $p<0.05$ and in linear regression, $Y = 18.71\log_{10}(X) + 0.84$ where Y is basal area and X is age).

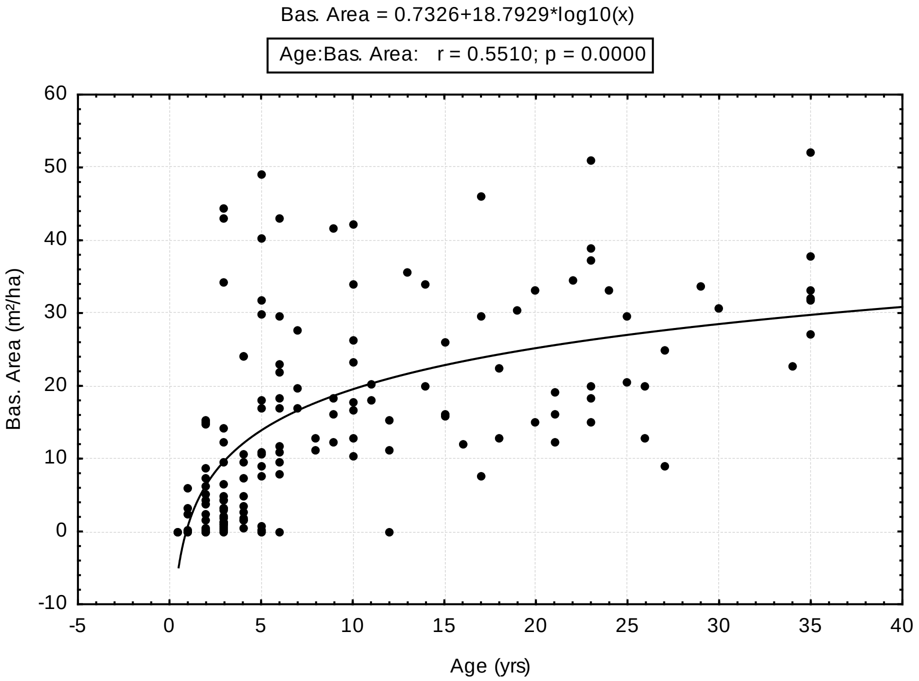


Figure 8.6: Variation of the basal area with age of the fallows

Thus, basal area in the plots stretched from 0 (plot 136) to 52.1m² per ha (plot 3).

At stand level, G7 had the lowest basal area of 2.5 m² per ha for the frequently disturbed fallows while the highest value 26.4m² per ha was observed in G3, constituted of old fallows.

8.1.3.7 Age and stem density

Stem density was positively correlated (fig. 8.7) with age of the fallows (N = 144, r = 0.38 at $p<0.05$ and $Y = 605.44\log_{10}(X) + 491.02$ in linear regression with Y stem density and X age).

Stem density varied from 0 to 2700 individuals per ha. Low values were observed in the *Chromolaena* thickets where some fallows totally lacked trees. The highest density (2700 individuals per ha) was found in a three-year old fallow where a stand of *Musanga cecropioides* developed over a former banana field. At group level, G7 had the lowest density of 263 stems per ha while G6 had the highest 1379 per ha.

8.1.3.8 Variation of species richness with age of the fallows

The graph of variation of the species number with age of the fallows shows two trends (fig. 8.8). Few years after abandonment of the fallows, the species richness increases considerably. Beyond a fallow age of 35 years, the increase of species number is low. The two parameters age and species number are nevertheless positively correlated (N = 144, r = 0.4 at $p<0.05$ and the regression equation is Y = $9.95\log_{10}(X) + 51.81$, where Y is the species richness and X the age of the fallows expressed in years.)

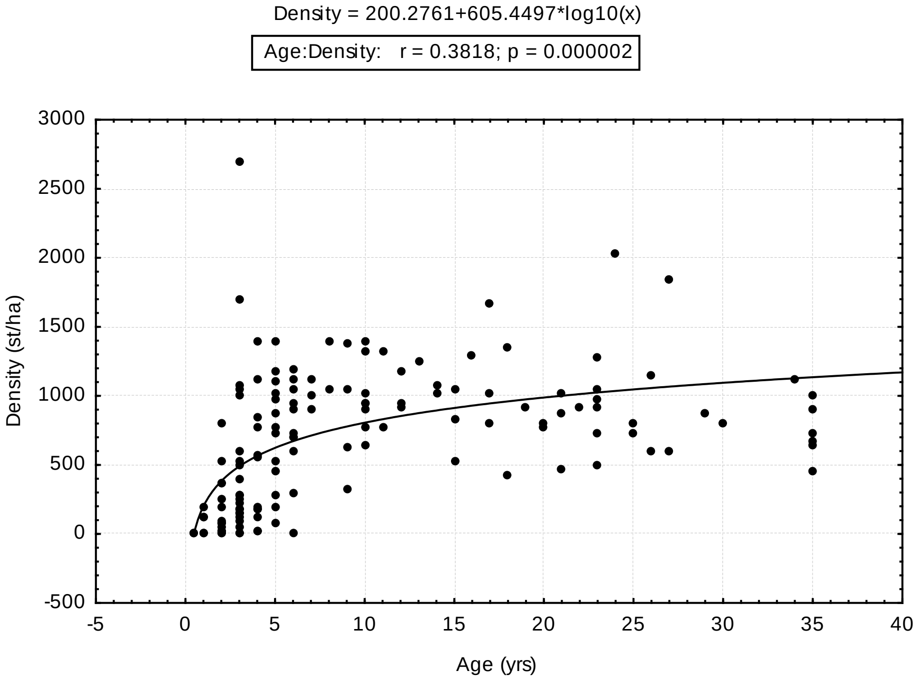


Figure 8.7: Variation of the stem density with age of the fallows

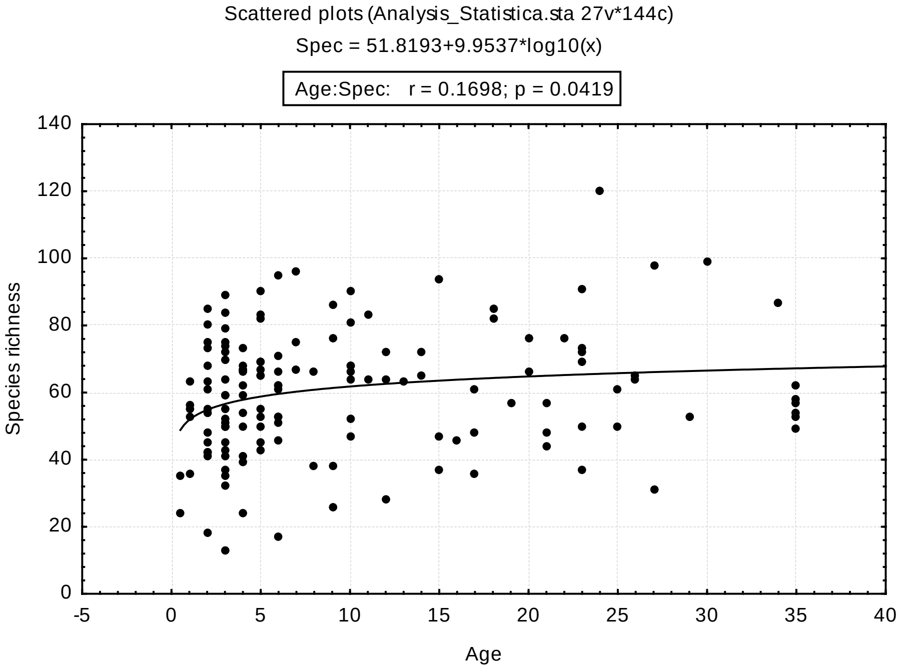


Figure 8.8: Variation of the species richness with age of the fallows

8.1.3.9 Variation of the proportion of woody species with the proportion of herbaceous species

The proportion of woody plant species is inversely proportional to that of herbaceous. Thus, an increase of the proportion of herbaceous species was accompanied by a decrease of woody species (fig. 8.9). The two parameters are negatively correlated (N = 144, r = -0.8 at $p<0.05$ and $Y = -0.92X + 75.53$ in linear regression where Y is the proportion of herb species and X that of woody species). For instance, plot 6 that has the lowest proportion of herbaceous plants is the one with the highest proportion of woody plants.

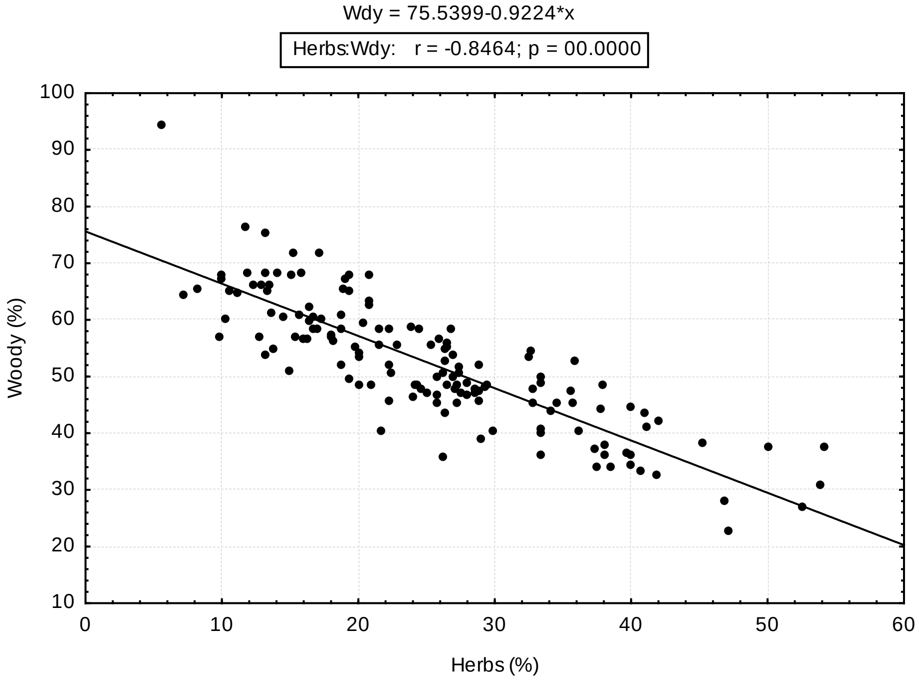


Figure 8.9: Variation of the proportion of woody species according to the proportion of herbs

8.1.3.10 Variation of the proportion of trees with canopy closure

The proportion of trees in the fallows increases considerably with canopy closure (fig. 8.10). When the canopy is open as is the case during cropping period, the proportion of trees is low. When the field is abandoned, the proportion of trees increases since there is no human interference. The two parameters are positively correlated (N = 144, r = 0.43 at $p < 0.05$ and $Y = 14.99\log_{10}(X) + 23.83$ where Y is the proportion of trees and X the canopy closure).

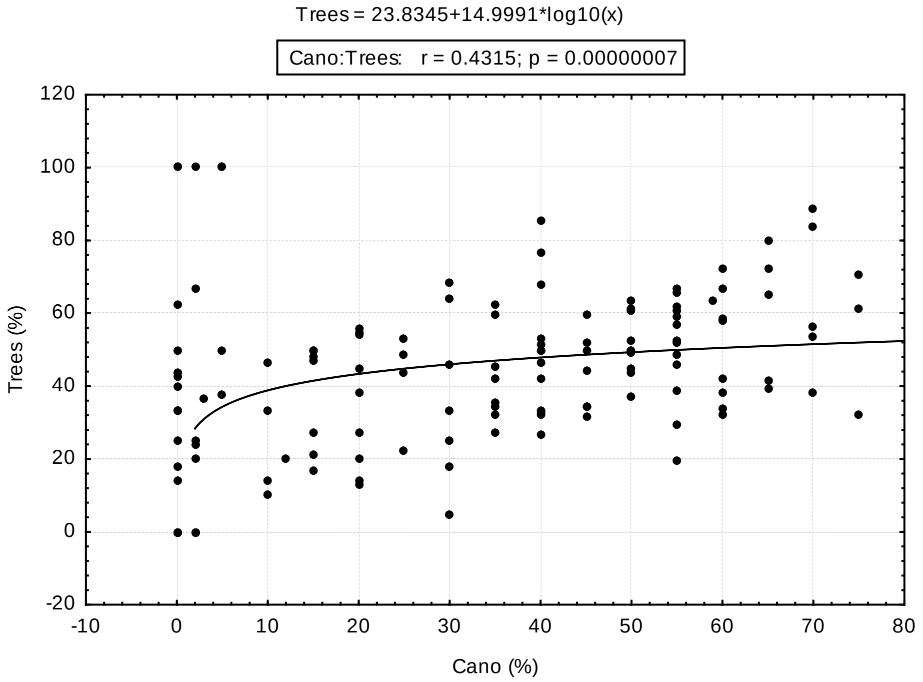


Figure 8.10: Variation of the proportion of trees with canopy closure

8.1.3.11 Variation of the proportion of herbs with canopy closure

The canopy closure influences the proportion of herbaceous species. The two parameters are negatively correlated (fig. 8.11). When the canopy closes up, the proportion of herbaceous species reduces. Inversely, an increase of the proportion of herbs is observed only when the canopy is largely open. In the course of succession, most of the herb species found in the fallows were annual shade intolerant species. In old fallows with conditions similar to those of neighbouring mature forest, the herbaceous species like *Centothecca lappacea, Streptogyne crinita, Cyanastrum cordifolia* available were mostly those of mature forest. Herbs are always present in mature forest despite their low proportion and their presence can be interpreted as evidence that the variation of the proportion of herbs with canopy closure follows a logarithmic function: $Y = -9.95 \log(X) + 37$. The correlation coefficient at $p < 0.05$ is 60.63.

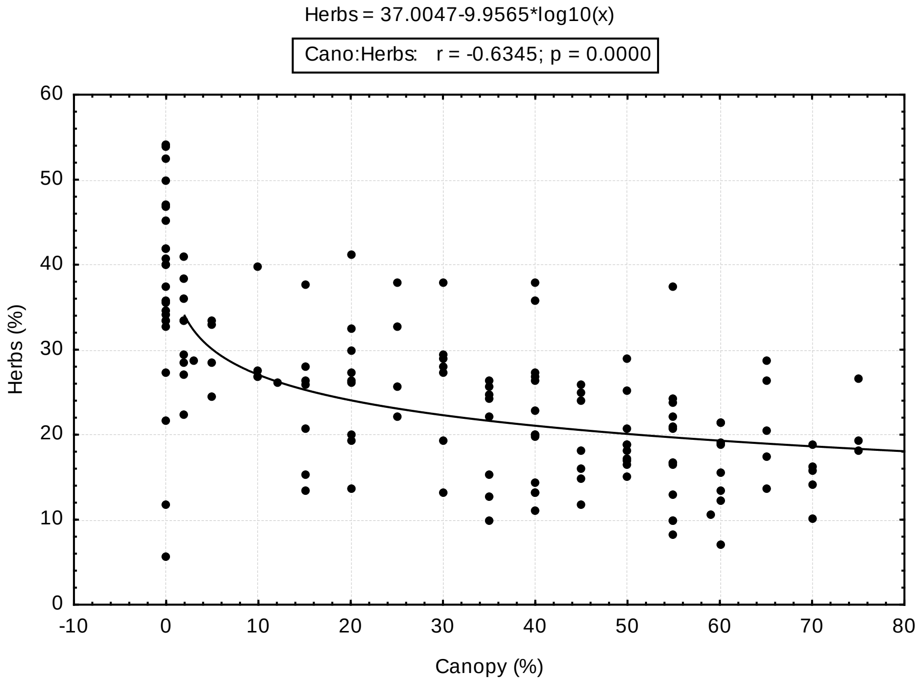


Figure 8.11: Variation of the proportion of herbs with canopy closure

8.2 Abundant and dominant species

Only abundance and dominance of woody species whose individuals were counted is described here. In all vegetation groups, regardless the intensity and frequency of land-use, the distribution of tree and shrub individuals according to dbh classes (see chapter 5) has the same L shape. The majority of all the 3379 individuals belonging to 232 species recorded in this study are found in the shrub stratum since their dbh is between 5 and 20 cm. In each vegetation group, at least 80% of individuals counted belonged to this dbh range.

Group 7 with 96.5% has the highest relative abundance, followed by G5 where they represent 95.5%. The lowest value 82.6% was found in G3. In this shrub stratum, some species were most abundant and dominant. *Musanga cecropioides* and *Macaranga hurifolia* are abundant and dominant in this vegetation layer of almost all groups. *Musanga cecropioides,* whenever present in a vegetation group, is either abundant, dominant or both. *Musanga cecropioides* is absent only in the understory of G3. Other species like *Anthocleista schweinfurthii, Harungana madagascariensis* and *Rauvolfia vomitoria* are abundant and dominant in few groups. Most of these abundant and dominant species are forest pioneers and other light demanding species. However *Trema orientalis,* another forest pioneer, is abundant and dominant only in the shrub layer of G8. This species was mostly recorded in the Ma'an area and was rare around Campo and Ipono.

Abundance and dominance of a species depends upon the age of the fallows. Thus species such as *Aidia micrantha* and *Myrianthus arboreus* are abundant or dominant in groups 1 to 3 while *Leonardoxa africana* is found only in G6. A total of 525 individuals belonging to 87 species had a dbh stretching between 20 and 50 cm. Very few of them were abundant and dominant in the shrub stratum. No species was abundant and dominant in all vegetation groups. However, most of the species abundant in at least five vegetation groups were forest pioneers. Apart from *Coelocaryon preussii* which is a shade tolerant species, all species on this table are either forest pioneer or non pioneer light demanding forest species just like in the understory.

In the medium tree layer comprising tree individuals of dbh between 50 and 100 cm, 37 species were recorded and very few of them are either abundant, dominant or both. Only *Pycnanthus angolensis* seems to be abundant and dominant in a large number of vegetation groups. Most of the species including *Macaranga hurifolia, Anthocleista schweinfurthii* and *Harungana madagascariensis* both abundant and dominant in the lower vegetation layers are absent.

In the upper layer, only three individuals of three different species were recorded. This layer is very poor in species and individuals.

8.3 Important plant families of the woody flora

This part concerns individuals with dbh of at least 5 cm. The number of species with individuals with a dbh of not less than 5cm ranges from 25 (G5) to 143 (G2).

8.3.1 *Chromolaena* thickets

In the herb stratum, Poaceae, Commelinaceae, Zingiberaceae and Asteraceae are predominant together with species such as *Centotheca lappacea, Palisota* spp., *Aframomum daniellii, Erigeron floribundum, Vernonia stellulifera* and individuals of *Chromolaena odorata*.

Some families like Cecropiaceae, Loganiaceae, Zingiberaceae, Marantaceae and Convolvulaceae, despite their low generic diversity, are the most frequent and their species have a good cover regardless of the stratum in which they occur. *Musanga cecropioides, Anthocleista schweinfurthii, Ipomoea involucrata* and *Anthonotha macrophylla* can serve as examples.

In the shrub and tree layer (individuals of at least 5 cm dbh), the contribution of each family can be estimated (tab. 8.1) based on Family Important Value index (F.I.V). The top six families in the thickets are the Leguminosae and the Euphorbiaceae which are more important both in groups 7 and 8 while the Cecropiaceae, Loganiaceae, Arecaceae and the Myristicaceae are most important in one of the two groups.

Table 8.1: Important plant families in the shrub and tree layers

	Vegetation groups							
Families	1	2	3	4	5	6	7	8
Euphorbiaceae	40.2	45.3	59	40.5	50	21	43.1	33.7
Cecropiaceae	27.8	33	17.3	45.9	23.7	7.9	18.1	25.7
Leguminosae	43.1	35.6	42	32.4	45.5	62	44	36
Myristicaceae	18	10	27.2	7.4	34	5.4	4	32.3
Apocynaceae	21.3	15	16	17.1	15.2	15.2	18.1	9
Moraceae	18.3	14	7.3	19.1	14.3	9	18	18
Rubiaceae	13.5	21	16.4	12.7	10.3	10.5	13.4	15
Loganiaceae	6.1	7.6	0	7	14.7	21	41	6.4
Palmae	5.7	7.6	0	19.1	17.5	0	26.2	14.3
Annonaceae	7.2	8.7	3.7	9.7	0	39.4	5.3	9.7
Guttiferae	2.3	2.8	4.3	7.2	27.7	14	12.9	3.8
Sterculiaceae	7	7.3	12.4	5.2	0	4	7.8	13.6

The Leguminosae are represented by 10 species for a relative diversity of 15.6%. These species are distributed in the three sub-families as follows: seven species to the Leguminosae-Mimosoideae (*Albizia adianthifolia, A. zygia, Calpocalyx heitzii, Inga edulis, Pentaclethra macrophylla, Piptadeniastrum africanum* and *Tetrapleura tetraptera*), two species to the Leguminosae-Caesalpinioideae (*Anthonotha macrophylla* and *Pellegriniodendron diphyllum*), while the Leguminosae-Papilionoideae are represented only by *Milletia mannii*. The Leguminosae also have the highest relative dominance due to the fact that some of their species have individuals of good dbh as it is the case of *Piptadenistrum africanum* with two individuals of 55 and 53.8 cm dbh. They have also the highest relative frequency of 13% and all these factors together give them the highest value of F.I.V which is 44% in G7 and 36% in G8. The importance of the sub-family of Leguminosae-Mimosoideae is due to the fact that most of its species are related to openings and are non pioneer light demanding species.

The Euphorbiaceae show almost the same trend as the Leguminosae. They also have a high diversity with 11 species and 94 individuals representing a relative abundance of 18.1%. The most abundant is *Macaranga hurifolia* with 46 individuals representing almost half (48.9%) of the woody population of this family. These values together with the relative dominance and frequency (respectively 11 and 12%) make this family the second most important one with a family important value index of 43.1% in G7 and 33.7% in G8. A considerable number of forest pioneer species belongs to this plant family. Examples in this study are *Alchornea cordifolia, Bridelia micrantha, Macaranga barteri, M. hurifolia,* and *M. monandra*.

The Loganiaceae are represented only by one species, *Anthocleista schweinfurthii*, and this justifies the low relative diversity of 2.2%. However, *Anthocleista schweinfurthii* is often found in the tree layer with more than 10 individuals and dbh between 15 and 25 cm. This explains their relative dominance of 11.2%. This family is more important in G7 (41%) than in G8 (6.4%).

The Cecropiaceae have a low relative density of 3.2% since they are represented only by two species in the thickets, *Musanga cecropioides* and *Myrianthus arboreus* which account for 80 individuals. Their relative dominance is low and less than 10%. Many individuals of these species are of small dbh despite high number. Their importance is higher in G8 (25.7%) than in G7 (18.1%).

The Arecaceae are represented by *Elaeis guineensis* the oil palm tree, and their relative diversity is 2.2%. In the plots, a total of 7 individuals were recorded with dbh between 20 and 62 cm. This can be an explanation for their high dominance (14%). It grows spontaneously in the fields, imported by large birds or mammals. At Afan Essokie, many nuts of the oil palm were seen in the dung of the African palm civet (*Nandinia binotata*) in a thicket of *Chromolaena odorata*. Farmers do not eliminate all stems of oil palm in their fields. Some are spared and maintained for oil, ropes and wine production. Dead branches are used as firewood. Thus, it is understandable that this family has the highest relative dominance of 14%. However, their frequency in the plots was low (4.2%).

The Myristicaceae are more important in G8 (32.3%) than in G7 (4%) due to the dominance of *Coelocaryon preussii* which is the largest individual in that group with a dbh of 73.8 cm. This family is only represented by *Coelocaryon preussii* and *Pycnanthus angolensis*.

8.3.2 Less disturbed fallows

As in the regularly disturbed fallows, Euphorbiaceae, Cecropiaceae and Leguminosae are the most important families of the woody flora with respect to F.I.V values (tab. 8.2). However, some families with low species diversity such as the Guttiferae, Myristicaceae and the Loganiaceae are occasionally important as well. They have a high value of F.I.V in a particular vegetation group. Their presence is due to the abundance, the size and the frequency of their individuals in the plots.

In groups 4 and 5, representing the young phases of succession, the Euphorbiaceae, Cecropiaceae and the Leguminosae are the most important families. Each of them has a F.I.V of at least 20%. If the Euphorbiaceae and the Leguminosae are well diverse, the abundance and dominance of *Musanga cecropioides* explains the high F.I.V of the Cecropiaceae. In G4, some fallows were pure stand of *Musanga cecropioides.* In G5, the Guttiferae are also important with a F.I.V of 27.7%. The importance of this family is due to the abundance and dominance of *Harungana madagascariensis* which characterizes this succession phase made of shrubs and which replaces the herbaceous step.

In the transitional phases represented by groups 1 and 2, these families are again the most important ones together with the Apocynaceae. The Apocynaceae have a F.I.V of 21.3% which is due to the abundance of *Rauvolfia macrophylla* and *Funtumia elastica.* The abundance and frequency of *Aidia micrantha* become important until the Rubiaceae have a F.I.V of 21% in G2. At this successional phase, the Moraceae and the Myristicaceae are potentially important with F.I.V values of 18.3% and 18% respectively.

In groups 3 and 6, which are constituted by old fallows, the importance of the Cecropiaceae diminishes and this family is replaced by the Myristicaceae. The Arecaceae are absent in G3 and G6 since *Elaeis guineensis* the most common species of this plant family is a light-demanding species. The Euphorbiaceae have the highest FIV due to the presence and abundance of *Dichostemma glaucescens* beside other species of this family already found in the other groups.

In G6, Annonaceae become important thanks to the abundance, frequency and dominance of *Xylopia aethiopica*. This species is very common in the plots of this vegetation group and is found in all vegetation layers, from seedlings to tall trees. Its relative frequency is 83.3%.

The guild category of the species intervenes. Thus, the Loganiaceae and the Arecaceae are absent in G3 made of old fallows with high canopy closure. Since species of these families are pioneers and light demanding, they cannot withstand shade. At the inverse, the Sterculiaceae and the Annonaceae rich in shade tolerant species are absent in the young fallows of G5 where canopy closure is low.

Either for the regularly or the less disturbed fallows, the Rubiaceae are not among the most important families despite their high diversity. This is due to the fact that this family was represented by small shrubs of low dbh.

Chapter 9: Influence of ecological factors on succession

9.1 Farming system and succession

9.1.1 Vegetation before the last cropping

Farmers in southern Cameroon clear almost all types of vegetation types to make fields: mature forest, secondary forest and dense thickets of *Chromolaena odorata.* When summarizing the number of plots demarcated in the fallows, in terms of previous vegetation type, most of them (47.2%) emanated from fields created by clearing mature forest, followed by *Chromolaena* thickets (30.6%) and secondary forest (22.2%). The reason of the fact that farmers prefer to clear mature forest and *Chromolaena* thickets is the search of fertile soil since mature forest trees of large size contain a high concentration of nutrients. Decomposition of plant debris and burning contribute in the release of mineral nutrients and exchangeable cations (Christanty1986). The size of trees in mature forest is bigger than in secondary or other degraded lands and they produce a large quantity of ashes when they are burnt.

Chromolaena odorata is often recriminated as a nuisance for its capacity to invade open lands (Rouw 1991, Koutika & Rainers 2010). For this reason, this plant is known in Cameroon under different terms according to areas. In the southern Cameroon it is called “Afan bekoro” meaning in the Beti tribes something that seizes someone’s fallow. The thickets of *Chromolaena odorata* are so tied that it is difficult to move in. For this reason, in the Yaounde area, it is often called “Nkondengui” in reference to the central prison of Yaounde. In the Bamileke regions, it is known under “fop lah” which means “abandoned land or abandoned compound”. In the Sa’a area situated at about 60 kilometres North of Yaounde, Biholong (1986) reports that this plant is known there as “Sa’a-nam” that is “invader of the Sa’a area.

Chromolaena odorata was introduced in Cameroon in 1954 by foresters and agronomists (Biholong 1986) for its capacity to improve soil fertility. In Cameroon and elsewhere in tropical areas (Kanmegne et al. 1999, Koutika et al. 2004, Rouw 1991, Roder et al. 1995 and Kassi N’Dja & Decocq 2008), farmers often prefer clearing fallows dominated by *Chromolaena odorata* rather than mature or secondary forest. They realize that in fields created by clearing dense thickets of *Chromolaena*, their crops do well and give good yields (Biholong 1986). There is evidence that *Chromolaena* improves soil fertility (Koutika et al. (2004), Ngobo et al. (2004). *Chromolaena* residues decompose faster at a rate of 1.39 mg/g/day and release more nitrogen after five weeks (Kanmegne et al. 1999). Many species of the Leguminosae develop root nodules hosting bacteria of the genus *Rhizobium* which are good nitrogen-fixing agent. This symbotic association is important in improving soil fertility. In Cameroon, *Chromolaena* has shown higher performance as potential fertilizer plant than some Leguminosae species such as *Calliandra calothyrsus* and *Pueraria phaseolioides* (Kanmegne et al. 1999, Koutika et al. 2004). Koutika et al. (2004) found in the first 10 cm of the soil that the concentrations of nitrogen, carbon, exchangeable calcium and potassium were higher in fallows dominated by *Chromolaena odorata* than in fallows with *Pueraria phaseliodes* and *Calliandra calothyrsus*.

Another importance of *Chromolaena* thickets is in field management. In fallows developed from fields created by clearing *Chromolaena* thickets, weed infestation is lower than in fallows emanating from natural bush (Ikuenobe & Analiefo 2003). In Laos, another reason why farmers appreciate *Chromolaena* in the farms is the fact that they can easily remove it from the field during weeding by hand (Roder et al. 1995). In Côte d'Ivoire, Slaats et al. (1996) found that *Chromolaena odorata* suppressed the perennial grass species *Imperata cylindra* which is difficult for farmers to control in their fields. Apart from improving soil fertility and facilitating weed management, *Chromolaena odorata* is also important as cover plant species which is used to fight against erosion (Biholong 1986).

In contrast to mature forests which host trees with large diameter and hard wood like the iron wood *Lophira alata*, secondary forest trees are soft and easy to fell down. Secondary forests are mostly cleared when the farmer is not physically fit or when he already had some plots either in mature forest, *Chromolaena* thickets or both. The farmer often clears young secondary forest when he want plant groundnut. Although clearing is mostly done by men, Dounias (1996) pointed out that this task is also done by widows.

9.1.2 Number of cropping cycles

Forest recovery does not depend only on the type of vegetation cleared before the last cropping but also on the frequency and intensity of disturbance (Uhl 1987, Brown & Lugo 1990, Chinea 2002, Chazdon 2003). Although shifting cultivation is widely distributed (Brookfield & Paddoch 1994, Thrupp et al. 1997), many different patterns of forest recovery in the cultivation cycle have been described (Lebrun & Gilbert 1954, Kahn 1982, Saldarriaga et al. 1988, Aide & al. 2000).

In the scope of the current study, the number of cropping cycles on the same plot has a distinct impact on forest recovery. Two main groups of fallows can be distinguished, the less disturbed and the heavily or regularly disturbed ones.

In most of the less disturbed fallows, the rate of disturbance was low (not more than two cropping cycles). Referring to classification analysis, canopy closure is considered as the discriminating parameter responsible for the first division of the set of relevés into the two main categories. Canopy closure can reach 75% in some of these fallows. The vegetation groups in the less disturbed fallows are physiognomically heterogeneous representing different succession phases. They include a gradation of succession steps from young fallows (G5 and G4) to relatively old ones (G3). The transitional phases are represented by G1 and G2. Each of these two groups comprises fallows of different ages. G6 represents fallows on hydromorphic soil. The old fallows in groups 3 and 6 are physiognomically similar to mature forest of the area, indicating that less disturbed fallows represent the normal successional phases of forest recovery after disturbance. The two vegetation groups can be considered as subunits of a particular unit. The difference between the two is probably the drainage. Our results are consistent with those of Guarigata et al. (1997) and Chazdon (2003) who state that when land use is not severe, secondary forest will rapidly recover. It is a progressive series in which the fallow develops to a forest structurally similar to that it replaces (Schnell 1971).

Dense thickets of *Chromolaena* are predominant in regularly disturbed fallows. These thickets are physiognomically homogenous although this vegetation type is represented by two different groups (7 and 8). In these fallows, there had been many cropping cycles. The multiple farming cycle system is closely correlated to fallow length as an important parameter. Five to six decades ago, in southern Cameroon (Diaw 1997) the fallow period was long and could reach 20 years just like in other tropical areas (Nye and Greenland 1960). Due to recent urbanization with opening of many roads in the forest block and population growth, fallow length has become obviously shorter (Kotto-Same et al. 1997, Szott et al. 1999, Aweto & Iyanda 2003). An overview on the literature of this topic is given by Mertz (2002) and Ickowitz (2006). The time span between two cultivation periods is highly variable from one region to another. In Cameroon, Ickowitz (2004) found that the length of the fallow period differs from one household to another and even in the plots of the same household. The shortening of fallow length is widespread in tropical areas (Rouw 1993, Roder et al. 1995, Slaats et al. 1996) and not peculiar to southern Cameroon. Fallow length varies also according to crops (Ickowitz 2006).

The vegetation type growing on the fallow is another factor contributing to shorter fallow length. A thicket of *Chromolaena odorata* can guide farmers in their search of new plots for cultivation. Taking into account that farmers prefer clearing *Chromolaena odorata* fallows because of the advantages already mentioned above, there is no doubt that it reinforced their intention to shorten fallow length.

Christanty (1986) proposed a classification of fallow periods according to their length. She distinguished short fallows with a length of 1 to 2 years, bush fallows where the fallow period is between 6 and 10 years and forest fallows with fallow length of 20 to 25 years. In the present study, the fallow period of most of the plots dominated by dense thickets of *Chromolaena odorata* was between 1 and 3 years and fits in the Christanty classification. Fields were created after clearing young fallows not more than five years old. Even in the coastal area where farmers complained about low yields of their crops because of the sandy nature of the soil, the fallows lengths did not exceed five years. This farming practice curtails the process of forest succession. Within 20 to 25 years corresponding to a normal forest fallow period as it was in the past (Diaw 1997, Kotto-Same et al. 1997), the same plot had undergone not less than three to four cropping cycles.

9.1.3 Succession following farming

According to the farming practice, forest recovery follows two main pathways in southern Cameroon. Whether the field had been created from either mature, secondary or *Chromolaena* thickets and taking into account the number of cropping cycles in the same plot, succession sequence are markedly different. The two main groups of fallows distinguished in the present study reflect the influence of the farming practice on forest recovery. Multiple farming cycles and shorter fallow length lead to dense thickets of *Chromolaena odorata.* At the opposite, fallows less disturbed and created by clearing either mature or secondary forest are covered by vegetation types reflecting the various successional stages in a normal sequence. The main difference between the two categories of fallows is the land-use history.

Keeping in mind the different steps of shifting cultivation, it is easy to assess the impact of multiple cropping cycles on forest recovery. During each farming cycle, the farmer clears, burns and weeds. Forest recovery is governed by three main factors (Alexandre 1982a, 1989, Uhl 1987) two of which are affected by the impact of fire in the clearing process. In the forest of Côte d'Ivoire, Alexandre (1982) distinguished three different factors which he named "potentiel végétatif", "potentiel séminal édaphique" and "potentiel advectif".

9.1.3.1 "Potentiel végétatif"

"Potentiel végétatif" refers to plant residuals that survived disturbance comprising seedlings, sprouts, coppices and stumps of trees. It is equivalent to regeneration mechanisms described by Uhl (1987) in forests of Amazonia. According to their capacity to respond to a newly created disturbance in tropical forests, Riswan (1981) and Uhl et al. (1982) recognized that primary forest species recover by sprouts.

In less disturbed fallows with not more than two farming cycles, plant residuals are less affected and can contribute to succession towards mature forest. In most cases, farmers cleared and burnt mature and secondary forests to establish their plots. After the harvest, fields were abandoned. If reconverted to crops fields, this was done many years later. The long fallow period enabled the plant residuals to grow and contribute to "heal" of the forest from the disturbance. Many studies on forest succession in tropical areas (Alexandre 1989, Uhl 1987, Bellingham & Sparrow 2000, Nepstad et al. 1996, Guariguata & Ostertag 2001) recognize that sprouts, seedlings and coppices are of overwhelming importance. Alexandre

(1989) considers them as the first floristic potential that governs forest recovery. Fallows in groups 3 and 6 are old in age and physiognomically similar (canopy closure, no dense understory, and high basal area) to the neighbouring mature forests of the area. These results show that structural characteristics of secondary forest rapidly recover when land-use had not been intensive (Uhl et al. 1988, Guariguata et al. 1997, Chinea 2002). In absence of frequent disturbance, forest pioneers species will rapidly close the gap due to their capacity of rapid regrowth.

In contrast, fallows with regular cropping cycles within short periods are dominated by dense thickets of *Chromolaena odorata*. Creating a new farm by clearing a former field firstly consists in destroying the regeneration mechanisms or “potentiel végétatif”. Burning contributes to annihilate the plant residuals and increases the level of stress on them. Successive fire can destroy all sprouts of some forest species (Uhl 1987, Rouw 1994). The above-ground biomass is reduced due to successive clearing and burning. For example, in fields prepared for groundnut, cultivation requires repeated burning after clearing. This technique is detrimental to regeneration mechanisms. Weeding consists in removal of unwanted plant individuals that grow profusely and reduce crop yields. This removal lowers the number of species and species density. Plant individuals that had been able to escape clearing and burning can be suppressed during weeding. Not only weeds are removed, but seedlings of forest trees and their sprouts are also cut.

In Côte d’Ivoire, Rouw (1991) found that persistence of *Chromolaena odorata* in fallows is enhanced by regular cutting and burning of the vegetation. In Northern India, the persistence of *Chromolaena* in the fallows can last up to 20 years (Kushwaha et al. 1981). Summarizing, it becomes evident that land use frequency and intensity lead to the persistence of dense *Chromolaena* thickets and a much slower forest recovery (Aide et al. 1995, Uhl et al. 1990, Chazdon 2003, Uriarte et al. 2004).

9.1.3.2 “Potentiel séminal édaphique” or seed bank of the soil

Most of the studies of forest recovery in tropical areas (Alexandre 1982a, 1989, Uhl 1987, Rouw 1993, Saldarriaga et al. 1988) emphasize the importance of the seed bank of the soil. It constitutes what Alexandre (1982a) called “potentiel séminal édaphique”. A large number of the seedlings found in abandoned fields during recovery arise from seeds buried in the soil before canopy opening. This is the only way some plants can regenerate in cleared areas especially those which cannot grow by sprouts (Bellingham & Sparrow 2000). The storage of seeds produced in large quantities by the existing vegetation, takes place before, during and after canopy opening. During and after clearing, wind and other dispersal agents enrich the opened ground with seeds. After opening of the canopy, the subsequent light radiation and temperature fluctuation at the forest soil during sunny days trigger the germination of the viable seeds, especially those of colonizing plant species by breaking up their dormancy

(Guevara & Gomez-Pompa 1972, Swaine & Whitmore 1988, Vasquez-Yanes & Orozco Segovia 1994).

Fire used to burn plant remains after clearing can destroy a good quantity of the seeds in the soil. Special types of crops planted in the field can favour erosion of seed bank, for example when the soil is tilled during planting of groundnuts. The use of hoes to till the soil exposes the seeds at the surface and, therefore, they become vulnerable to fire. Multiple cropping cycles and burning within short intervals will drastically reduce the seed stock in the soil.

The seed bank plays an important role in fallows dominated by *Chromolaena*. The persistence of this vegetation type can be explained by the shortening of fallow length before reconversion of a former field to a new one. *Chromolaena* produces large quantities of wind dispersed seeds. Biholong (1986) reports that a single mature individual of *Chromolaena odorata* can produce about 100000 seeds per year. In Ghana, Honu & Dang (2002) reported that *Chromolaena* can distribute over seven millions viable seeds per ha to a disturbed area. The seeds of *Chromolaena* are mostly stored in the upper two centimetres of the soil (Yadav & Tripathi 1982, Honu & Dang 2002). Etejere (1980) found that *Chromolaena* seeds buried in the soil remain viable for 26 months. Yadav & Tripathi (1981) reported that seeds of *Chromolaena* are able to increase their dormancy with burial although only 33% are viable. Thus, if a thicket is cleared one or two years after abandonment to make a new field, the new field will not be safe of *Chromolaena* infestation even if there is no input from outside. Although the upper parts of *Chromolaena* burn well, fire does not affect the underground clump and the plant can regenerate new shoots from which it develops. The capacity of *Chromolaena* to develop roots at the notes when in contact with the soil enables it to establish and cover large areas. The persistence of *Chromolaena* thickets can be explained by the continuous renewal of its population in the fallows. In fact, Biholong (1986) found that stems of *Chromolaena* die after 4 to 6 years and release an opening in the canopy of the thicket which is immediately occupied by the new individuals resulting from germination of seeds that were stored in the soil of the thicket.

In the less disturbed fallows, the absence of regular clearing and burning favours forest recovery. Trees and shrubs present in these fallows bear fruits containing a large quantity of seeds that can enrich the seed bank of the soil. These seeds will germinate, grow and become new individuals that will increase the density of the woody flora. The distribution of dbh classes during succession showed that classes between 5 and 20 cm were well represented. One can suggest that the high number of individuals with dbh standing between 5 and 10 cm is partly due to germination of seeds. If succession is not interrupted, species already present on the site create new microenvironments that favour the establishment of other species with different ecological requirements (Connell & Slatyer 1977, Finegan 1996, Tucker et al. 1998). The low intensity of clearing and burning resulted in the availability of plant residuals and seeds in the soil.

The two patterns of succession show that this process is highly influenced by both frequency and intensity of the disturbance (Uhl 1987, Guariguata & Ostertag 2001, Chazdon 2003).

9.1.3.3 "Potentiel advectif" and vegetation around the fallows

9.1.3.1 Seed sources and seed dispersers

Succession is also controlled by the input of seeds and other diaspores from the vegetation surrounding the fallows. This input from outside is what Alexandre (1982a, 1989) called "potentiel advectif". The fruiting period of some large forest trees such as *Lophira alata, Piptadenistrum africanum* and *Terminalia superba* is during the dry season. These large trees are wind dispersed and the germination of their seeds requires light. The coincidence between their fruiting period and clearing of the forest gives them an advantage over other species dispersed by animals. Some of the seeds carried by wind into the cleared area must germinate within a short period because their dormancy is very short (Gomez-Pompa et al. (1972). If the germination of these seeds requires light, the proximity of their sources to the plot is necessary (Guariguata & Ostertag 2001). Depending on the strength of the wind as well as their weight and distribution ability, seeds populating the fallow can come from an external source. In Ghana, Swaine & Hall (1983) found seeds of *Ceiba pentandra* in a cleared area situated at 50 m from the mother tree.

In the less disturbed fallows, the surrounding vegetation is mostly mature or secondary forest, and constitutes the habitat for many fruiting tree species dispersed by mammals and birds. Da Silva et al. (1996) reported that birds are mostly involved in the dispersal of seeds in early successional stages especially those of forest pioneer tree species. Another parameter to take into account is the structure of the fallows. Under low disturbance, canopy closure increases with time since abandonment. The height of the fast growing forest pioneers species will approach that of some trees in the surrounding vegetation, so that animals can easily move from the forest to the fallows. Such interaction favours seed dispersal (Nepstad et al. 1996).

In fallows that had undergone many cropping cycles, two phases can be considered. The first phase is the period between clearing and the establishment of a *Chromolaena* thicket. During this period, there is input of seeds from the surrounding vegetation. Even seeds deposited by animals that visited the fallows before can germinate. It is exactly the case for the tree species whose seeds require light for their germination. Other seeds of forest species disseminated by wind germinate within a short time. Afterwards, they have to compete with other plants (Swaine & Hall 1983, Alexandre 1989) amongst which there can be young individuals of *Chromolaena*. At this particular moment, *Chromolaena* already has a good coverage and is dominant. During the second phase when the thicket is already built up, it acts as a shield or barrier which other seeds cannot penetrate to reach the forest floor. The fallows cannot easily receive seed input from the surrounding vegetation. Honu & Dang (2000) reported that only

7% of the full sunlight reaches the soil under the canopy of *Chromolaena odorata* when the thicket is built up. It means that the germination of seeds of forest tree species which requires full sun light (for their germination) will be jeopardized if these seeds have not yet germinated. All these arguments show the negative impact of *Chromolaena odorata* on forest succession. Very often even in openings of about 25 to 30 cm diameter created by dead stems of *Chromolaena,* its seeds can germinate. Furthermore, most of the plots at the proximity of these fallows were also dense thickets of *Chromolaena* contributing in renewal of seeds and persistence of the thickets. Only when *Chromolaena* thickets grow old and show signs of reduced vitality that forest species present under its canopy can take over. Summarizing, the proximity of the seed sources plays a dominant role in forest succession (Swaine & Hall 1983, McClanahan 1986, Guariguata et al. 1997, and Guariguata & Ostertag 2001), but it seems that this factor is less effective in *Chromolaena* stands especially when the thicket is built up.

Farmers in the entire study area often complain that their crops are destroyed by medium sized apes belonging probably to the genus *Cercopithecus.* They move in herds of not less than 20 to 30 individuals. Once arrived in a field, they feed on various crops available. We had the opportunity at many occasions to see them jumping in the forest from tree to tree. At Ipono and Afan-Essokie, farmers showed us the damage caused by apes at the expense of groundnuts, bananas and maize. Other negative signs of mammals on crops were the leaves of *Xanthosoma sagittifola* eaten by the black bay duiker (*Cephalophus dorsalis*) and stems of maize cut in pieces by cane rat (*Trinomys swinderianus*). These are only few examples of animals interacting with fallows. In Uganda, Chapman & Chapman (1999) reported that mammals visiting fields can easily bring in seeds that cannot be dispersed neither by birds nor bats. A study by Gautier-Hion et al. (1985) in Gabon showed a good correlation between wildlife and seed dispersal in tropical forest. The presence of seed dispersers (sensu Gautier-Hion et al. 1985) enhances the input of seeds from outside. In their feces and dungs, there are intact seeds of forest trees species. In Côte d’Ivoire, viable seeds of forest species were found in dungs of elephant and duiker (Alexandre 1978, 1982b) and primates (Kunz & Linsenmair 2008). Characteristics of the fruits such as colour, weight, size, and presence of seed coat are important in seed dispersal since they attract specific categories of animal (Gautier-Hion et al. 1985).

9.1.3.2 Role of spared trees

Besides the three main factors described above, trees left behind by farmers during slashing are important in forest succession (Guevara et al. 1986, Carrière et al. 2002). They provide shade under which the farmers can rest and some are sources of non-timber forest products. They are visited by various frugivorous animals (bats, birds and others) searching for food or resting place (Guevara et al. 1986). High values of tree and stem density were observed in less disturbed fallows. The consequence of this structural detail is the availability of potential fruits and perches for birds, bats and other animals crossing or visiting the fallows. During their stay in the fallows, they defecate or regurgitate seeds of fruits they ate elsewhere. Charles-Dominique (1986) found that birds disperse more seeds under these remnant trees than bats which, by contrast are more involved in seed dispersal under shrubs especially in degraded areas. In southern Cameroon, we found that many birds like *Corytheola cristata* (the great blue turaco), hornbills, amongst which *Ceratogymna elata* (yellow-casqued hornbill) and *Bycanistes fistulator* (piping hornbill), visited trees in the fallows. Some of the birds like *Psittacus erythacus,* the African grey parrot, spent the night on the trees. The interaction between these birds and mammals and the fallows results in enrichment of the latter with seeds of plant species from outside the fallows.

However, the contribution of these seeds to succession depends on their germination capacity under shade created by the crown of the trees. It is obvious that early successional species cannot germinate and grow under the canopy. Thus, in this new microenvironment only seeds of mature forest shade tolerant species can germinate and grow. The impact of remnant trees can be observed in *Chromolaena* thickets although they are only present in small number. The shade created by these selected trees weakens *Chromolaena* which finally dies and releases space for forest species.

9.1.3.3 Vegetation around the fallows and dynamics

Dynamics of the fallows is also largely influenced by the surrounding vegetation. Whether a fallow is surrounded by a forest or a *Chromolaena* thicket, succession will follow different trajectories.

In less disturbed fallows, the surrounding vegetation was mostly either mature or secondary forest. Their contribution to succession is the input of seeds and other diaspores as already described. In these fallows, there are remarkable populations of tree and shrubs. During their fruiting period and according to fruit characteristics, they are visited by animals in search of food which can disseminate seeds and contribute to forest recovery. In these fallows, forest recovery is speeded up until the fallow is structurally similar to a mature.

In regularly disturbed fallows, conditions are totally different. The majority of fallows were surrounded by *Chromolaena* stands contributing to the persistence of the thickets. However, if the direct environment was a forest (as it was the case for some fallows in G8), the influence on the dynamics of the thickets was in favour of forest species. The centripetal invasion of the thickets by forest species is partly due to this forest environment. Since *Chromolaena odorata* is a light demanding plant species, it does not withstand any shade. In such a condition, the stems become very weak and die regardless the soil fertility (Biholong 1986). The better the shade created by the crown of trees in the surrounding vegetation, the greater is the senescence of *Chromolaena.* The senescence of *Chromolaena* stems gives advantage to shade tolerant forest trees which were in standby under the thickets to develop. Mostly forest trees have no persistent seed bank or are sprouts that had been covered by the *Chromolaena* thicket. This forest environment can also act as filter for the seeds of *Chromolaena* which cannot germinate under the shade of forest trees or cross the forest vegetation. These arguments show that “the conditions of the vegetation around a site had a great effect on community recovery” (Purata 1986).

Chapter 10: Recovery of structural and floristic characteristics during succession

10.1 Structural changes

10.1.1 Physiognomic changes

The normal pathway of forest succession in the less disturbed fallows is bound to the recovery of structural characteristics. During succession and in stable conditions (absence of further disturbance), forest structure changes gradually and is connected with a change in floristic composition.

In the course of forest recovery, the structure of the fallows changes with variable proportions of the different life-forms. Shrubs and trees are the most represented categories. The increase of the proportion of woody species and tree individuals with time since abandonment of the field contributes to the canopy closure, especially due to the fast growth in height of forest pioneer species. As the diversity of woody plants increases with age of the fallows, the canopy closure increases and the proportion of herb species decreases. Most of the herbaceous species are light demanding annual weeds, and cannot grow under the canopy of forest trees. Some species which are absent in the plots at the time of abandonment of the field succeed to establish in following the autogenic changes created by forest pioneer species (Finegan 1984). The shade created by the forest pioneer species modifies the microenvironment in the fallow considerably which is then suitable for germination of seeds of shade tolerant species. These changes gradually lead to a replacement of light demanding herbs by species newly arrived in the fallows. In fact there is a sort of shift from one group of species to another within a period according to the principle of the relay floristics (Egler 1954). Summarizing, succession is the shifting temporal dominance of the plot by different groups of species which have particular ecological requirement (Finegan 1984).

The strong positive correlation existing between age of the fallow and the proportion of woody species and tree individuals is in consistence with results of Keever (1950), Christensen & Peet (1984), and Lawrence (2004) who found that diversity of woody plants increases during succession.

At stand level, the mean canopy closure was low in G 7 which had the highest proportion of herbs. The lowest proportion of herb species was observed in G 3 that had the highest mean values for the canopy closure, the proportion of woody plants and trees. Inversely, the lowest proportion of tree individuals was observed in G 7 and highest proportion in G 3. The link between canopy closure and diversity of herb and woody species is obvious as light is the main factor governing the germination of the seeds.

In most of the less disturbed fallows the canopy closure reached up to 60% between three to five years of abandonment. Most of these fallows were of low to moderate size and were generally surrounded by either mature or secondary forest. The consequence is their rapid "cicatrising" due to the high canopy closure with age of the fallows. This high canopy closure is due to the fast growth of forest pioneer species. As the disturbance in these fallows was low, the available regeneration mechanisms (sprouts, seedlings and saplings) and also the shrub and tree individuals already present, contributed to speeding up the recovery of the structure of the secondary forest. The pathway towards old growth forest is then accelerated. Chinea (2002) found that in absence of further disturbance in the fallows the regeneration mechanisms control forest recovery.

The proportion of climber species was not correlated with age.

10.1.2 Age and basal area

Frequency and intensity of disturbance which impact forest recovery are also perceived in the variation of basal area. The highest value (26.4 m² per ha) is observed in G 3 consisting of old less disturbed fallows while the lowest (2.5 m² per ha) is found in G 7.

The multiple cropping cycles characterizing the *Chromolaena* thickets reduce the above-ground biomass and the basal area. The regular cutting and burning that accompanied every clearing, affects tree and shrub population in the fallows. Many of the tree and shrub individuals recorded in these fallows are sprouts of small dbh which can be cut easily because of the softness of their wood. The lowest basal area of 2.5 m² per ha found in G 7 results from multiple cropping cycles. However, the low value cannot be explained by the farming system alone. In G 8 where stands of *Chromolaena* were also found, the basal area was 7.7 m² per ha, more than three times larger than that of G 7. The difference between the two groups can be explained by the previous vegetation of the fallows. As already mentioned, a higher number of plots (31.2%) was established after clearing mature or secondary forest in G 8 than in G 7 (18.7%). The number of trees with a dbh of 20 cm or more was higher in G 8 (25 individuals or 10.2%) than in G 7 (10 or 4.1%). Probably trees selected during clearing by farmers are responsible of the higher value of basal area in G 8. For instance, three individuals of the oil palm *Elaeis guineensis* were found in each of the two groups. This species can grow in the wild even if not planted. The other criteria of selection are the large dbh and the hardness of the wood, such as in *Panda oleosa* and *Pentaclethra macrophylla*. The difference is also due to the difference in the size of the biggest tree. The biggest tree in G 8, *Coelocaryon preussii,* had a larger dbh (73.8 cm) than *Elaeis guineensis* (62 cm), the biggest tree in G 7. Another reason is the absence of trees and shrubs in some fallows in G 7, which contributes to the low basal area.

Because the frequency of cropping cycles was low in the less disturbed fallows, most of the sprouts and saplings had the possibility to develop both in height and in thickness. The growth in thickness increased the dbh of the species and ipso facto the basal area. This development also concerns pre-existing trees spared during clearing.

Most studies on mature and secondary forests in Africa or in the Neotropics have focused on structural characteristics (Uhl 1987, Swaine et al. 1987, Saldarriaga et al. 1988, Kammesheidt 1992, Guariguata et al 1997, Tucker et al. 1998, Gemerden 2004) and can be compared with our study in southern Cameroon (tabl. 10.1).

The results of the present work are close to those of the studies achieved in the Neotropics (Uhl 1987, Saldarriaga et al. 1988, Tucker et al. 1998, Rivera et al. 2000, Chinea 2002, Chinea & Helmer 2003) and similarly illustrate the fact that the frequency and intensity of disturbance affected the basal area.

Other studies conducted either in Cameroon (Gemerden 2004) or elsewhere in tropical regions (Aide et al. 1996, Aide et al. 2000, Zimmerman et al. 1995) exhibit values of basal area which are larger than the values of the present study. In each of these cases, the difference between the values of their basal area and that of this study is not less than 11.1 m² per ha.

The above comparison of the recovery of basal area raises some comments. The minimum dbh in southern Cameroon (5 cm) was higher than in the studies of Germerden (2004) and those from the Neotropics (1 and 2.5 cm). It can be predicted that if the minimum dbh in this study was downgraded to 1 or 2.5 cm like in the studies in the South and Central America, the values of the basal area would have been larger than the current results. The other reason is length of the time since abandonment. The low value of the highest age of the abandoned fields in the Neotropics is 25 years (Chinea 2002) which is by 10 years lower than the oldest fallows in southern Cameroon (35 years). Chinea (2002) found a coefficient of variation of 0.11 in 32 fallows while in the current study, this coefficient is 0.3 and it means that in this study, the rate of recovery is somehow faster than in Puerto Rico. The size of the plot can explain these discrepancies. Most of the plots were 50 m² (cases by Aide and Zimmerman) while in this study each plot covered an area of 400 m². Considering a plot of 50 m² in tropical forest is not representative, as many trees and shrub individuals belonging to the same vegetation unit can be missed during floristic inventory.

Table 10.1: Comparison of some structural characteristics during succession in southern Cameroon and the Neotropics

	Basal area (m^2)		Stand age (yr)		Stem density (stems/ha)		Dbh (cm)	Height (m)	Plot size (m^2)
	Min	Max	Min	Max	Min	Max	Min	Min	
This study	2.5 [6.8]	26.4	0.5 [1]	35	475[263]	1379	5		400
Gemerden et al. (2003)	2.1	35.7	10	60	1906	4131	2	0.5	625
Swaine et al. (1987)*	28 (30.8)	52			392	734	10		
Uhl (1987)	0.5	7	1	5				2	100
Saldarriaga et al. (1988)	11	36*	10	>60			1	2	300
Aide et al. (1995)					4000 (14000)	11000	1		50
Aide et al. (1996)	5	40	9.5-15	>60	8000	14000	1		50
Aide et al. (2000)	30	39	35-40	>70			1		50
Zimmerman et al. (1995)	30	45	5	≥60	6000	8000	1		50
Tucker et al. (1998)	2.7	7	[1-4]		407	773			
	3.8	15		[6-10]					
	9	11.3	(20)	7					
Rivera et al. (2000)	5.5 [6.6]	23.6 [44.5*]	≤ 5	≥ 25[30]			1		200[500]
Chinea (2002)	10	30	5	>45	500 (2600)	2000	2.5		250
Chinea & Helmer (2003)	3.4	21.5					2.5		
Kammesheidt (1992)*	26.2	[33.6]			410	458			

(* in mature forest

The values of basal area found in this study are very close to those of mature forest as reported by Swaine et al. (1987) in Ghana and Kammesheidt (1992) in Paraguay and Venezuela.

10.1.3 Age and stem density

The variation of stem density between 263 and 1379 stems per ha is an important information that helps to understand the process of forest recovery in relation with farming system. The lowest value is observed in G7 while the highest is found in G3. Multiple clearing and burning affecting the regularly disturbed fallows can explain their low stem density. Seedlings and saplings of forest species are also eliminated during weeding.

In the less disturbed fallows, the long time span since abandonment of the fields is favouring recovery. The low intensity and low frequency of disturbance result in increasing stem density. The increase is also a consequence of other ecological factors such as canopy closure and proportion of types of plants. As new woody plant species (climbers excluded) are established in the fallow, the number of individuals increases which leads to an increase of stem density.

Most of the studies on forest succession have considered stem density (tab. 10.1) as an important parameter which expresses structural changes during forest recovery. Apart from Tucker et al. (1998), all these studies exhibit values of stem density larger than those of this study. The maximum density in this study does not even reach the minimum values of Germerden (2004), Aide et al. (1995), Aide et al. (1996), and Zimmerman et al. (1995) which are all from abandoned fields or farms. The low density in the present study can be explained by the minimum dbh considered. This minimum dbh value of 5 cm excludes a large number of stem of dbh [between 1 or 2.5 and 4.9 cm] that would have increased the stem density. The lower the minimum dbh, the higher the number of shrub individuals and the stem density. In contrast, upgrading the minimum dbh to 10 cm as is the case in Ghana (Swaine et al. 1987), leads to a low stem density. The values of this study fit in the range of those of mature forests (Swaine et al. 1987, Kammesheidt 1992).

The results and arguments developed above concerning the values of the basal area and the stem density are in consistence with results of Purata (1986), Guariguata et al. (1997), and Guariguata & Ostertag (2001) who reported that during succession, structural characteristic can rapidly approach those of mature forest. The results also corroborate with those of Chinea (2002) who considered that age of the fallows since abandonment is a good predictor of recovery of structural characteristics. The discrepancies observed in values of basal area of this study and those of other authors especially for old-growth stands can be explained by the fact that the recovery of this structural parameter does not follow a linear but a logarithmic trend. Beyond a certain age of abandonment, the increase of dbh of forest species is very slow.

10.2 Floristic changes

10.2.1 Influence of farming cycles

Land use and farming system influence the species richness. Succession depends on the floristic potential (Clements 1916 cit. Alexandre 1989) defined as all species present at a given time. The species present at the time of disturbance, but also those which arrive in the plot shortly after, initiate succession.

In the regularly disturbed fallows, repeated cropping cycles in the same plot within short periods cause decline and even exhaustion of regeneration mechanisms (Uhl 1987, Uhl et al. 1982, Rouw 1993 1994, Kammesheidt 1998). Not only weed individuals are eliminated but also those of forest species regardless their guild category. Since seeds of pioneer species are largely present in the soil of tropical forests (Guevara & Gomez-Pompa 1972), it can be assumed that despite successive burnings, new individuals of forest pioneer species will still grow in the field from the remaining quantity of seeds available after burning. Thus the negative aspect of the multiple cropping cycles within short intervals mostly concerns non-pioneer forest species. Some of these species are eliminated from the field during weeding. Sprouts and coppices that speed up forest recovery (Murphy & Lugo 1986) are also destroyed by multiple farming cycles in the same plot. Lawrence (2004) reported that “abundance of late successional species should decline with the number of prior cycles.” In these regularly disturbed fallows, the herbaceous species, mostly weeds, are dominant a few months after the abandonment of the fields as is the case for plots 2 and 4 which are both six months old. The negative net effect of *Chromolaena odorata* hampers succession until the thickets weaken and die, then allowing succession to continue. In other words, the mechanism of succession in the regularly disturbed fallows follows the inhibition model of Connell & Slatyer (1977) due to the persistence of *Chromolaena* thickets.

In the less disturbed fallows, the situation is different since the intensity and frequency of interference by farming are low and forest pioneers are the most abundant and dominant species in some vegetation groups. Therefore, the normal succession is taking place. The maximum age of 35 years and the predominance of forest pioneer species in the tree layer indicate that the succession still continues. The different vegetation groups represent the trajectory towards the mature forest. Herbaceous species are among the first colonizers of the abandoned field. They are part of the initial floristic composition defined as colonizer element since the abandonment of disturbed land (Egler 1954). The presence of shrub and tree individuals in the field casts shade which contributes naturally to break weed infestation (Rouw 1995) and explains the low importance of herbaceous species in the less disturbed fallows. G5, the youngest group within the less disturbed fallows, represents the shrub stage which follows the herbaceous phase and is characterized by *Harungana madagascariensis* in this vegetation layer. When *H. madagascariensis* starts to die some years later, it is replaced by *Musanga cecropioides, Anthocleista schweinfurthii* and *Macaranga hurifolia* which are all forest pioneer tree species. It is obvious that the change in species composition is followed by the change of life forms starting from herbs to shrubs and then trees.

In G4 where most of the fallows are former banana fields, the vegetation is mostly formed by pure stand of *Musanga cecropioides* mixed in some cases with *Macaranga hurifolia*.

10.2.2 Guild categories and species replacement during succession

10.2.2.1 Forest pioneer species

The species replacement during succession has always been a major concern for plant ecologists who described several models and mechanisms to explain this process (Egler 1954, Connell & Slatyer 1977, Connell et al. 1987, Pickett et al. 1987). The precondition is a good knowledge of the ecological characteristics of the species. After disturbance, plant residuals and the seed bank of the soil contribute largely to succession. Forest pioneer species produce large quantities of small-sized fruits dispersed mostly by birds and bats. When the field is abandoned, most of the species establishing in the fallows from seeds are forest pioneers since their seeds have a long dormancy and longevity. For instance in Côte d'Ivoire, seeds of the forest pioneer *Trema orientalis* are still viable after being stored for 30 years in the soil and the density of these seeds is very high, 300 - 3000 per square meter (Alexandre 1978). The fast growth of forest pioneer species enables them to fill canopy openings and to form a canopy in a very short period of time (Swaine & Whitmore 1988, Finegan 1984, 1996). Their wood is of poor quality justifying why they are often called weed trees. Alexandre (1982a) reports that their growth strategy is "trouée-trouée" (gap-gap) since they accomplish their entire life cycle in the openings. They correspond to the ruderal strategy of Grime (1974) because their establishment and development are possible only if a disturbance occurs in the forest. They have a short lifespan which does not exceed 30 years for some species like *Musanga cecropioides* and their maximum height can be 20 m, except for a few species like *Musanga cecropioides* (Alexandre 1989). Following their life history, forest pioneer species are r-selected (Pianka 1970).

10.2.2.2 Non pioneer light demanding species

The concomitant presence of pioneer and non pioneer species in all vegetation groups illustrates the mechanism of species replacement during succession. Forest pioneers do not regenerate under their canopy. It means that they create “conditions unsuited for themselves, but suited for the invasion of the next group” (Egler 1954: 414). The ecological conditions created by the shade of pioneer species are similar to those prevailing in a mature forest and then, shade tolerant forest species can establish under their canopy.

The shade tolerant species form a heterogeneous group. For example, in the fallow young individuals of *Piptadeniastrum africanum, Lophira alata, Funtumia elastica* and *Spathodea campanulata* are growing in early stages of succession together with forest pioneers because the germination of their seeds requires light and can only take place in openings. They were not present at the outset but just invaded. Finegan (1996) considers their early colonizing behavior as a “prerequisite” for their growth and development. They can withstand the shade created by the forest pioneers. When the pioneers die, their development speeds up until they can reach their maturity in forest canopy as is the case for *Piptadeniastrum africanum* and *Lophira alata.* They are known under many terms such as “non pioneer light demanding species” (Hawthorne & Abu-Juam 1995), “long-lived biological nomads” (van Steenis 1958), “late secondary species” (Budowski 1965), or “long-lived pioneers” (Finegan 1996). Most of them are wind dispersed and can reach the forest canopy. For this last reason, Alexandre (1989) called them “géantes anémochores” and their capacity to resprout is high. Their establishment during succession follows the tolerance model (Connell & Slatyer 1977) and portrays very well the relay floristics as described by Egler (1954). They have a long lifespan and most of them can be found in the forest upper tree stratum of mature forest. Their strategy does not correspond to one of the categories of Pianka (1970). They start their life cycle in the opening or gap (“trouée”) and finish it in the forest (“forêt”). Their growth corresponds to the “forêt-trouée” (forest-gap) strategy of Alexandre (1982a). They can develop slowly under the canopy of the pioneers and their growth is speeded up when the pioneers die. Thus they are a good example for illustrating the stress strategy (Grime 1974). Most of them furnish good timber of high economic value.

10.2.2.3 Shade tolerant or forest species

The most important change in floristic composition during forest recovery is very subtle and takes place in the understory of the secondary forest (Peña Claros 2003). In the understory of these less disturbed fallows, numerous shade tolerant species such as *Coelocaryon preussii, Annickia chlorantha*, *Diospyros conocarpa*, and *Cola marsupium* are found. These species produce large seeds which do not have any dormancy and which must germinate immediately in the fallows after dispersal (Vasquez-Yanes & Orozco Segovia 1993). The shade already casted by the forest pioneers increases the soil moisture and creates suitable conditions for the germination of their seeds and their establishment. Finegan (1984) considers that the establishment of shade tolerant forest species is possible due to forest pioneer trees which alleviate the hard conditions prevailing in the fallows at the time of disturbance. They have a long lifespan and a late sexual maturity, which are life histories of K-selected species (Pianka 1970) and their development fits with the competition strategy (Grime 1974). Their full life cycle is accomplished in forest and they belong to the "forêt-forêt" strategy of Alexandre (1989). Their seeds are dispersed by many agents, among them mammals and large birds (e.g. hornbills) or by autochory. Out of the different means of seed dispersal (fig. 6.4), zoochory is predominant in fallows of the different vegetation groups and influences recovery and establishment of shade tolerant forest species known to have large seeds (Alexandre 1989). As the canopy closes up as already said, it becomes possible for many mammals to interact with the fallows and to enrich them in seeds of forest species (shade bearers) present in their dungs.

Species replacement does not take place in a trenched way. In other words, a group of species of the same guild category does not disappear completely before their replacement by species of another guild. From the early colonizing species to the shade tolerant, species replacement operates according to an ecological continuum between the three main guild categories presented above. From one phase of forest succession to another, species replacement takes place in an overlapping way. Before one wave of species characteristic for one step of forest succession disappears, the young individuals of species that will dominate the upcoming step are already present even in a discrete form. Many forest species present show intermediate characters. For example, *Canarium schweinfurthii, Pycnanthus angolensis, Piptadeniastrum africanum,* and *Lophira alata* are all non pioneer light demanding species. But whereas *Canarium schweinfurthii* and *Pycnanthus angolensis* are zoochorous (the fruits are drupes), *Piptadeniastrum africanum* and *Lophira alata* are wind dispersed (seeds are samara). This explains the difficulty that some ecologists often encounter in classifying plant species according to their guild category, despite abundant literature on the topic (Budowski 1965, 1970, Mangenot 1955, van Steenis 1958, Swaine & Whitmore 1988).

10.3 Species diversity

Species richness shows a weak positive correlation with age. Studies in tropical forests document the variation of species richness in secondary or primary forests in Cameroon and in Venezuela and Columbia (tabl. 10.2). The study area of Tchouto et al. (2006) partly covers the area of the present study while that of Zapfack et al. (2002) is Ebolowa and Mbalmayo (Yaounde area). Of the studies conducted in Cameroon, only that of Tchouto et al. (2006) does not concern secondary forest but different types of mature forest.

Table 10.2: Comparison of diversity indices in some tropical forests

	Area	Age		Species richness		*Chromolaena*	Shannon index		Pielou evenness	
		Min	Max	Min	Max	Number	Min	Max	Min	Max
This study	Cameroon	1	35	13	120	389	2.0	4 .6	0.7	0.9
Gemerden (2004)	Cameroon	10	60	75	173					
Tchouto et al. (2006)	Cameroon			78	140		4.7			
				18	108		4.5			
				93	147		5.1			
				81	143		4.9			
				63	145		4.7			
Zapfack et al. (2002)	Cameroon			[160]	[171]	149	6.6	7.0		0.9
Uhl (1987)	Neotropics	1	5	17	36		1.9	2.8		
Saldarriaga et al. (1988)	Neotropics	60	80	(60, 62, 66)	(72, 73, 60, 79)					
				(63, 66, 75, 96)						

The maximum values of species richness, indices of Shannon and Pielou evenness of the present study are almost similar to those of other authors. The lowest values of the diversity indices are from the regularly disturbed fallows and can be explained by the dominance of *Chromolaena* thickets. Under homogeneous ecological conditions, the diversity is low and is great if the conditions are diverse and varied (Odum 1963 cit. Grime 1973). In fallows established on sandy soil in the coastal area, species diversity is low, due to the sandy nature of the soil. The coarse grains of sand in this area increase the permeability of the soil and affect the cation exchange capacity. All soil nutrients are washed out and carried away.

The species richness of the *Chromolaena* thickets is higher than that described by Zapfack et al. (2002). The large difference between their value and that of this study can be explained by the fact that in their sampling method, they considered only trees and shrubs of at least 5 cm dbh while the other types of plants (herbs and climbers) were not recorded.

Beyond a certain age, species diversity is similar to that of old growth. The values of species richness and the Shannon diversity index of old fallows are similar to those of mature forest (Saldarriaga et al. 1988, Tchouto et al. 2006). But although the species richness of the fallows is approaching that of mature forest, the quality of the species (floristic composition) is not the same. These results are consistent with those of Brown & Lugo (1990), Finegan (1996) and Guariguata & Ostertag (2001), according to who the species richness in secondary forest is rapidly recovered and can reach that of mature forest after few decades but not the floristic composition.

10.4 Important families and genera

The flora of the fallows is dominated by species related to the Guinea-Congolian phytochory. The study area belongs to the Guineo-Congolian Regional Centre of endemism (White 1979, 1983) which is divided by the Dahomey Gap into the Upper Guinea zone (G) in the West and the Lower Guinea zone (LG) in the East including countries like Cameroon, Gabon, and Equatorial Guinea.

With respect to the values of the family important index (FIV), the Euphorbiaceae, Leguminosae, Cecropiaceae, Moraceae, Myristicaceae, Annonaceae, Rubiaceae, Apocynaceae, Arecaceaea, Guttifereae and the Sterculiaceae are the most important plant families. Apart from the Arecaceae, Cecropiacea, and the Moraceae, all these most important families are mentioned by White (1983) as characteristic families of the Guineo-Congolian phytochory. Besides these families with high FIV, the Scytopetalaceae, Pandaceae, and the Lepidobotryaceae which were represented in the fallows are endemic to this phytochory. It is also the case with the Hoplestigmataceae and the Pentadiplandraceae which were present in some fallows by *Hoplestigma pierreanum*, and *Pentadiplandra brazzeana* respectively even though we did not record them in the plots.

This centre of endemism is one of the richest regions in Africa in terms of plant diversity and endemism (Linder 2001), and includes species endemic to Cameroon (Cam), the Upper Guinea (G), and the Lower Guinea (LG) areas. The results of this study are in consistence with those of others authors (Sonké 1998, Gemerden 2004, Tchouto 2004, Ngok Banak 2005) who emphasized the abundance both in species and genera of families like Euphorbiaceae, Rubiaceae, Leguminosae and Annonaceae in the forest of the Congo Basin. Their importance in fallows is just a consequence of their predominance at the regional level. Letouzey (1968, 1985) focused on the importance of the sub-family of Leguminosae-Caesalpinioideae in the evergreen forest of the area. He mentioned that most of the tree species occurring in the canopy of this forest belong to this subfamily. In the present study, this subfamily is represented by 20 species. In the tree stratum, *Berlinia bracteosa, B. auriculata, Distemonanthus benthamianus, Eythrophloeum ivorense, Gilbertiodendron brachystegioides, Guibourtia ehie,* and *Hymenostegia afzelii* are present. Species of Leguminosae-Mimosoideae were also frequent and dominant especially *Albizia adianthifolia, A. zygia, Pentaclethra macrophylla* and *Piptadeniastrum africanum.* Most of these species, except *Pentaclethra macrophylla,* are non pioneer light demanding with wind-dispersed seeds and are part of the initial floristic composition (Egler 1954) which Finegan (1984) considers as the “cornerstone” of succession.

The arguments developed for the families are also valid at generic level. Many genera (e.g. *Amphimas, Antrocaryon, Discoglypremna, Gilbertiodendron,* and *Heckeldora*) are endemic to this centre of endemism.

Age influences the flora of the fallows. In young fallows, herbaceous species were found and their abundance and presence decreased with increasing age. For example species like *Selaginella myosorus* and *Ipomoea involucrata* were often abundant in young fallows but absent in old ones.

Some families like the Commelinaceae, Cyperaceae, Dioscoreaceae and the Poaceae are well represented due to the fact that the establishment of most of their species takes place in disturbed forest areas where the canopy is opened (Egler 1954, Finegan 1984, Alexandre 1989).

Some genera are exclusive to one of the two main groups of fallows. Ruderal herb species are common in *Chromolaena* thickets. In the less disturbed fallows, the autogenic changes are accompanied by gradual replacement of forest pioneers by shade tolerant forest species belonging to genera like *Diospyros, Cyanastrum,* and *Cola.*

10.5 Abundance and dominance of pioneers species

Abundant and dominant species in all vegetation layers are mostly forest pioneers. They produce large numbers of seeds which constitute the majority of the seed bank of the soils of tropical forests (Finegan 1996). Canopy opening allows the light to reach the forest soil and stimulate the germination of their seeds. Their abundance and dominance in the course of succession can be explained by their large quantity and density in the soil of the fallows (Guevara & Gomez-Pompa 1972, Alexandre 1978, Finegan 1996).

Under the canopy of these trees, their seeds cannot germinate and develop because they are light demanding species (Alexandre 1982a, 1989, Brown & Lugo 1990, Finegan 1996).

In fallows with no trees (*Chromolaena* thickets), young individuals of forest pioneer species are abundant since they can sprout from stumps of trees that had been felt during clearing (Rouw 1993) or result from seeds stored in the soil. In other words, individuals of forest pioneer species were forming large part of the regeneration mechanisms (Uhl, 1987). The age of the fallows is correlated with the abundance and dominance of forest pioneers. The oldest fallows have an age of 35 years, covering the lifespan of most forest pioneer species which is between 10 and 30 years (Finegan 1996). *Musanga* was very often present among the abundant and dominant species in the different vegetation layers. In some old fallows, some dead stems of forest pioneer species are found. The importance of *Musanga* over other pioneer species is probably due to the high survival of the seeds in comparison to other pioneers, like *Macaranga hurifolia* of which only 5% of the seeds in the soil are viable (Kahn & Namur 1978). Among all species of the genus *Macaranga, M. hurifolia* is the most frequent in the shrub and lower tree strata of different vegetation groups. It has a fast growth and 18 months after germination of its seeds, it can reach a maximum height of 15 m (Kahn & Namur 1978). In Côte d'Ivoire, Kahn & Namur (1978) reported that *Macaranga hurifolia* is only present in former fields that had not undergone repeated cropping cycles. The situation in southern Cameroon is different since *Macaranga hurifolia* is not only present in the regularly disturbed fallows, but is also abundant and dominant in the understory of less disturbed fallows. In an environment where no stands of *M. hurifolia* are bordering the fallows, its individuals probably come from the seed bank. The low seed predation of *M. hurifolia* in southern Cameroon can be hypothesized.

The abundance of forest pioneer species can be understood by their light requirements during their full life cycle. Forest pioneer species are able to tolerate the extreme temperature and low fertility of the soil that prevail in the early environment of abandoned fields (Finegan 1984).

The shrub stratum shows a high specific diversity compared to other vegetation layers. In this layer, comprising individuals of 5 to 20 cm dbh, the most abundant and dominant species are forest pioneers. Also individuals of other guild categories such as *Calpocalyx heitzii, Milicia excelsa,* and *Sacoglottis gabonensis* which are either non pioneer light demanding or shade tolerant species are present. Taking into account that understory species can determine the floristic composition of the future canopy (Swaine & Hall 1988, Oldeman 1990), there is no doubt that after the disappearance of the pioneers, the upcoming mature forest will have the structural characteristics of the one that was cleared originally.

10.6 Dominance of Marantaceae and Zingiberaceae in the understory of groups 1 and 2

10.6.1 Marantaceae and Zingiberaceae in Central Africa

In Central Africa, many patches of forest are dominated by thickets of Marantaceae and Zingiberaceae. Their description is often focused on their origin, which can be anthropogenic (Letouzey 1985), paleaoclimatic (Foresta 1990, Maley 1990, and Dowsett-Lemaire 1996) or edaphic (Tchiengué 2004). This vegetation type is found on the slopes of Mount Cameroon (Letouzey 1985), as well as on Mount Kupe (Tchiengué & Nkongmeneck 2010). Most of the authors (Foresta 1990, Maley 1990, Dowsett-Lemaire 1996) think that the thickets give evidence of former past extent of savannas in the Central African forest block.

In the Mayumbe region, Foresta (1990) found that these thickets cause a delay of forest succession according to the inhibition model of Connell & Slatyer (1977). Both on Mount Kupe and in the Mayumbe region, the density of woody tree and shrub individuals in the thickets is very low. The few trees present are typical of semi-deciduous forest, mixed with forest pioneer tree species.

Large leaves of different species of Marantaceae and Zingiberaceae constitute an obstacle to the germination of the seeds in the soil. They act as a barrier to the sunlight which cannot reach the soil to trigger germination of the seeds.

10.6.2 Thickets of Marantaceae and Zingiberaceae in Southern Cameroon

Marantaceae and Zingiberaceae form dense thickets in the understory of fallows of G1 and G2. Of the eleven species of these two families recorded, ten occur in G1 and G2. Most of the species encountered in the thickets comprise *Haumania danckelmaniana, Marantochloa* spp., *Megaphrynium megaphyllum,* and *Sarcophrynium prionogonium* for Marantaceae, *Aframomum* spp., and *Renealmia* spp. for Zingiberaceae. Only *Hypselodelphys zenkeriana* is absent in the fallows of these vegetation groups.

The structure of these fallows is quite different from that of other thickets of Marantaceae and Zingiberaceae described by Letouzey (1985) and Maley (1990) for Mount Cameroon, Tchiengué & Nkongmeneck (2010) for Mount Kupe, Foresta (1990) for the Mayumbe region, and Dowsett-Lemaire (1996) for Congo. In southern Cameroon, most of the shrub and tree individuals are forest pioneer tree species.

The density of trees and shrubs in G1 and G2 is 756 and 954 individuals per ha respectively which is in contrast with results of Letouzey (1985), Maley (1990), Foresta (1990) and Tchiengué (2004). Foresta (1990) reports that no tree is found per 1000m². In our study on the contrary, individuals of dbh between 5 and 20 cm represent 84.3% in G1 and 82.7% in G2 and can be viewed as sign of good forest regeneration. A tree layer is present and most of the individuals are those of forest pioneer species. In these fallows mostly established on former groundnut fields, not more than two farming cycles had taken place. The use of hoes to plant groundnuts brings out seeds that were present in the upper centimeters of the soil depth. The dominance of Marantaceae and Zingiberaceae species can be explained by their abundance in the part of the seed bank brought out by hoeing.

The other argument that strengthens the difference is that thickets of Marantaceae and Zingiberaceae described elsewhere were found not far from savanna communities while in southern Cameroon, they are a transitory phase in a successional process with numerous forest pioneer tree species.

10.6.3 Factors governing the abundance of Marantaceae and Zingiberaceae in the understory of groups 1 and 2

For an understanding of the abundance of Marantaceae and Zingiberaceae species in the understory of fallows in G1 and G2, the dispersal, ecology and biology of the species must be known. Ley (2008) reports that apes and monkeys are dispersal agents of some Marantaceae species while *Haumania* and *Hypselodelphys* species are dispersed by gravity. Williamson et al. (1990) and Tutin & Fernandez (1993) found seeds of *Aframomum, Megaphrynium* and *Sarcophrynium* in faeces of these animals.

During their frequent visits to the fallows, mammals can transport away seeds or fruits of the mentioned species contributing to enlarge their dispersal area. Their abundance may only be explained by the abundance of their seeds in the site.

From an ecological perspective, they are light demanding species (especially for the germination of their seeds) which prefer to grow and to develop in gaps just like forest pioneer tree species. Considering that seeds of forest pioneer species constitute the majority of the seed bank of the tropical forests soil (Guevara & Gomez-Pompa 1972), there is no doubt that the dominance of Marantaceae and Zingiberaceae species in the understory of the fallows of G1 and G2 is due to the large quantities of their seeds in the seed bank of the soil. The most abundant species belong to the genera *Aframomum, Haumania* and *Megaphrynium.* Probably these species of Marantaceae and Zingiberaceae had been present at the beginning of the succession and the fast growth of forest pioneer species allowed them to escape the competition with Marantaceae and Zingiberaceae. Their stems were high enough and the large leaves of Marantaceae and Zingiberaceae could not hamper the germination of their seeds.

Another hypothesis is that in the plots, the germination of the seeds of forest pioneers took place before that of the Marantaceae and Zingiberaceae.

From a biological point of view, the abundance of the Marantaceae and Zingiberaceae can be understood by their quick vegetative reproduction. The species are endowed with large branched rhizomes which allow them to expand and occupy more space (Foresta 1990). From these large rhizomes, they can produce new shoots contributing henceforward to dominate in the understory of the fallows. Their seeds, like those of pioneer forest species, have a hard testa which protects them from high temperatures during the burning that follows clearing of the forest (Ley 2008). It gives them an advantage over seeds of other species.

10.6.4 Situation in other vegetation groups

Marantaceae and Zingiberaceae (especially *Haumania danckelmanniana*, *Megaphrynium macrostachyus* and *Aframomum daniellii*) are dominant only in the understory of G1 and G2. In the other groups, they are just present but not dominant. Their abundance depends upon the intensity of disturbance and type of crops that had been planted in the plots. Thus in G7, after many farming cycles and with short fallow length leading to poor canopy closure, these species are rare. Although some of them are light demanding, their absence or low performance can be explained by the multiple clearing and burning within short interval of time that affect the seed bank of the soil.

In the former cassava fields (G5) which do not require more than one burning and a strong weeding like in groundnut fields, they are still rare. Cassava can grow even in presence of weeds because it competes well. This is not the case with groundnuts where all weeds are eliminated from the fields. In G3 and G6 constituted of old fallows, the relatively close canopy does not allow the dominance of Marantaceae and Zingiberaceae species. At the same time, the germination of their seeds is limited since only a small quantity of light reaches the soil. Despite the young age of the fallows, the situation is almost similar in G8.

In G4 comprising fallows developed from former banana fields planted with or without *Cucumeropsis mannii*, Marantaceae and Zingiberaceae species were not dominant probably because banana fields do not require a strict maintenance as is the case for groundnuts. Most of these banana fields were created at the expense of mature forest and did not undergo many burnings and weedings. The establishment and growth of forest tree species is then more accelerated. The canopy becoming more and more close, the Marantaceae and Zingiberaceae do not have chance to develop.

Conclusion: Implications to forest management and conservation of the biodiversity

One main novelty of the Cameroonian forest law N° 094/01 of January 20, 1994 is the creation of community forest. This law gives to local people the possibility to exert some rights on the resources of the forest neighbouring their villages, including the exploitation of timber species. The sustainability of this practice requires good management of the forests regardless their mature or secondary nature. With respect to the agricultural activities, the management plan must take into consideration the farming practice to avoid hampering of forest recovery.

There have been many attempts to eradicate *Chromolaena odorata* in former forested land (Roder et al. 1995, Honu & Dang 2000). In Ghana, Honu & Dang (2000) found that removal of *Chromolaena odorata* allowed forest tree species which were in standby under its canopy to grow normally. However, this technique requires a large hand labour and is time consuming. Only natural regeneration can provide good results.

The dynamics of the thickets depends not only upon the vegetation type neighbouring them, but also on the trees that had been selected by the farmers during forest clearing. *Chromolaena odorata* is a shade intolerant plant species. The shade created by the trees already present in the fallows before the establishment of the weed weakens the stems of *Chromolaena* and leads to its death. In case of competition between forest and a *Chromolaena* thicket, forest always invades the thicket in a centripetal way. The shade created by trees in the forest surrounding the thicket weakens the stems of *Chromolaena odorata* which finally die. This is always the case when the vegetation around the fallows is either a mature or a secondary forest. However, if the surrounding vegetation of the thickets consists of similar thickets, forest recovery is speeded up only under available isolated trees. The trees that had been spared during clearing, casts shade and favour disappearance of *Chromolaena*. This new condition allows the seedlings of shade tolerant forest species which were under the canopy of *Chromolaena* to develop. The senescence of stems of *Chromolaena odorata* starts under these isolated trees. However, some stems of *Chromolaena odorata* are often found in the forest but their development is hampered by shade of the available trees. Their spreading capacity is very limited and the individuals die after a short period.

On the basis of the above arguments and taking into account the colonizing capacity of *Chromolaena odorata,* efficient management methods will also include the creation of a forest buffer zone around the fields. This buffer zone will contribute to prevent invasion by *Chromolaena* in the following ways. It will constitute a sort of natural forest boundary or filter that *Chromolaena odorata* seeds cannot cross. This buffer zone will provide suitable shade that will hamper the development of *Chromolaena* in case it succeeds to get established in the field after abandonment. It can be viewed as source of seed inputs especially for forest tree species, and will facilitate the interaction between seed dispersers, mainly mammals, and the fallows, thus enriching the fallows in seeds of forest tree species.

Selection of some forest trees during clearing by farmers is not sufficient to speed forest recovery. Some patches of mature forest or old secondary forest must be also left behind during clearing. These forest patches, apart from acting as *Chromolaena* filters, will serve as reservoir of forest species. In this case, recovery will be accelerated since the forest tends to expand in a coalescent way. They will enrich the fields after abandonment with seeds of forest species. This management approach is consistent with results of Lawrence (2004) who recommended that patches of primary forest should be left in secondary forest in order to serve as “a repository of late successional species”.

Fire is not selective and burns not only the plant remains but also the stumps of tree species. Stumps are good sources of sprouts of forest tree species after disturbance and play an important role in recovery of structural characteristics of the forest after disturbance and the preservation of these stumps was already suggested (Delvaux 1958, Aweto 1981 and Zinke et al. 1978 cited by de Rouw 1993).

At the light of the results of this study, the end-point of recovery following agricultural activities in the dense tropical area is always a forest, regardless the frequency of farming cycles. With regard to the fact that farmers often like to clear dense thickets of *Chromolaena odorata* to establish their crop fields, this technique can be considered as essential in preserving tropical mature forests. It could decrease the pressure on the remaining patches of mature forests in the tropics and contribute to the conservation of the biodiversity.

12 Summary

The ongoing debate on deforestation in the tropics usually points out agriculture and logging as the main causes. The two activities are often linked and the trails created by logging companies with their heavy machines are afterwards used by farmers to penetrate deep into the forest and cultivate. Shifting cultivation is a widespread agricultural practice in the tropics and its sustainability is often a matter of controversy. It is necessary to investigate forest recovery after shifting cultivation, analyze its succession stages for comparison with regeneration after natural disturbance, and evaluate its role for discussing the hazards of deforestation.

This study investigates forest succession on post shifting cultivation fallows in southern Cameroon along a transect from Campo at the Atlantic coast to Ma'an in the interior. The study area is under an equatorial climate with high annual precipitation of ≥1500 mm and covered by different types of dense tropical forest. From the coastal evergreen forest at Campo to the semi-deciduous forest at Ma'an, many intermediary forest types can be found.

Studies of forest succession after shifting cultivation can follow a diachronic (regular follow up of fallows at regular timescale) or a synchronic approach (synchronous study of fallows of different ages). The synchronic approach was adopted in this study and consisted in analyzing a chronosequence of 144 plots demarcated in fallows at different successional stages.

Data were collected in fallows with ages from six months to 35 years selected with the help of farmers who provided data regarding their age and history. Determination of the age was not easy because farmers do not keep records regarding the year of farming. However, by cross checking different events that had occurred at both village and national levels, it was possible to estimate the age of the fallows. Farmers provided information related to the history of the fallow including the type of vegetation that was cleared prior to the last farming (mature or secondary forest or thicket of *Chromolaena odorata*), the number of farming cycles carried out in the farmer's plot (not the experimental plot), and the type of crop that was lastly planted. The vegetation surrounding the fallow was also noted. This vegetation could be a forest (mature or secondary), a thicket of *Chromolaena odorata* or a forest on one side of the fallow and a thicket on the other. The history of the fallow and the types of the vegetation surrounding the fallow were considered as categorial variables.

A 20x20 m² plot was demarcated at the center of each fallow in order to avoid margin effect. The floristic inventory recorded all plant species present in the plot. A Braun-Blanquet cover-abundance index was assigned to each species according to the vegetation layer in which it was found.

In each plot, all tree and shrub individuals of at least 5 cm diameter at breast high (1.30 m above ground level) were counted. Multi-stemmed trees were considered as separate individuals. For trees with larges buttresses and stilt roots, the dbh was measured above the buttresses and the stilt roots. Soil samples were taken in order to determine the texture. Fertile plant material was collected and deposited at the National Herbarium of Cameroon (YA) and at the Senckenberg Herbarium in Frankfurt (FR). The percentage of canopy closure was determined by estimating the projection on the ground of the area covered by each species.

A total of 605 plant species belonging to 424 genera and 104 families were recorded in the plots, comprising 493 dicotyledons, 90 monotyledons, 21 ferns and 1 gymnosperm. The floristic composition of the fallows is narrowly linked to the regional flora of the area. Thus, the most important families like Fabaceae, Euphorbiaceae, Myristicaceae and Annonaceae belong to the characteristic floristic inventory of the Guineo-Congolian regional centre of endemism. Some of the species are strict or narrow endemic to the area.

Two data matrices, the main and the second one, were created. The main matrix contains floristic data and the second one the data on the categorical and other variables. Prior to the analysis, the values on the main matrix were log transformed and imported in PC-Ord, the computer package which was used for data analysis. For the multivariate analysis, Nonmetric Multidimensional Scaling (NMS) was performed as ordination method and Cluster Analysis for vegetation classification. The ordination analysis helped to seek the influence of ecological factors governing the floristic data while classification enabled to discriminate vegetation groups. For each vegetation group, an indicator species analysis (ISA) and a Monte Carlo test were carried out to determine the indicator species of each vegetation group and their p-value. For a good description of the vegetation groups, some phytosociological and structural parameters like the relative frequency, relative density, relative dominance, and importance value index were calculated. For each species recorded in the fallows, some of its autecological characters (life form, diaspore dispersal, phytogeographical distribution, Plant Functional Type = PFT, guild) were noted. Some of the parameters calculated were integrated in the second matrix.

The NMS ordination showed that different quantitative factors, such as canopy closure and proportion of life forms, have an influence on the floristic composition of the vegetation of the fallows. The different arrows emanating from the centroid are directed to the vegetation groups where the corresponding factor or structural parameter is high. Thus the proportion of herbs is high in the regularly disturbed fallows which are dominated by dense thickets of *Chromolaena odorata,* and low in the other groups. At the opposite, the proportions of woody species, mainly trees, are high in the less disturbed fallows and low in the *Chromolaena* thickets. The same observation is valid for diversity parameters. The highest values of species richness, Pielou evenness, and Shannon and Simpson diversity indices are exhibited for the less disturbed fallows. These results highlight the influence of disturbance intensity on forest recovery. Because only two different values were used in the study, the influence of precipitation was not considered even if it is assumed to influence vegetation.

The entire data set of 144 fallows was split into eight vegetation groups of unequal size by classification analysis. They belong to two main categories, the regularly and the less disturbed fallows. The regularly disturbed fallows (groups 7 and 8) comprise a total of 48 relevés emanating from fields which in most cases had undergone multiple farming cycles and in which the density of trees is very low. They are dominated by dense thickets of *Chromolaena odorata*. Their fallow length is between one to three years. In some cases, especially in the coastal area, fallow length can reach five years even if the structure of the vegetation is not different from the others, because of the sandy nature of the soil. In these fallows established on sandy soil, the species richness is low and some of them do not have any tree individual. According to the nature of the vegetation prior to farming and the surrounding, the regularly disturbed fallows are divided into two groups (groups 7 and 8). In group 7, the fields had been created by clearing thickets of *Chromolaena odorata*, which at the same time are surrounding the fallows. In group 8, on the contrary, fields had been established mostly at the detriment of secondary forest, and the fallows which developed afterwards are bordered by mature and secondary forest or thickets of *Chromolaena odorata*. Succession in these fallows is delayed due to the persistent *Chromolaena odorata* thickets and only when these thickets senesce, forest recovery can take place.

The role of trees selected during clearing is of paramount importance in forest recovery. They are visited by many animals (birds and mammals) which during their stay enrich the fallows in seeds present in their dung and this contributes to the establishment of some species which had not been present before. Their shade contributes to the senescence of the *Chromolaena odorata* thickets, favouring the growth of seedlings and saplings of forest tree species under its canopy.

The intensity and frequency of disturbance highly influence forest recovery in these fallows. Regular clearing and burning drastically reduce stem densities.. Group 7 has the lowest stem density of 263 individuals per ha while in group 8 it was 469 individuals per ha. These values of the stem density are in the same trend as those of the basal area. Most of the woody plants are shrubs with dbh between 5 and 20 cm, in the majority sprouts arising from stumps of forest trees that had been cut down during clearing. Another agricultural practice responsible for the characteristics of groups 7 and 8 is shortening of the fallow length, i.e. a former field is cropped again after a short fallow period of two to three years. Thus seedlings as well as young shoots emanating from stumps of trees are continuously eliminated. The consequence of such a practice is the rarity of trees with large dbh, a low canopy closure, and a high proportion of herbaceous species. Around Campo beach where soils are constituted of coarse sand, *Pteridium aquilinum* co-dominates in few plots with *Chromolaena odorata* and the species richness is low.

In the less disturbed fallows represented by 96 relevés, the situation is different. Vegetation groups 1 to 6 represent the normal pathway of forest recovery similar to regeneration after natural disturbance. In these fallows, the number of farming cycles does not exceed two. The surrounding vegetation is either a mature or a secondary forest which favors the input of seeds into the fallows. Consequently, in fallow plots surrounded by forest, the speed of recovery is fast. The absence of regular clearing, burning, and weeding characterizing the frequently disturbed fallows, allows the regeneration mechanisms to control forest recovery. Plant residuals and seeds from the seed bank of the soil play a major role in this process. During succession, the site is sequentially dominated by one species or group of species which considerably modify the conditions, thus allowing other species with ecological requirements different to the previous ones to establish.

Group 5 is the shrub stage which follows immediately after the herbaceous phase. The mean age of these fallows (former cassava fields) is three years, and this succession step is dominated by the pioneer shrub *Harungana madagascariensis* which disappears after a few years. Group 4 is composed of fallows developed from former banana fields. They are dominated by stands of *Macaranga hurifolia* and *Musanga cecropioides*. The peculiarity of these fallows is the presence of *Funtumia elastica* and *Rauvolfia macrophylla* in the tree layer. The mean age of the fallows is seven years.

Groups 1 and 2 are transitory phases to an old stage. Their tree stratum is dominated by forest pioneers. The influence of the farming practice is perceived in these groups. Their fallows were former groundnut fields. The understory is dominated by Marantaceae and Zingiberaceae, especially *Aframomum daniellii* and *Megaphrynium macrostachym* in group 1 and *Haumania danckelmaniana* in group 2. These species grow under the forest pioneers which dominate the lower and medium tree strata. The richness of the soil seed bank in seeds of Marantaceae and Zingiberaceae is an explanation for their dominance in the understory.

Vegetation groups 3 and 6 constitute the oldest fallows (≥ 20 years). They are characterized by tall trees and a clear understory resembling mature forests. Most of their structural characteristics, like high basal area, high canopy closure, and low proportion of herbaceous species, approach those of mature forest. Vegetation groups 3 and 6 have also in common the hydromorphic environment. In group 3, the fallows were found near swamps with *Raphia* sp. In group 6, the fields had been created by clearing periodically inundated mature forest. Because the fallows are old and had enough time to develop, the number of diagnostic species is higher than in the other groups.

After abandonment, the tree species in the plots establish according to the guild category to which each of them belongs. Forest pioneer species are early colonizers of disturbed lands because they are shade intolerant and require light for seed germination and growth. In all vegetation groups, forest pioneers are the most abundant guild in the shrub and tree strata. They are present at the outset of succession, together with non pioneer light demanding species, and are mostly wind dispersed. The dormancy of their seeds is limited, and wind dispersal allows them to colonize open areas. Their fast growth enables them to fill the canopy gap in a short time. Forest pioneer species cast shade which considerably modifies the conditions in the understory, leading to the establishment of shade tolerant woody species. In southern Cameroon, some of them, like *Piptadeniastrum africanum, Distemonanthus benthamianus,* and *Lophira alata* are economically important and good timber species. This shows that secondary forests, if well managed, can contribute to the gross domestic product of the country.

The age of the fallows influences the recovery of structural characteristics. Age is positively correlated with basal area, canopy closure, proportion of woody species and stem density, provided the absence of any further disturbance. At the opposite, the proportion of herbs is negatively correlated with age. At the early stage of succession, shortly after abandonment, the proportion of herbaceous species is high, especially when there had been many farming cycles in the plot. With increasing age of the fallow, the proportion of herbs decreases because they are mostly shade intolerant. They are successively replaced by woody plant species whose proportion increases with age. The values of some of these structural characteristics, like the basal area and species richness, are similar to those of mature forest. Under undisturbed succession, their recovery is fast.

In comparison to the high values of stem density found elsewhere in tropical Africa, Asia and South and Central America, the values found in this study are significantly lower. This can be explained by the different sample methods. We considered only individuals with ≥ 5 cm dbh, while the other studies also included shrubs with dbh ≤ 5 cm.

This study shows that in the dense tropical forests, the end-point of recovery following agricultural activities is always a forest, regardless the frequency of farming cycles in the same plot. Some successional phases, like the dense thickets of *Chromolaena odorata*, can last longer than others, but are finally also replaced by forest. However, although the values of species richness in former fallows approach those of mature forest, the quality of the species is not necessarily the same. The floristic composition of a recovered forest is never a facsimile of the original forest that was destroyed.

Concluding the results of the study, some suggestions for management plans of tropical forest can be made, taking into consideration the advantages and disadvantages of *Chromolaena odorata*. Some patches of mature forest or old secondary forest must always be left behind during clearing. These forest patches, apart from acting as *Chromolaena* filters, will serve as reservoir of forest species. In this case, recovery will be accelerated since the forest tends to expand in a coalescent way. Stumps are good sources of sprouts of forest tree species after disturbance and should therefore be preserved in the fields. The technique preferred by farmers to clear dense thickets of *Chromolaena odorata* for their fields can be considered as essential for preserving mature tropical forests. It can decrease the pressure on the remaining forest patches and thus helps to conserve biodiversity.

13 Zusammenfassung

Die Abholzung tropischer Regenwälder schreitet ungebremst voran, verursacht vor allem durch Landwirtschaft und Holzeinschlag. Oft folgt dabei die Landwirtschaft der Holzgewinnung, denn die Schneisen, die von den schweren Maschinen der Holzfäller oder zur Erschließung der Rodungsgebiete in den Wald geschlagen werden, werden anschließend von Bauern genutzt, um weiter in den Wald einzudringen und dort neue Felder anzulegen. Der Anbau von Kulturpflanzen findet in den Tropen in der Regel im Wanderfeldbau statt - nach einigen Jahren des Anbaus wird das Feld aufgelassen. Die Nachhaltigkeit dieser Praxis ist allerdings umstritten. Um die Rolle des Wanderfeldbaus bei der Abholzung der tropischen Wälder abschätzen zu können, ist es notwendig, die Regeneration des Waldes auf diesen Flächen zu untersuchen und ihren Ablauf mit der Regeneration infolge natürlicher Störungen zu vergleichen.

Für das südliche Kamerun, entlang eines Transsekts von Campo an der Küste bis nach Ma'an im Landesinneren, untersucht die vorliegende Studie die Sukzession auf Brachen des Wanderfeldbaus im zentralafrikanischen Regenwald. Die Niederschläge betragen dort, unter äquatorialem Klima, mehr als 1500 mm pro Jahr. Die immergrünen Wälder an der Küste gehen ins Landesinnere hin in halbimmergrüne Wälder über, parallel mit abnehmenden Niederschlägen.

Um Sukzessionen nach dem Wanderfeldbau zu untersuchen, gibt es zwei Möglichkeiten. Beim diachronen Ansatz wird über einen längeren Zeitraum die Sukzession auf einigen Brachen verfolgt, der synchrone Ansatz hingegen hält die Stadien der Sukzession auf Brachen unterschiedlichen Alters fest, ohne bei jeder einzelnen ihre individuelle Entwicklung zu untersuchen. In der vorliegenden Arbeit wurde synchron vorgegangen und eine Chronosequenz von 144 Brachen in verschiedenen Sukzessionsstadien aufgenommen. Die Brachezeit betrug zwischen sechs Monaten und 35 Jahren. Informationen zu Alter und vorheriger Nutzung der Brachflächen lieferten die örtlichen Bauern. Da die Bauern keine Aufzeichnungen führen, musste das Alter mittels Abgleich mit regionalen oder landesweiten Ereignissen abgeschätzt werden. Auch zum Vegetationstyp, der vor dem letzten Anbauzyklus gerodet worden war, zur Zahl der Anbauzyklen in der Fläche und über die zuletzt angebaute Kulturpflanze wurden die Bauern befragt. Zudem wurde die umgebende Vegetation der Fläche notiert. Die Vorgeschichte der Brache und die Vegetation um die Brache herum wurden in der Analyse als kategorische Variablen berücksichtigt.

Für die floristische Aufnahme wurde in der Mitte jeder Brache eine Fläche von 20 x 20m² abgesteckt um Randeffekte zu vermeiden. Alle Pflanzenarten wurden aufgenommen und die Artmächtigkeit, getrennt nach Vegetationsschichten, unter Verwendung der Braun-Blanquet-Skala abgeschätzt.

In jeder untersuchten Fläche wurden Bäume und Sträucher mit mindestens fünf Zentimetern Durchmesser in Brusthöhe (dbh, 1,3 m über dem Boden) aufgenommen. Mehrstämmige

Bäume wurden als getrennte Individuen gewertet. Bei Bäumen mit Brett- oder Stelzwurzeln wurde der Brusthöhendurchmesser oberhalb des Wurzelansatzes gemessen. Fertiles Pflanzenmaterial wurde gesammelt und im Nationalherbar Kameruns in Yaoundé (HNC) deponiert; Duplikate befinden sich im Herbarium Senckenbergianum, Frankfurt (FR). Um die Bodentextur zu bestimmen, wurden Bodenproben genommen. Der Kronenschlussgrad in Prozent wurde bestimmt, indem abgeschätzt wurde, wie viel Boden die Kronen überdeckten.

In den untersuchten Flächen wurden insgesamt 605 Pflanzenarten gefunden; sie gehören zu 424 Gattungen aus 104 Familien und beinhalten 493 Dikotyledonen, 90 Monokotyledonen, 21 Farne und 1 Gymnosperme. Die floristische Zusammensetzung der Brachen ist eng an die regionale Flora des Gebiets gekoppelt. Die in den Aufnahmen wichtigen Pflanzenfamilien – Fabaceae, Euphorbiaceae, Myristicaceae und Annonaceae – gehören zu den charakteristischen Familien der Guineo-Congolischen Region. Einige der Arten sind strikt, andere fast endemisch im Untersuchungsgebiet.

Zwei Datenmatrizen, die Hauptmatrix und die zweite Matrix, wurden angelegt. Die Hauptmatrix enthält die floristischen Daten, die zweite Matrix die Daten zu den kategorischen und anderen Variablen. Vor der Analyse wurden die Daten der Hauptmatrix logarithmiert und in PC-Ord importiert, der Software zu Datenanalyse. Für die multivariate Analyse wurde das „Nonmetric Multidimensional Scaling“ (NMS) als Ordinationsverfahren durchgeführt und für die Vegetationsklassifizierung eine Clusteranalyse. Das Ordinationsverfahren half auf der Suche nach den ökologischen Faktoren, welche die floristischen Daten bestimmen, während die Klassifikation erlaubte, Vegetationsgruppen zu unterscheiden. Um die Indikatorarten jeder Vegetationsgruppe zu bestimmen, wurden für jede Vegetationsgruppe eine Indikatorartenanalyse („Indicator Species Analysis“, ISA) und ein Monte-Carlo Test durchgeführt. Die ISA berechnet für jede Art in jeder Gruppe einen Indikatorwert (IndVal). Ist der IndVal einer Art in einer Gruppe hoch und der p-Wert nach dem Monte-Carlo Test unter 0,05, ist eine Art diagnostisch für diese Vegetationsgruppe.

Für die vollständige Beschreibung der Vegetationsgruppen wurden weitere pflanzensoziologische und strukturelle Parameter berechnet, wie relative Häufigkeit, relative Dichte, und „Importance Value Index“ (IVI). Einige der berechneten Parameter wurden in die zweite Matrix integriert. Für jede Art wurden zudem einige ihrer autökologischen Merkmale (Lebensform, Samenverbreitungstyp, phytogeographische Verbreitung, PFT = „Plant Functional Type“, Gilde) erfasst.

Die NMS-Ordination zeigte, dass verschiedene quantitative Faktoren wie Kronenschluss und Anteil der Lebensformen einen Einfluss auf die floristische Zusammensetzung der Brachen hatten. Sehr hoch ist beispielsweise der Anteil der Kräuter in den regelmäßig gestörten Brachen, die von dichten *Chromolaena odorata*-Dickichten dominiert werden. Umgekehrt ist in den weniger gestörten Brachen der Anteil der Gehölze hoch und in den *Chromolaena odorata*-Dickichten niedrig. Ähnliches gilt für die Parameter der Diversität. Die höchsten Werte für Artenreichtum, ermittelt über Pielou-Äquität, Shannon- und Simpson-Indices, wurden in den am wenigsten gestörten Brachen erreicht. Die Ergebnisse belegen den Einfluss der Störungsintensität auf die Waldsukzession.

Mit Hilfe der Klassifikationsanalyse wurden die 144 Brachen in acht Vegetationsgruppen von ungleicher Größe eingeteilt. Die Vegetationsgruppen lassen sich zwei Hauptkategorien zuordnen, den regelmäßig gestörten und den weniger gestörten Brachen. Die regelmäßig gestörten Brachen (Gruppen 7 und 8) umfassen insgesamt 48 Aufnahmen von Feldern, die in den meisten Fällen mehreren Anbauzyklen unterworfen waren und in denen Artenreichtum und Baumdichte sehr gering sind. Sie sind dominiert von *Chromolaena odorata*-Dickichten und waren zum Untersuchungszeitpunkt ein bis drei Jahre alt. In einigen Fällen, vor allem in der Küstenregion, waren Brachen dieser Gruppe auch fünf Jahre alt. Die sandige Textur des Bodens bedingte hier die Ähnlichkeit mit den jüngeren Brachen.

Abhängig von der gerodeten und der umgebenden Vegetation, konnten die regelmäßig gestörten Brachen in zwei Gruppen (Gruppe 7 und 8) untergliedert werden. In Gruppe 7 waren die Felder in *Chromolaena odorata*-Dickichten angelegt worden und dieser Vegetationstyp umgibt dann auch die Brachen. In Gruppe 8 hingegen waren die Felder vorwiegend in Sekundärwald angelegt worden; diese Brachen sind von voll entwickeltem Wald, Sekundärwald oder *Chromolaena odorata*-Dickichten umgeben. Die Sukzession in beiden Gruppen ist wegen der sehr konkurrenzkräftigen *Chromolaena odorata*-Dickichte verzögert. Erst nachdem die Dickichte gealtert sind, kann die Regeneration des Waldes einsetzen. Die Baumdichte ist sehr niedrig und in einigen Brachen ist nicht ein einziger Baum vorhanden. Dabei sind Bäume, die während des Anlegens des Feldes ausgespart werden, von herausragender Bedeutung für die Waldregeneration. Sie werden von vielen Tieren aufgesucht, die mit ihrem Dung Samen in die Brachen eintragen, auch von solchen Arten die vorher in der Brache nicht (mehr) vorhanden waren. Der Schattenwurf der Bäume in den Brachen trägt zudem zur Alterung der *Chromolaena odorata*-Bestände bei und ermöglicht den Sämlingen und Schösslingen der Waldbäume, die Regeneration des Waldes einzuleiten.

Intensität und Häufigkeit der Störungen Haben einen starken Einfluss auf die Regeneration der Brachen. Regelmäßiges Abholzen und Brennen reduzieren die Stammdichte drastisch – in einigen Brachen stand kein einziger Baum. Insgesamt hat Gruppe 7 mit 263 Individuen pro Hektar die niedrigste Stammdichte; in Gruppe 8 sind es 469 Individuen pro Hektar. Die Bestandsgrundfläche („basal area“) zeigt den gleichen Trend. Bei den meisten Gehölzen dieser Gruppe handelt es sich um Sträucher mit einem dbh zwischen fünf und zwanzig Zentimetern. In der Regel sind es Stockausschläge aus den Stümpfen der Waldbäume, die beim Anlegen des Feldes gerodet wurden. Ein weiterer bestimmender Faktor für die Gruppen 7 und 8 ist die Verkürzung der Brachezeit. Die Felder werden bereits nach zwei bis drei Jahren Brachezeit wieder bebaut. Sämlinge der Bäume und Stockausschläge der Stümpfe werden ständig wieder gekappt. Die Folge ist, dass Bäume mit größerem dbh selten sind; der Kronenschluss ist gering, und die krautigen Pflanzen stellen einen hohen Anteil an der Vegetation der Flächen. Um Campo Beach, mit seinen Böden aus grobem Sand, co-dominiert *Pteridium aquilinum* mit *Chromolaena odorata* in den Brachen; ihr Artenreichtum ist sehr niedrig.

Die weniger gestörten Brachen sind durch 96 Aufnahmen repräsentiert. Die Vegetationsgruppen 1 bis 6 repräsentieren den normalen Weg der Waldsukzession, ähnlich der Regeneration nach natürlichen Störungen. Auf diesen Flächen hatten maximal zwei Anbauzyklen stattgefunden. Der umgebende Wald (voll entwickelt oder sekundär) sorgt für den Eintrag von Samen in die Brachen, und die Regeneration der Flächen verläuft zügig. Auch Stockausschläge und die Samenbank der Brachen kommen hier zum Tragen, da anders als bei den häufig gestörten Brachen, regelmäßiges Abholzen, Brennen und Jäten nicht in so großem Ausmaß stattfinden.

Kurz nach dem Auflassen der Felder ist der Anteil der Kräuter sehr hoch. Im Verlauf der Sukzession werden die Flächen nacheinander von Arten oder Gruppen von Arten dominiert, die jeweils die ökologischen Bedingungen auf den Flächen beträchtlich verändern. So ermöglichen sie Arten mit anderen ökologischen Ansprüchen als sie selbst, sich zu etablieren.

Das Strauchstadium, das auf die krautige Phase folgt, ist in Gruppe 5 zusammengefasst. Das Durchschnittsalter dieser Brachen - auf ihnen war zuletzt Maniok angebaut worden - liegt bei drei Jahren. Dieses Sukzessionsstadium wird von dem Pionierstrauch *Harungana madagascariensis* dominiert, der aber nach einigen Jahren wieder verschwindet.

Die Baumpionierarten *Macaranga hurifolia* und *Musanga cecropioides* dominieren in den Brachen der Gruppe 4. Hier waren zuletzt Bananen kultiviert worden. Das Besondere dieser Brachen ist, dass in der Baumschicht *Funtumia elastica* und *Rauvolfia macrophylla* vorhanden sind; in den anderen Gruppen ist das nicht der Fall. Im Durchschnitt sind diese Brachen sieben Jahre alt.

Gruppen 1 und 2 sind mit einem Durchschnittsalter von 16-17 Jahren Übergangsstadien zur späten Phase. In der unteren und mittleren Baumschicht sind Waldpioniere zahlreich; im Unterwuchs dominieren Marantaceae und Zingiberaceae: *Aframomum daniellii und Megaphrynium macrostachyum* in Gruppe 1 und *Haumania danckelmanniana* in Gruppe 2. Alle Brachen dieser Gruppen waren vorher Erdnussfelder. Der Grund für die Dominanz der Marantaceae und Zingiberaceae liegt vermutlich in der Samenbank des Bodens. Für den Anbau von Erdnüssen muss, anders als bei anderen Kulturpflanzen, mehrfach gebrannt werden, und ein Großteil der Samen im Boden wird dadurch zerstört. Die hartschaligen Samen dieser Pflanzenfamilien hingegen sind feuerresistent und reichern sich dadurch relativ im Boden an.

Die Vegetationsgruppen 3 und 6 bilden die ältesten Brachen (≥ 20 Jahre). Sie sind gekennzeichnet durch hohe Bäume und einen lichten Unterwuchs, der dem voll entwickelter Wälder ähnelt. Die meisten ihrer strukturellen Merkmale, wie Bestandsgrundfläche („basal area“), Kronenschluss und ein niedriger Anteil krautiger Pflanzen nähern sich denen voll entwickelten Waldes an. Gemeinsam ist diesen beiden Gruppen der hydromorphe Boden. Die Brachen der Gruppe 3 liegen in der unmittelbaren Nähe zu *Raphia*-Sümpfen, und die Felder der Gruppe 6 waren in periodisch überschwemmten Wäldern angelegt worden. Aufgrund des hohen Alters der Brachen und der langen Regenerationszeit ist die Zahl der diagnostischen Arten höher als in den anderen Gruppen.

Nach dem Auflassen der Felder siedeln sich die Baumarten entsprechend ihrer Gildenzugehörigkeit an. Zunächst kolonisieren Pionierarten die gestörten Flächen. Sie können Schatten nicht ertragen und benötigen Licht für Samenkeimung und Wachstum. In allen Vegetationsgruppen sind die Pioniere die häufigste Gilde in den Strauch- und Baumschichten. Viele sind windverbreitet und gelangen so in offene Flächen, wo sie zügig keimen. Ihr schnelles Wachstum ermöglicht es ihnen, die Lücke im Kronendach in kurzer Zeit zu schließen. Die Pioniere beschatten die Flächen und verändern so die Bedingungen im Unterwuchs zu Gunsten der schattentoleranten Gehölzarten. Im südlichen Kamerun sind einige von ihnen, wie *Piptadeniastrum africanum, Distemonathus benthamianus* und *Lophira alata*, wirtschaftlich wichtige und wertvolle Nutzholzarten. Sie belegen, dass Sekundärwälder, wenn sie gut gemanagt werden, zum Bruttoinlandsprodukt des Landes positiv beitragen können.

Mit zunehmendem Alter der Brache verändern sich die strukturellen Merkmale. Bestandsgrundfläche, Kronenschluss, Anteil der Gehölzarten und Stammdichte nehmen zu und der Anteil der Kräuter nimmt ab, vorausgesetzt, dass keine weiteren Störungen stattfinden. Auch der Artenreichtum gleicht sich dem von voll entwickeltem Waldbestand an.

Im Vergleich zu den hohen Stammdichten, die bisher für Afrika, Asien und Süd- und Mittelamerika publiziert wurden, sind die Werte in unserer Studie signifikant niedriger. Das kann methodisch erklärt werden, denn hier werden, anders als in den anderen Studien, Gehölzindividuen mit einem Stammumfang <5 cm nicht berücksichtigt.

Die Ergebnisse zeigen, dass im Gebiet des dichten tropischen Regenwaldes der Endpunkt der Regeneration nach dem Wanderfeldbau immer ein Wald ist, unabhängig von der Zahl der Anbauzyklen in einer Fläche. Einige Sukzessionsphasen, beispielsweise die *Chromolaena odorata*-Dickichte, können sich länger behaupten, aber auch sie werden letztlich durch Wald ersetzt. Obwohl die Diveritäts-Werte jene von voll entwickeltem Wald erreichen, ist die Artenzusammensetzung nicht unbedingt die gleiche. Die floristische Zusammensetzung eines Sekundärwaldes ist nie eine exakte Kopie des Waldes, der zerstört wurde.

Schlussfolgernd aus der vorliegenden Untersuchung können Empfehlungen zur Bewirtschaftung der tropischen Wälder im südlichen Kamerun gegeben werden. Dabei sind neben den Nachteilen auch die Vorteile von *Chromolaena odorata* zu berücksichtigen. Zunächst sollten beim Anlegen neuer Felder immer einige Bestände voll entwickelten oder alten Sekundärwaldes stehen gelassen werden. Sie dienen zum einen als Filter, die vor dem Eintrag von *Chromolaena* schützen, und zum anderen als Reservoir für Waldarten. So kann die Regeneration beschleunigt werden. Baumstümpfe sollten ebenfalls in den Feldern belassen werden, denn Stockausschläge sind ein weiterer Ausgangspunkt der Regeneration. Aber auch die Vorliebe der Bauern, *Chromolaena odorata*-Bestände zu roden um ihre Felder anzulegen, trägt essentiell zum Erhalt der tropischen Wälder bei, denn es reduziert den Druck auf die verbleibenden Waldbestände und erhält so die Biodiversität.

14 References

Aide TM, Zimmerman JK, Herrera L, Rosario M, Serrano M (1995) Forest recovery in abandoned tropical pastures in Puerto Rico. For Ecolog Manag 77:77-86

Aide TM, Zimmerman JK, Rosario M, Marcano-Vega H (1996) Forest recovery in abandoned cattle pastures along an elevational gradient in Northeastern Puerto Rico. Biotropica 28(4):537-548

Aide TM, Zimmerman JK, Herrera L, Pascarella JB, Riviera L, Marcano-Vega H (2000) Forest regeneration in a chronosequence of tropical abandoned pastures: implications for restoration ecology. Restor Ecolog 8(4):328-338

Alexandre DY (1978) Observations sur l'écologie de *Trema guineensis* en basse Côte d'Ivoire. Cah ORSTOM, Ser Biol 13(3):261-266

Alexandre DY (1982a) Aspects de la régénération naturelle en forêt de Côte d'Ivoire. Candollea 37:579-588

Alexandre DY (1982b) La dispersion de *Solanum verbascifolium* en Côte d'Ivoire: rôle des Céphalophes. Rev Ecolog (Terre et Vie) 36:293-295

Alexandre DY (1989) Dynamique de la forêt dense de Côte d'Ivoire. Stratégies écologiques des arbres de la voûte et potentiels floristiques. Collect Etudes Thèses ORSTOM, Paris

Aubréville A (1965) Principes d'une systématique des formations végétales tropicales. Adansonia 5(2):153-196

Aweto AO (1981) Secondary succession and soil fertility restoration in south western Nigeria. I Succession. J Ecolog 60:601-607

Aweto AO, Iyanda AO (2003) Effects of Newbouldia laevis on soil subjected to shifting cultivation in the Ibadan area, Southwestern Nigeria. Land Degrad Dev 14:51-56

Bagnoul F, Gaussen H (1953) Saison sèche et indice xérothermique. Bull Soc Hist Nat Toulouse 88:193-240

Bebwa B (1990) Biomasse et minéralomasses d'une jachère préforestière de deux ans dans les environs de Kisangani (Zaïre). Belg J Bot 123(1/2):92-102

Bellingham PJ, Sparrow AD (2000) Resprouting as life history strategy in plant communities. Oikos 89:409-416

Biholong M (1986) Contribution à l'étude de la flore du Cameroun: Les Asteracées. Thèse de Doctorat, Université Bordeaux III

Bouxin G (2004) Les techniques d'analyse factorielle et d'ordination. http://users.skynet.be/bouxin/ASDV/Ordinationtechniques.pdf. Accessed 1 October 2010

Brokaw NVL (1985) Gap-phase regeneration of three pioneer species in a Neotropical forest. Ecolog 66(3):682-687

Brookfield H, Padoch C (1994) Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices. Enviro 36(5):6-21

Brown S, Lugo A (1990) Secondary forests. J Trop Ecolog 6:1-32

Bruelheide H (2000) A new measure of fidelity and its application to defining groups. J Veg Sci 11(2):167-178

Budowski G (1965) Distribution of tropical American rain forest species in the light of successional process. Turrialba 15:40-42

Budowski G (1970) The distinction between old secondary and climax species in tropical Central America lowland forests. Trop Ecolog 11:44-48

Carrière S (1999) “Les orphelins de la forêt”. Influence de l’agriculture itinérante sur brûlis des Ntumu et des pratiques agricoles associés sur la dynamique forestière du sud Cameroun. Thèse de Doctorat, Université de Montpellier II, Montpellier

Carrière SM, André M, Letourmy P, Olivier I, McKey D (2002) Seed rain beneath remnant trees in a slash and burn agricultural system in southern Cameroon. J Trop Ecolog 18(3):353-374

Chapman RS, Chapman CA (1999) Seed dispersal and potential forest succession in abandoned agriculture in tropical Africa. Ecolog Appl 9(3):998-1008

Charles-Dominique P (1986) Inter-relations between frugivorous vertebrates and pioneer plants: Cecropia, birds and bats in French-Guyana. In: Estrada A & Fleming TH (eds) Frugivores and seed dispersal, Dr. W. Junk, Dordrecht, pp 119-135

Chazdon RL (2003) Tropical forest recovery: legacies of human impact and natural disturbances. Perspect Plant Ecolog Evol Syst 6:51-71

Chinea JD (2002) Tropical forest succession on abandoned farms in the Humacao municipality of eastern Puerto Rico. For Ecolog Manag 167:195-207

Chinea JD, Helmer HE (2003) Diversity and composition of tropical secondary forests recovering from large scale clearings: results from the 1990 inventory in Puerto Rico. For Ecolog Manag 180:227-240

Christanty L (1986) Shifting cultivation and tropical soil: patterns, problems and possible improvements. In: Marten GG (ed) Traditional agriculture in South Asia: a human ecology perspective. Westview Press, Colorado, pp 226-240

Christensen NL, Peet RK (1984) Convergence during secondary forest succession. J Ecolog 72(1):25-36

Chytrý M, Tichý L, Holt J, Botta-Dukát Z (2002) Determination of diagnostic species with statistical fidelity measures. J Veget Sci 13:79-90

Clark CJ, Poulsen JR, Malonga R, Elkan PWJr (2009) Logging concessions can extend the conservation estate for central African tropical forests. Conserv Biol 23(5):1281-1293

Clements FE (1916) Plant succession: an analysis of the development of vegetation, Carnegie Institute, Washington

Conklin H (1957) Hanunóo agriculture. Unasylva 11:172-173

Conklin H (1961) The study of shifting cultivation Curr Anthropol 2(1):27-61.

Connell JH, Slatyer RO (1977) Mechanisms of succession in natural communities and their role in community stability and organization. Am Natu 111:1119-1144

Connell JH, Noble IR, Slatyer RO (1987) On the mechanisms producing successional change. Oikos 50:136-137

Coombe DW (1960) An analysis of the growth of Trema guineensis. J Ecolog 48(1):219-231

Coombe DE, Hadfield W (1962) An analysis of the growth of Musanga cecropioides. J Ecolog 50(1):221-234

Curtis JT (1955) A note on recent work dealing with the spatial distribution of plants. J Ecolog 43:309

Curtis JT, McIntosh RP (1951) An upland forest continuum in the prairie-forest border region of Wisconsin. Ecolog 32:476-496

Dansereau P, Lems K (1957) The grading of dispersal types in plant communities and their significance. University of Montreal, Montreal

Da Silva JMC, Uhl C, Murray G (1996) Plant succession, landscape management, and the ecology of frugivorous birds in abandoned Amazonian pastures. Conserv Biol 10(2):491-503

Delvaux JC (1958) Effets mesurés des feux de brousse sur la forêt claire et la coupe à blanc dans la région d'Elisabethville. Bull Agron Congo Belg 49:689-714

Denslow JS (1980) Patterns of plant species diversity during succession under different disturbance regimes. Oecologia (Berl) 46:18-21

Diaw CM (1997) Si, Nda bot and Ayong. Shifting cultivation, land uses and property rights in southern Cameroon. 21st RDF Network paper. Overseas Development Institute, London

Dounias E (1996) Recrûs forestiers post-agricoles: perceptions et usages chez les Mvae du Sud-Cameroun. J Agric Trad Bot Appl 38(1):153-178

Dowsett-Lemaire F (1996) Composition et evolution de la végétation forestière au Parc National d'Odzala, Congo. Bull Jard Bot Natl Belg 65:253-292

Dufrêne M, Legendre P (1997) Species assemblages and indicator species: a need for a flexible asymmetrical approach. Ecolog Monogr 67:345-366

Duveiller G, Defourny P, Desclée B, Mayaux P (2008) Deforestation in Central Africa: estimates at national, regional and landscape levels by advanced processing of systematically-distributed Landsat extracts. Remote Sens Environ 112(5):1969-1981

Eggert MKH, Höhn A, Kahlheber S, Meister C, Neumann K, Schweizer A (2006) Pits, graves and grains: archaeological and archaeobotanical research in southern Cameroon. J Afr Archaeol 4:273-298

Egler FE (1954) Vegetation science concepts I. Initial floristic composition, a factor in old-field vegetation developement. Veg 4:412-417

Elenga H, Schwartz D, Vincens A, Bertaux J, Namur C, Martin L, Wirrmann D, Servant M (1996) Diagramme pollinique holocène du lac Kitina (Congo): mise en évidence des changements paléobotaniques et paléoclimatique dans le massif forestier du Mayombe. C R Acad Sci Paris 323(2a):403-410

Etejere EO (1980) Viability of herbicide-treated seeds of Eupatorium odoratum L. Weed Res 20:361-363

Evrard C (1968) Recherches écologiques sur le peuplement forestier des sols hydromorphes de la Cuvette Centrale Congolaise. Publ INEAC 110:1-295

FAO (2010) Global forest resources assessment. FAO, Rome

Finegan B (1984) Forest succession. Nat 312(8):109-114

Finegan B (1992) The management potential of neotropical secondary lowland rain forest. For Ecolog Manag 47:295-321

Finegan B (1996) Patterns and process in Neotropical secondary rain forest: the first 100 years of succession. Trend Ecolog Evol 11 (3):119-124

Foresta H (1984) Agriculture sur brûlis en forêt tropicale humide. A propos du rôle du feu dans la compétition entre espèces cultivées et espèces pionnières. Turrialba 34(4):537-542

Foresta H (1990) Origine et évolution des savanes intramayombiennes (R.P. du Congo). II. Apports de la botanique forestière. In: Lanfranchi R, Schwarz D (Eds) Paysages quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp 367-382

Gauch HGJr (1982) Multivariate analysis in community ecology. Camb Univ Press New York

Gauthier-Hion A, Duplantier JM, Quiris R, Feer F, Sourd C, Decoux JP, Dubost G, Emmons L, Erard C, Heckeitsweiler P, Mougazi A, Roussilhon C, Thiollay JM (1985) Fruits characters as a basis of fruit choice and seed dispersal in a tropical forest vertebrate community. Oecolog 65:324-337

Gemerden BS, Olff H, Parren MPE, Bongers F (2003a) The pristine rain forest? Remnants of historical human impacts on current tree composition and diversity. J Biogeogr 30:1381-1390

Gemerden BS, Shu GN, Olff H (2003b) Recovery of conservation values in Central African rain forest after logging and shifting cultivation. Biodivers Conserv 12:1553-1570

Gemerden BS, (2004) Disturbance, diversity and distributions in Central African rain forest. Dissertation, Wageningen Agricultural University

Gérard P (1960) Etude écologique de la forêt dense à Gilbertiodendron dewevrei de la région de l'Uéle. Publ INEAC 87:1-159

Gillet J (1986) Les phytocénoses forestières du jura nord occidental. Essai de phytosociologie intégrée. Thèse de doctorat, Université de Besançon

Gomez-Pompa A, Vasquez-Yanes C, Guevara S (1972) The tropical rain forest: a non-renewable resource. Sci 177:762-765

Gomez-Pompa A, Vasquez-Yanes S (1974) Studies on secondary succession of tropical lowlands: the life cycle of secondary species. Proceeding of the first international congress of Ecology, The Heague

Gomez-Pompa A, Flores Guido JS, Sosa V (1987) The “Pet Kot”: a-man made tropical forest of the Maya. Interc 12:10-15

Goodall DW (1954) Objective methods in the classification of vegetation III. An essay on the use of factor analysis. Aust J Bot 2(3): 303-324

Grime JP (1973) Competitive exclusion in herbaceous vegetation. Natl 242:344-347

Grime JP (1974) Vegetation classification with reference to strategy. Natl 250:26-31

Guevara S, Gomez-Pompa A (1972) Seeds from surface soils in a tropical region of Veracruz, Mexico. J Arn Arb Harvard Univ 53:312-335

Guevara S, Purata SE, van der Maarel E (1986) The role of remnant forest trees in tropical secondary succession. Veg 66(2):77-84

Guarigata MR, Chazdon RL, Denslow JS, Dupuis J, Anderson L (1997) Structure and floristics of secondary and old-growth forest stands in lowland Costa Rica. Plant Ecolog 132:107-120

Guarigata MR, Ostertag R (2001) Neotropical secondary forest succession: changes in structural and functional characteristics. For Ecolog Manag 148:185-206

Guinochet M (1955) Logique et Dynamique du peuplement végétal. Masson Paris.

Guinochet M (1973) Phytosociologie. Masson et Cie, Paris

Hall JS, Harris DJ, Medjibe V, Ashton PMS (2003) The effects of selective logging on forest structure and tree species composition in a Central African forest: implications for management of conservation areas. For Ecolog Manag 183:249-264

Hauser S (2006) Soil temperature during burning of large amounts of wood, effects on pH soil and subsequent maize yields. Conference on International Agricultural Research for Development. University of Bonn, Bonn

Hawthorne WD, Abu-Juam M (1995) Forest protection in Ghana with particular reference to vegetation and plant species. IUCN, Gland

Hill MO (1979a) DECORANA, a FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and systematic, Cornell university, Ithaca, New York

Hill MO (1979b) TWINSPAN a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematics, Cornell University, Ithaca, New York

Hill MO, Gauch HGJr. (1980) Detrended Correspondence analysis: an improved ordination technique. Veg 42:47-58

Hirschfield HO (1935) A connection between correlation and contingency. Proc Cambridge Philos Soc 31:520-524

Honu YAK, Dang QL (2000) Response of tree seedlings to the removal of Chromolaena odorata Linn., in a degraded forest in Ghana. For Ecolog Manag 137:75-82

Honu YAK, Dang QL (2002) Spatial distribution and species composition of tree seeds seedling under the canopy of the shrub, Chromolaena odorata Linn., in Ghana. For Ecolog Manag 164:185-196

Horn HS (1974) The ecology of secondary succession. Annu Rev Ecolog Syst 5:25-37

Hotelling H (1933) Analysis of a complex of statistical variables into principal components. J Exp Psycholog 24:417-441

Ickowitz A (2004) The economics of shifting cultivation and deforestation in Cameroon. Dissertation, University of California.

Ickowitz A (2006) Shifting cultivation and deforestation in tropical Africa: critical reflexions. Dev Chang 37(3):599-626

Ikuenobe CE, Analiefo GO (2003) Influence of Chromolaena odorata and Mucuna pruriens fallow duration on weed infestation. Weed Res 43(3):199-207

Kahn F (1978) Evolution structurale du peuplement à Macaranga hurifolia. Cah ORSTOM, 13 (3):223-238

Kahn F, de Namur C (1978) Le stade à Macaranga hurifolia: installation, développement et disparition. Cah ORSTOM, 13(3):255-259

Kahn F (1982) La reconstitution de la forêt tropicale humide dans le sud-ouest de la Côte d'Ivoire. ORSTOM, Paris

Kammesheidt L (1992) Investigaciones comparativas de estructura en bosques primarios y secundarios en el departemento de San Pedro, Región Oriental de Paraguay. Cuad For 4:1-87

Kammesheidt L (1998) The role of tree sprouts in the restoration of stand structure and species diversity in tropical moist forest after slash and burn agriculture in Eastern Paraguay. Plant Ecolog 139:155-165

Kanmegne J, Duguma B, Henrot J, Isirimah NO (1999) Soil fertility enhancement by planted-tree fallow species in the humid lowlands of Cameroon. Agrofor Syst 46(3):239-249

Karsenty A, Gourlet-Fleury S (2006) Assessing sustainability of logging practices in the Congo basin's managed forest: the issue of commercially species recovery. http://ecologyandsociety.org/vol11/issl/art26. Accessed March 3, 2012

Kassi N'Dja JK, Decocq G (2008) Successional patterns of plant species and community diversity in a semi-deciduous tropical forest under shifting cultivation. J Veget Sci19:809-820

Keever C (1950) Causes of succession on old fields of the Piedmont, North Carolina. Ecolog Monogr 20(3):229-250

Keay RWJ (1959) Lowland vegetation on the 1922 lava flow Cameroon Mountain. J Ecolog 47:25-29

Kent M, Cooker P (1992) Vegetation description and analysis. A practical approach. Wiley & Sons, Chichester, New-York, Brisbane, Toronto, Singapore

Klemick H (2011) Constraints or cooperation? Determinants of secondary forest cover under shifting cultivation. Agrofor Resour Econ Rev 40(3):471-487

Knight DH (1975) A phytosociological analysis of species-rich tropical forest on Baro Colorado Island, Panama. Ecolog Monogr 45:259-284

Kotto-Same J, Woomer PL, Moukam A, Zapfack L (1997) Carbon dynamics in slash-and-burn agriculture and land use alternatives of the humid forest zone in Cameroon. Agric Ecosyst Environ 65:245-256

Koutika LS, Hauser S, Meutem-Kamga JG, Yerima B (2004) Comparative study of soil properties under Chromolaena odorata, Pueraria phaseoloides and Calliandra calothyrsus. Plant Soil 266:315-323

Koutika LS, Rainey HJ (2010) Chromolaena odorata in different ecosystems: weed or fallow? Appl Ecolog Environ Res 8:131-142

Kruskal JB (1964) Nonmetric multidimensional scaling: a numerical method. Psychometrika 29:115-129

Kunz BK, Linsenmair KE (2008) The role of olive baboon (Papio anubis Cercopithecidae) as seed disperser in a savanna-forest mosaic of West Africa. J Trop Ecolog 24(3):235-246

Kushwaha SPP, Ramakrishnan PS, Tripathi RS (1981) Population dynamics of Eupatorium odoratum in successional environments following slash and burn agriculture. J Appl Ecolog 18:529-535

Laurence WF (1999) Reflections on the tropical deforestation crisis. Biol Conserv 91:109-117

Lawrence D (2004) Erosion of tree diversity during 200 years of shifting cultivation in Bornean rain forest. Ecolog Appli 14(6):1855-1869

Lebrun J (1947) La végétation de la plaine alluviale au Sud du lac Edouard. Exploration du Parc National Albert, Mission Lebrun (1937-1938) I. Bruxelles

Lebrun J, Gilbert G (1954) Une classification écologique des forêts du Congo. Publ INEAC 63:1-89

Leroux M (1983) Le climat de l’Afrique tropicale. Champion, Génève

Letouzey R (1960) La forêt à Lophira alata Banks de la zone littorale camerounaise. Bois et Forêts des Tropiques 53:9-20

Letouzey R (1968a) Etude phytogéographique du Cameroun. Lechevalier, Paris

Letouzey R (1968b) Flore du Cameroun, volume 7: Les botanistes au Cameroun. MNHN, Paris

Letouzey R (1982) Manuel de botanique forestière, Afrique tropicale. CTFT, Nogent-sur-Marne

Letouzey R (1985) Notice de la carte phytogéographique du Cameroun au 1:500000. 4) TV: Domaine de la forêt dense humide toujours verte. ICIV, Toulouse

Ley A (2008) Evolutionary tendencies in African Marantaceae: evidence from floral morphology, ecology and phylogeny. Dissertation, University of Mainz

Linder HP (2001) Plant diversity and endemism in Sub-Saharan Africa. J Biogeogr 28:169-182

Lubini A (1982) Végétation messicole et postculturale des sous-régions de Kisangani et de la Tshopo (Haut-Zaïre). Thèse de Doctorat, Université de Kisangani

Lubini A (1986) Végétation adventice et postculturale de Kisangani et de la Tshopo (Haut-Zaïre). Bull Jard Bot Natl Belg 56: 315-348

Lubini A, Kusehuluka K (1991) La forêt ombrophile semi-sempervirente à Celtis milbraedii et à Gambeya lacourtiana dans la région de Kikwit (Zaïre). Bull Jard Bot Natl Belg 61:305-334

Luftensteiner HW (1980) The eco-sociological spectra of dispersal value in two plant communities. Veg 41(2):61-67

Maley J (1990) L'histoire récente de la forêt dense humide africaine: essai sur le dynamisme de quelques formations forestières. In: Lanfranchi R, Schwarz D (Eds) Paysages quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp 367-382

Maley J, Brenac P (1998) Vegetation dynamics, palaeoenvironments and climatic changes in the forests of western Cameroon during the last 28,000 years B.P. Rev Palaeobot Palynol 99:157-187

Mangenot G (1955) Etude sur les forêts des plaines et plateaux de la Côte d'Ivoire. Etudes Eburnéennes IV:5-81

Mbarga Binzi MA (1992) Processus de reconstitution de la forêt dense mésophile guinéenne: cas du secteur forestier de la région de Yaoundé. Thèse de Doctorat, Université de Paris-Sud

McClanahan TR (1986) The effect of seed source on primary succession in a forest ecosystem. Veg 65:175-178

McCune B, Grace JB, Durban DL (2002) Analysis of ecological communities. Gleneden Beach, Oregon

McCune B, Mefford MJ (2006) PC-ORD. 5.19 Multivariate Analysis of ecological Data. Gleneden Beach, Oregon

McKey D (2008) Cecropia peltata, an introduced Neotropical pioneer tree is replacing Musanga cecropioides in southwestern Cameroon. Biotropica 20(3):262-264

Mertz O (2002) The relationship between length of fallow and crop yields in shifting cultivation: a rethinking. Agrofor Syst 55:149-159

Monod T (1957) Les grandes subdivisions chorologiques de l'Afrique. CSA/CCTA, Londres

Mori SA, Boom BM, Carvalino AM, Santos TS (1983) Ecological importance of Myrtaceae in an Eastern Brazilian wet forest. Biotropica 15(1):68-70

Mosango M, Lejoly J (1987) Le rôle de l'association à Musanga cecropioides dans la reconstitution de la forêt dense humide du Zaïre. Colloq Phytosociol 15:733-746

Mosango M, Lejoly J (1990) La forêt dense humide à Piptadeniastrum africanum et à Celtis mildbraedii des environs de Kisangani (Zaïre). Mitt Ints Allg Bot 23b:853-970

Mueller-Dombois D, Ellenberg H (1974) Aims and methods of vegetation ecology. John Wiley & Sons, New York, London, Sydney, Toronto

Murphy PG, Lugo AE (1986) Ecology of tropical dry forest. Annu Rev Ecolog Syst 17:67-88

Nepstad D, Uhl C, Serrão EAS (1996) Surmounting barriers to forest regeneration in abandoned, highly degraded pastures: a case study from Paragonimas, Para Brazil. In: Anderson, AB (ed) Alternatives to deforestation: steps towards sustainable use of Amazon rain forest. Columbia Univ. Press, New York, pp 215-229

Neumann K, Bostoen K, Höhn A, Kahlheber S, Ngomanda A, Tchiengué B (2012) First farmers in the central African rainforest: a review from southern Cameroon. Quat Res 246:53-62

Ngako V (2007) Géologie, ressources minières. In: Jeune Afrique (ed) Atlas de l'Afrique: Cameroun, Collect Jeune Afrique, Paris, pp 60-61

Ngobo MN, McDonald M, Weise S (2004) Impacts of type of fallow and invasion by Chromolaena odorata on weed communities in crop fields in Cameroon. http://www.ecologyandsociety.org/vol9/issue2/art1. Accessed March 29, 2009

Ngok Banack L (2005) Diversité végétale des inselbergs et des dalles rocheuses du nord Gabon. Thèse de doctorat, Université Libre de Bruxelles

Ngomanda A, Neumann K, Schweizer A, Maley J (2009) Seasonality change and the third millennium BP rainforest crisis in southern Cameroon. Quat Res 71:307-318

Nicholson SE (2000) The nature of rainfall variability over Africa on scales of decades to millennia. Glob Planet Chang 26:137-158

Nougier J (1979) Géologie. In: Jeune Afrique (ed) Atlas de la République Unie du Cameroun. Collect Jeune Afrique, Paris, pp 72-73

Nye PH, Greenland DJ (1960) The soil under shifting cultivation. Harpenden, UK

Oldeman RAA (1990) Dynamics in tropical rain forests. In: Holm-Nielsen LB, Nielsen IC, Baslev H (eds) Tropical forests. Botanical dynamics, speciation and diversity. Springer, New York, pp 3-21

Pavillard J (1935) Eléments de sociologie végétale (Phytosociologie). Actualités scientifiques et industrielles. Herman et Cie, Paris

Peña Claros M (2003) Changes in forest structure and species composition during secondary forest succession in the Bolivian Amazon. Biotropica 35(4):450-461

Pianka ER (1970) On r- and K-selection. Am Natu 104:592-597

Pickett STA, Collins SL, Armesto JJ (1987) Models, mechanisms and pathways of succession. The Bot Rev 53(3):335-371

Purata SE (1986) Floristics and structural changes during old-field succession in the Mexican tropics in relation to site history and species availability. J Trop Ecolog 2:257-276.

Raunkiaer C (1934) The life forms of plants and statistical plant geography. Clarendon Press, Oxford.

Richards PW (1952) The tropical rain forest: an ecological study. Camb Univ Press, Cambridge

Richards PW (1955) The secondary succession in the tropical rain forest. Sci Prog 43(169):45-57

Riswan S (1981) Natural regeneration in lowland tropical forest in East Kalimatan. Biotropica special 13:145-152

Rivera LW, Aide TM (1998) Forest recovery in the karst region of Puerto Rico. For Ecolog Manag 108:63-75

Rivera LW, Zimmerman JK, Aide TM (2000) Forest recovery in abandoned agricultural lands in a karst region of the Dominic Republic. Plant Ecolog 148:115-125

Robyns W 1948 Les territoires phytogéographiques du Congo Belge et du Rwanda – Urundi. Acad Roy Sci Col, Bruxelles

Roder R, Pengchanh S, Keoboualapha B, Maniphone S (1995) Chromolaena odorata in slash-and-burn rice systems in Northern Laos. Agrofor Syst 31:79-92

Rouw A (1991) The invasion of Chromolaena odorata (L.) Robinson & King (ex Eupatorium odoratum) and competition with native flora, in a rain forest zone, South-West Côte d'Ivoire. J Biogeogr 18(1):13-23

Rouw A (1993) Regeneration by sprouting in slash and burn rice cultivation Tai rain forest Côte d'Ivoire. J Trop Ecol 9(4):387-408

Rouw A (1994) Effect of fire on soil, rice, weed and forest regrowth in a rain forest zone (Côte d'Ivoire). Catt 22:133-152

Rouw A (1995) The fallow period as a weed break in shifting cultivation (tropical wet forests). Agric Ecosyst Environ 54:31-43

Roux G, Roux M (1967) A propos de quelques méthodes de classification en phytosociologie. Rev Stat Appl 15:59-72

Runge J, Eisenberg J, Sangen M (2006) Geomorphic evolution of the Ntem alluvial basin and physiographic evidence for Holocene environmental changes in the rain forest of SW Cameroon (Central Africa) – preliminary results. Z Geomorph NF 145:63-79

Saldarriaga JG, West DC, Tharp ML, Uhl C (1988) Long term chronosequence of forest succession in the upper Rio Negro of Colombia and Venezuela. J Ecolog 76:938-958

Sangen M (2011) New results on palaeoenvironmental conditions in equatorial Africa derived from alluvial sediments of Cameroonian rivers. Proceedings of the Geologists' Association 122:212-223

Schnell R, (1952) Végétation et flore de la région montagneuse du Nimba. Mém IFAN, 22:1-604

Schnell R (1971) Introduction à la phytogéographie des pays tropicaux. Volume 2 : Les milieux et les groupements végétaux. Gauthier-Villars, Paris

Shepard RN (1962) The analysis of proximities: Multidimensional scaling with an unknown distance function I. Psychometrika 27:125-139

Sokal RR, Rohlf FJ (1995) Biometry, 3rd edn. Freeman & Co, New York

Slaats JJP, Heiden WMV, Stockmann CM, Wessel M, Jansen BH (1996) Growth of the Chromolaena odorata fallow vegetation in semi-permanent food crop production systems in southwest Côte d'Ivoire. Neth J Agric Sci 44:179-192

Sonké B (1998) Etudes floristiques et structurales des forêts de la Réserve de Faune du Dja. Thèse de Doctorat, Université Libre de Bruxelles

Steenis CGGJ (1958) Rejuvenation as a factor for judging the status of vegetation types; the biological nomad theory. In: Proceedings of the symposium on humid tropics vegetation. UNESCO, Paris, pp 212-215

Suchel JB (1972) La répartition des pluies et les régimes pluviométriques au Cameroun: travaux et documents de géographie tropicale. Ceget, Bordeaux

Suchel JB (1989) Les climats du Cameroun. Thèse de Doctorat d'Etat, Université de St-Etienne

Sukachev V (1943) Biogeocoenology and phytocoenology. CR Acad Sci 47:429-431

Swaine MD, Hall JB (1983) Early succession on cleared forest land in Ghana. J Ecol 71 (2):601-627

Swaine MD, Lieberman D, Putz FE (1987) The dynamics of tree population in tropical forest: a review. J Trop Ecolog 3(4):359-366

Swaine MD, Whitmore TC (1988) On the definition of ecological species groups in tropical rain forest. Veg 75(1/2):81-86

Szott LT, Palm CA, Buresh RJ (1999) Ecosystem fertility and fallow function in the humid and sub humid tropics. Agrofor Syst 47:163-196

Tansley AG (1935) The use and abuse of vegetational concepts and terms. Ecolog 16:284-307

Tchawa P (2007) Relief et hydrographie. In: Jeune Afrique (ed) Atlas de l'Afrique: Cameroun, Collect Jeune Afrique, Paris, pp 58-59

Tchiengué B (2004) Etude écologique et floristique d'un massif de la ligne du Cameroun. Thèse Doctorat 3ème Cycle, Université Yaoundé I

Tchiengué B, Nkongmeneck BA (2010) Forêts submontagnardes au Cameroun: végétation et flore de l'étage inférieur du mont Koupé. In: van der Burgt X, van der Maesens LGJ, Onana JM (eds) Systematic and Conservation of African Plants. Proc18th AETFAT Congr Yaoundé, Cameroon. Royal Botanic Gardens Kew, London, pp 701-708

Tchiengué B, Neumann K, Rüdiger W, Becker U (in press) Chromolaena odorata thickets in forest recovery in southern Cameroon

Tchouto MGP (2004) Plant diversity in a Central African rain forest: implications for biodiversity conservation in Cameroon. Dissertation, University of Wageningen

Tchouto MGP, Boer WF, Wilde JJFE, van der Maesen LJG (2006) Diversity patterns in the flora of the Campo-Ma’an rain forest, Cameroon: do tree species tell it all? Biodivers Conserv 15:1353-1374

Tichý L (2002) JUICE software for vegetation classification. J Veg Sci 13:451-453

Trupp LA, Hecht S, Browder J (1997) The diversity and dynamics of shifting cultivation: myths, realities, and policy implications. WRI, Washington DC

Tucker JM, Brondizio ES, Moran EF (1998) Rates of forest recovery in eastern Amazonia: a comparison of Altamira and Brangantina regions Pará State, Brazil. Interc 23(2):64-73

Turner IM, Chew PT, Ali I (1997) Tree species richness in primary and old secondary tropical forest in Singapore. Biodivers Conserv 6:537-543

Tutin CEG, Fernandez M (1993) Composition of the diet of chimpanzees with comparison with that of sympatric lowland gorilla in the lope Reserve in Gabon. Am J Primatol 30:195-211

Uhl C (1987) Factors controlling succession following slash and burn agriculture in Amazonia. J Ecolog 75(2):377-407

Uhl C, Jordan C, Clark K, Clark H, Herrera R (1982) Ecosystem recovery in Amazon caatinga forest after cutting, cutting and burning, and bulldozer clearing treatments, Oikos 38 (3):313-320

Uhl C, Buschbacher R, Serrão EAS (1988) Abandoned pastures in eastern Amazonia I. patterns of plant succession. J Ecolog 76:663-681

Uhl C, Nepstad D, Buschbacher R, Clark K, Kauffman B, Subler R (1990) Studies of ecosystem response to natural disturbances provide guidelines for designing sustainable land use systems in Amazonia. In: Anderson A.B. (Ed) Alternatives to deforestation: steps towards sustainable use of Amazon rain forest. Columbia University Press, New York, pp 24-42

Uriarte M, Riviera LW, Zimmerman JK, Aide TM, Power AG, Flecker AS (2004) Effects of land use history on hurricane damage and recovery in a Neotropical forest. Plant Ecolog 174:49-58

van der Maarel E (1975) The Braun Blanquet approach in perspective. Veg 30(3):213-219

van der Maarel E (1979) Transformation of cover-abundance values in phytosociology and its effects on community similarities. Veg 39(2):97-114

Vasquez-Yanes C (1974) Studies on the germination of seeds of Ochroma lagopus Sw. Turrialba24:176-179

Vasquez-Yanes C, Orozco-Segovia A (1990) Seeds dormancy in the tropical rainforest. In: Bawa KS, Hadley M (Eds) Reproductive ecology of tropical forest plants. UNESCO, Paris, pp 247-259

Vasquez-Yanes C, Orozco Segovia A (1993) Patterns of seed longevity and germination in the tropical rainforest. Annu Rev Ecolog Syst 24:69-87

Vasquez-Yanes C, Orozco Segovia A (1994) Signal for seeds to sense and respond to gaps. In: Caldwell MM, Pearcy RW (eds.) Exploitation of environmental heterogeneity by plants. Academic Press, San Diego, pp 209-236

Vicat JP (1998) Esquisse géologique du Cameroun. In Vicat JP, Bilong P (eds) Géosciences au Cameroun. Geocam, Paris, pp 3-11

White F (1979) The Guineo-Congolian region and its relation to other phytochoria. Bull Jard Bot Natl Belg: 11-55

White F (1983) The vegetation of Africa. A descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. UNESCO, Paris

White LJT, Oates JF (1999) New data on the history of the plateau forest of Okumu, southern Nigeria: an insight into how human disturbance has shaped the African rain forest. Glob Ecolog Biogeogr 8:355-361

Whitmore T (1991) Tropical rain forest dynamics and its implications for management. In: Gomez-Pompa A, Whitmore T, Hadley M (eds) Rain forest regeneration and management. Parthenon Publishing, Lancaster, pp 67-89

Whittaker RH (1962) Classification of natural communities. Botan Rev 28:1-239

Williamson EA, Tutin CEG, Rogers ME, Fernandez M (1990) Composition of the diet of lowland gorilla in Lopé, Gabon. Am J Primatol 21:265-277

Willis KJ, Gillson L, Brncic TM (2004) How “virgin” is virgin rainforest? Sci 304:402-403

Yadav AS, Tripathi RS (1981) Population dynamics of the ruderal weed Eupatorium odoratum L. and its natural regulation. Oikos 36:351-361

Yadav AS, Tripathi RS (1982) A study on seed population dynamics of three weedy species of Eupatorium Weed Res 22:69-76

Yongo O, Foucault B (2001) Analyse phytogéographique de la forêt de Ngotto (République Centrafricaine). Syst Geogr Plant 71(2):847 – 857

Zapfack L, Engwald S, Sonké B, Achoundong G, Birang à Madong (2002) The impact of land conversion on plant biodiversity in the forest zone of Cameroon. Biodivers Conserv 11:2047-2061

Zimmerman JK, Aide TM, Rosario M, Serrano M, Herrera L (1995) Effects of land management and recent hurricane on forest structure and composition in the Luquillo Experimental Forest, Puerto Rico. For Ecolog Manag 77:65-76

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Publications

Tchiengue B., Neumann K., Wittig, R., Becker U. (in press) *Chromolaena odorata* thickets in forest recovery in southern Cameroon

Lachenaud O., Luke Q., **Tchiengué** B., Bytebier B. (in press) A new and a little-known *Chassalia* (Rubiaceae) species from Central Africa. Nord. J. Bot.

Neumann K., Bostoen K., Höhn A., Kahlheber S., Ngomanda A., **Tchiengue B.** (2012) First farmers in the central African rainforest: a review from southern Cameroon. Quat. Res. 246:53-62

Tchiengue B., & Nkongmeneck B.A. (2010) Les forêts submontagnardes au Cameroun : végétation et flore de l'étage inférieure du Mont Koupé. In: van der Burgt X, van der Maesens

LGJ, Onana JM (eds) Systematic and Conservation of African Plants. Proc.18th AETFAT Congr Yaoundé, Cameroon. pp 701-708

Harvey Y.B., **Tchiengue B.,** and Cheek M. (2010) The plants of Lebialem Highlands, Cameroon. A conservation checklist.

Cheek M & **Tchiengue B** (2010) A new species of *Argocoffeopsis fosimondi* (Rubiaceae) a new cloud forest shrub species from Fosimondi, Cameroon. In: Harvey, YB, **Tchiengue, B,** and Cheek, M (2010) (eds) The plants of Lebialem Highlands, Cameroon. A conservation checklist. 53-57

Group 6	Dbh classes (cm)																			
Species	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**NI**
Saccoglottis gabonensis	1																	1		2
Anthocleistha schweinfurthii	1	3	2		1	3				1										11
Calpocalyx heitzii									1											1
Xylopia aethiopica	5	9	5	9	11	2		1												42
Lophira alata	2		1	1		1		1												6
Alstonia boonei	1							1												2
Ongokea gore								1												1
Hymenostegia afzelii	4			2	1	1														8
Scyphocephalium mannii						1														1
Oncoba welwitschii		2	1	1																4
Garcinia mannii	2	1		1																4
Anthonotha macrophylla	79	17	4																	100
Macaranga barteri	7	5	1																	13
Berlinia auriculata	1	2	1																	4
Musanga cecropioides	4	6	1																	11
Carapa sp.	6		1																	7
Barteria nigritana	2		1																	3
Milicia excelsa			1																	1
Rauvolfia vomitoria			1																	1
Leonardoxa africana	8	3																		11
Psidium guajava	6	3																		9
Spathodea campanulata	12	2																		14
Angylocalyx sp.		2																		2
Chytranthus gilletii	2	1																		3
Macaranga hurifolia	2	1																		3
Bridelia micrantha		1																		1
Diospyros suaveolens	1	1																		2
Psychotria venosa	11																			11

Symphonia globulifera	10																			10
Alchornea cordifolia	10																			10
Harungana madagascariensis	6																			6
Ficus exasperata	5																			5
Rinorea campoensis	4																			4
Rauvolfia macrophylla	3																			3
Stachyothyrsus staudtii	2																			2
Diospyros conocarpa	2																			2
Milletia macrophylla	2																			2
Antrocaryon klaineanum	1																			1
Dialium	1																			1
Psydrax arnoldiana	1																			1
Margaritaria discoidea	1																			1
Diospyros cinnabarina	1																			1
Diospyros zenkeri	1																			1
Guibourtia ehie	1																			1
Leptonychia lasiogyne	1																			1
Englerophytum stelecanthum	1																			1
																				331

Family	Species	T.B	1	2	3	4	5	6	7	8
Acanthaceae	Acanthus montanus	Chd	0	1	0	0	0	0	0	0
Acanthaceae	Asystasia gangetica	Thd	1	1	0	1	0	1	1	1
Acanthaceae	Elytraria marginata	Chd	1	1	0	1	0	0	0	0
Acanthaceae	Hypoestes aristata	NnPh	0	0	1	0	0	0	0	1
Acanthaceae	Lankesteria elegans	NnPh	0	1	0	0	0	0	0	0
Acanthaceae	Nelsonia canescens	Chd	0	1	0	0	0	0	0	0
Acanthaceae	Pseuderanthemum ludovicianum	NnPh	0	1	0	1	0	0	0	0
Acanthaceae	Rhinacanthus virens	Thd	0	1	0	0	0	0	0	0
Acanthaceae	Thomandersia congolana	NnPh	0	1	0	0	0	0	0	0
Acanthaceae	Thomandersia laurifolia	NnPh	0	0	0	1	1	0	1	0
Acanthaceae	Thunbergia sp.	NnPh	0	0	0	1	0	0	0	0
Adiantaceae	Adiantum vogelii	Chd	1	1	0	1	0	0	1	1
Adiantaceae	Pityrogramma calomelanos	ep	0	0	0	0	0	0	1	0
Adiantaceae	Pteris acanthoneura	Thd	1	1	0	1	1	1	1	1
Amaranthac	Achyranthes aspera	Chd	0	1	0	0	0	0	0	0
Amaranthac	Celosia trigyna	Chd	0	1	0	1	0	0	0	1
Amaranthac	Cyathula prostrata	Hec	1	1	0	1	1	0	1	1
Amaryllidace	Scadoxus multiflorus	G rh	0	0	0	1	0	0	0	0
Anacardiace	Antrocaryon klaineanum	McPh	0	1	1	0	0	0	0	1
Anacardiace	Antrocaryon klaineanum	MgPh	0	0	0	0	0	0	0	0
Anacardiace	Antrocaryon klaineanum	MsPh	1	1	0	0	0	0	0	0
Anacardiace	Antrocaryon klaineanum	NnPh	0	1	1	1	0	1	0	0
Anacardiace	Lannea welwitschii	McPh	0	0	0	0	0	0	0	0
Anacardiace	Lannea welwitschii	MsPh	0	1	0	0	0	1	1	1
Anacardiace	Lannea welwitschii	NnPh	2	1	0	1	0	0	0	0
Anacardiace	Mangifera foetida	MsPh	0	0	0	0	1	0	0	0
Anacardiace	Mangifera foetida	NnPh	0	1	0	1	1	0	1	0
Anacardiace	Mangifera indica	McPh	0	0	0	1	0	0	0	0
Anacardiace	Mangifera indica	MsPh	0	0	0	1	0	0	0	0
Anacardiace	Mangifera indica	NnPh	0	1	0	1	0	0	0	0
Anacardiace	Pseudospondias microcarpa	McPh	0	1	0	0	0	0	0	0
Anacardiace	Pseudospondias microcarpa	MsPh	0	1	0	0	0	0	0	0
Anacardiace	Pseudospondias microcarpa	NnPh	0	1	0	0	0	0	0	1
Anacardiace	Sorindeia grandifolia	NnPh	0	0	0	0	0	0	0	1
Anacardiace	Spondias cytherea	McPh	0	0	0	1				
Anacardiace	Spondias cytherea	NnPh	0	1	0	0	0	0	0	0
Anacardiace	Trichoscypha acuminata	NnPh	0	1	1	1	0	0	0	0
Anacardiace	Trichoscypha laxiflora	NnPh	0	0	1	0	0	0	0	0
Annonaceae	Annickia chlorantha	NnPh	0	1	0	1	0	0	0	1
Annonaceae	Annona muricata	NnPh	0	1	0	1	0	0	0	0
Annonaceae	Annonaceae indet.	NnPh	0	1	1	1	0	0	0	0
Annonaceae	Anonidium mannii	McPh	0	1	0	0	0	0	0	0
Annonaceae	Artabotrys pierranus	Phgr	0	1	0	1	0	0	0	0
Annonaceae	Cleistopholis glauca	McPh	0	0	0	1	0	0	0	0
Annonaceae	Cleistopholis glauca	MsPh	1	0	0	1	0	0	0	0
Annonaceae	Cleistopholis glauca	NnPh	0	1	0	1	1	0	1	1
Annonaceae	Duguetia staudtii	NnPh	0	1	0	0	0	0	0	0
Annonaceae	Greenwayodendron suaveolens	NnPh	1	1	1	1	0	0	0	1
Annonaceae	Meiocarpidium lepidotum	NnPh	0	1	0	0	0	0	0	0

Annonaceae	Monanthotaxis klainei	Phgr	0	1	0	1	0	0	1	1
Annonaceae	Monodora myristica	McPh	0	1	0	0	0	0	0	1
Annonaceae	Monodora myristica	NnPh	0	1	0	0	0	0	1	1
Annonaceae	Piptostigma cf. fasciculatum	NnPh	1	0	0	0	0	0	0	0
Annonaceae	Uvaria cf. ngounyensis	Phgr	1	1	1	1	1	0	1	1
Annonaceae	Uvaria sp.	NnPh	0	1	0	0	0	0	0	0
Annonaceae	Uvariodendron connivens?	NnPh	0	1	1	0	0	0	0	0
Annonaceae	Uvariopsis	NnPh	1	0	0	0	0	0	0	0
Annonaceae	Xylopia aethiopica	McPh	0	1	0	0	0	1	0	0
Annonaceae	Xylopia aethiopica	MsPh	0	1	0	1	0	1	0	0
Annonaceae	Xylopia aethiopica	NnPh	1	1	0	1	1	1	1	1
Annonaceae	Xylopia hypolampra	McPh	0	1	0	0	0	0	0	0
Annonaceae	Xylopia hypolampra	NnPh	1	1	0	0	0	0	0	1
Annonaceae	Xylopia phloiodora	McPh	0	1	0					
Annonaceae	Xylopia phloiodora	MSPh	0	0	0	1	0	0	0	1
Anthericace	Chlorophyton orchidastrum	Chd	0	1	0	1	0	0	0	0
Apocynacea	Alstonia boonei	McPh	1	0	0	0	0	0	0	1
Apocynacea	Alstonia boonei	MsPh	1	1	0	0	0	1	0	0
Apocynacea	Alstonia boonei	NnPh	1	1	0	1	1	1	1	1
Apocynacea	Baissea baillonii	Phgr	1	1	0	1	0	1	1	1
Apocynacea	Callichilia bequaertii	NnPh	1	1	0	0	0	0	0	1
Apocynacea	Funtumia elastica	McPh	0	1	0	1	0	0	0	0
Apocynacea	Funtumia elastica	MsPh	1	1	0	1	0	0	0	0
Apocynacea	Funtumia elastica	NnPh	1	1	0	1	0	1	1	1
Apocynacea	Landolphia landolphioides	Phgr	1	1	1	1	0	1	1	1
Apocynacea	Landolphia owariensis	Phgr	1	1	1	1	0	0	1	1
Apocynacea	Picralima nitida	McPh	0	0	1					
Apocynacea	Picralima nitida	NnPh	1	0	1	1	0	0	0	1
Apocynacea	Pleiocarpa bicarpellata	NnPh	0	1	0	0	0	0	0	1
Apocynacea	Rauvolfia macrophylla	McPh	0	1	0	1	0	0	0	0
Apocynacea	Rauvolfia macrophylla	MsPh	1	1	0	0	0	0	0	0
Apocynacea	Rauvolfia macrophylla	NnPh	1	1	0	1	0	1	1	1
Apocynacea	Rauvolfia mannii	NnPh	0	1	0	1	0	0	0	0
Apocynacea	Rauvolfia vomitoria	McPh	0	1	0	1	0	1	1	1
Apocynacea	Rauvolfia vomitoria	NnPh	0	1	1	1	1			
Apocynacea	Strophanthus sp.	Phgr	0	0	0	0	0	1	1	0
Apocynacea	Tabernaemontana crassa	McPh	1	1	1	1	0	0	0	0
Apocynacea	Tabernaemontana crassa	MsPh	0	1	0	1	0	0	0	0
Apocynacea	Tabernaemontana crassa	NnPh	1	1	1	1	1	0	1	1
Apocynacea	Voacanaga africana	NnPh	0	1	0	1	0	1	1	1
Apocynacea	Voacanga bracteata	NnPh	0	0	0	1	0	0	0	0
Araceae	Anchomanes difformis	G rh	0	1	1	1	1	1	1	1
Araceae	Anubias barteri	G rh	1	1	0	1	0	0	1	1
Araceae	Culcasia scandens	Phgr	0	1	1	1	0	1	1	1
Araceae	Nephthytis poisonii	G rh	0	1	0	1	0	1	0	0
Araceae	Rhaphidophora africana	Phgr	0	0	0	1	0	0	0	0
Araceae	Rhektophyllum camerunense	Phgr	1	1	1	1	1	1	0	1
Araceae	Rhektophyllum mirabile	Phgr	1	1	1	1	1	1	1	1
Araceae	Stylochiton zenkeri	G rh	0	1	1	0	0	0	0	0
Araceae	Xanthosoma sagittaefolia	G rh	0	1	0	1	0	0	1	1

Araliaceae	Polyscias fulva	McPh	0	0	0	0	0	0	0	0
Araliaceae	Polyscias fulva	NnPh	0	1						
Aristolochia	Pararistolochia sp.	Phgr	0	0	0	0	0	1	0	0
Asclepiadace	Cynanchum cf. adalinae	Chd	0	0	0	0	0	0	1	1
Asclepiadace	Pergularia daemia	Phgr	1	1	0	1	1	1	1	1
Asclepiadace	Secamone afzelii	Phgr	1	1	1	0	0	0	0	1
Aspidiaceae	Ctenitis protensa	Thd	1	1	0	1	0	0	0	1
Begoniaceae	Begonia cf. quadrialata	Chd	0	1	0	0	0	0	0	0
Begoniaceae	Begonia hirsutula	Chd	0	1	0	0	0	0	0	0
Begoniaceae	Begonia sp.	Chd	0	1	0	0	0	0	0	0
Bignoniacea	Kigelia africana	NnPh	0	0	0	1	0	0	0	0
Bignoniacea	Markhamia lutea	McPh	0	1	0	0	0	0	0	0
Bignoniacea	Newbouldia laevis	NnPh	0	1	0	0	0	0	1	1
Bignoniacea	Spathodea campanulata	McPh	0	0	0	1	0	1	1	0
Bignoniacea	Spathodea campanulata	MsPh	0	1	0	1	0	0	0	0
Bignoniacea	Spathodea campanulata	NnPh	0	1	0	1	1	1	0	1
Bombacacea	Bombax buonopozense	MgPh	0	0	0	0	0	0	0	0
Bombacacea	Bombax buonopozense	MsPh	1	0	0	0	0	0	0	0
Bombacacea	Bombax buonopozense	NnPh	1	1	0	1	0	0	1	0
Bombacacea	Ceiba pentandra	McPh	0	1	0	0			1	
Bombacacea	Ceiba pentandra	MsPh	0	1	1	0	0	0	0	0
Bombacacea	Ceiba pentandra	NnPh	1	1	0	1	0	1	1	1
Bromeliacea	Ananas comosus	Thd	1	1	0	1	0	0	1	1
Burseraceae	Canarium schweinfurthii	McPh	1	1	0	0	0	0	0	0
Burseraceae	Canarium schweinfurthii	MsPh	1	1	0	0	0	0	0	0
Burseraceae	Canarium schweinfurthii	NnPh	1	1	1	1	1	0	0	1
Burseraceae	Dacryodes edulis	MsPh	0	0	0	1				
Burseraceae	Dacryodes edulis	NnPh	1	1	0	1	0	0	0	0
Burseraceae	Dacryodes macrophylla	McPh	1	0	1	0	0	0	0	1
Burseraceae	Dacryodes macrophylla	MsPh	1	0	0	0	0	0	0	0
Burseraceae	Dacryodes macrophylla	NnPh	1	1	0	0	0	0	0	0
Burseraceae	Santiria trimera	NnPh	0	1	1	0	0	0	0	0
Capparidace	Ritchea erecta	NnPh	0	1	0	0	0	0	0	0
Capparidace	Ritchea sp.	NnPh	0	1	0	0	0	0	0	0
Caricaceae	Carica papaya	NnPh	0	0	0	1	0	0	1	1
Cecropiacea	Musanga cecropioides	McPh	1	1	0	1	1	1	1	1
Cecropiacea	Musanga cecropioides	MsPh	1	1	1	1	1	0	1	1
Cecropiacea	Musanga cecropioides	NnPh	0	1	0	1	1	1	1	1
Cecropiacea	Myrianthus arboreus	McPh	1	1	1	0	0	0	1	1
Cecropiacea	Myrianthus arboreus	NnPh	1	1	1	0	1	0	0	1
Cecropiacea	Myrianthus preussii	NnPh	0	1	0	1	0	0	0	1
Celastraceae	Loeseneriella apocynoides var. guine	Phgr	0	1	0	1	1	0	1	1
Celastraceae	Salacia lucida	Phgr	1	1	1	1	0	1	1	1
Chrysobalan	Parinari excelsa	NnPh	0	1	0	0	0	0	0	0
Combretace	Combretum calobotrys	Phgr	1	1	0	1	1	1	1	1
Combretace	Combretum hispidum	Phgr	1	1	1	0	0	0	1	1
Combretace	Pteleopsis hylodendron	McPh	0	1	0	0	0	0	0	0
Combretace	Pteleopsis hylodendron	MsPh	0	1	0	0	0	0	0	0
Combretace	Terminalia superba	McPh	1	1	0	0	0	0	0	0
Combretace	Terminalia superba	MgPh	0	0	0	0	0	0	0	0

Combretace	Terminalia superba	MsPh	1	1	0	0	0	0	0	0
Combretace	Terminalia superba	NnPh	1	1	0	1	0	1	1	1
Commelinac	Aneilema beniniense	Thd	1	1	0	1	1	0	1	1
Commelinac	Commelina benghalensis	Chd	0	1	0	1	0	0	1	1
Commelinac	Commelina capitata	Chd	1	0	0	1	0	1	0	1
Commelinac	Cyanotis longifolia	G b	0	0	0	0	0	0	1	0
Commelinac	Palisota alopecurus	Chd	1	1	0	1	1	0	1	1
Commelinac	Palisota ambigua	Chd	1	1	1	1	0	0	1	1
Commelinac	Palisota barteri	Chd	1	1	1	1	1	1	1	1
Commelinac	Palisota hirsuta	Chd	1	1	1	1	0	0	1	1
Commelinac	Palisota mannii	Chd	0	1	0	0	0	0	0	0
Commelinac	Pollia condensata	Chd	1	1	1	1	0	0	0	1
Commelinac	Polyspatha paniculata	Chd	1	1	0	1	0	0	0	0
Commelinac	Stanfieldiella imperforata	Thd	1	1	0	1	0	1	1	1
Compositae	Ageratum conyzoides	Thd	0	1	0	1	0	0	1	1
Compositae	Bidens pilosa	Thd	0	0	0	0	0	0	1	0
Compositae	Chromolaena odorata	NnPh	1	1	0	1	1	1	1	1
Compositae	Dichrocephala	Thd	0	0	0	0	0	0	1	0
Compositae	Elephantopus mollis	Hec	0	0	0	0	0	0	1	1
Compositae	Emilia coccinea	Thd	0	0	0	1	1	0	1	1
Compositae	Erigeron floribundus	Thd	0	0	0	0	0	0	1	0
Compositae	Mikania cordata	Thc	1	1	0	1	1	0	1	1
Compositae	Synedrella nodiflora	Thd	0	0	0	1	0	0	1	1
Compositae	Vernonia frondosa	McPh	0	1						
Compositae	Vernonia frondosa	NnPh	1	1	0	1	0	0	1	1
Compositae	Vernonia sp.	NnPh	0	0	0	0	0	0	0	1
Compositae	Vernonia stellulifera	Thd	0	1	0	0	0	0	1	1
Connaraceae	Agelaea pentagyne	Phgr	1	1	1	1	0	1	1	1
Connaraceae	Cnestis corniculata	Phgr	1	1	1	1	1	1	1	1
Connaraceae	Cnestis ferruginea	Phgr	1	1	0	1	1	1	1	1
Connaraceae	Haemandradenia mannii	Phgr	0	1	0	1	0	0	1	1
Connaraceae	Rourea sp.	Phgr	0	1	0	0	0	1	1	1
Convolvulac	Ipomoea alba	Thc	0	0	0	0	1	0	0	0
Convolvulac	Ipomoea batatas	Thc	1	1	0	1	0	0	1	1
Convolvulac	Ipomoea involucrata	Thc	1	0	0	1	1	0	1	1
Convolvulac	Merremia aegyptia	Thc	0	0	0	0	0	0	0	1
Convolvulac	Neuropeltis acuminata	Phgr	0	1	0	0	0	0	0	0
Costaceae	Costus afer	G rh	1	1	1	1	1	1	1	1
Costaceae	Costus dubius	G rh	0	1	0	1	0	0	1	1
Costaceae	Costus lucanusianus	G rh	0	0	0	1	1	0	1	1
Cucurbitace	Coccinia barteri	Chc	0	1	0	0	0	0	1	1
Cucurbitace	Cognauxia podolaena	Chc	1	0	0	1	1	0	1	1
Cucurbitace	Momodica cabrei	Thc	1	1	0	1	0	0	0	1
Cucurbitace	Momordica charantia	Thc	1	0	1	1	0	0	0	1
Cucurbitace	Momordica cissoides	Thc	0	1	0	1	0	0	0	0
Cucurbitace	Momordica foetida	Thc	0	1	0	1	0	0	0	0
Cucurbitace	Raphidiocystis jeffreyana	Phgr	0	1	0	0	0	0	0	0
Cyperaceae	Cyperus alternifolius	G rh	0	0	0	0	0	0	1	0
Cyperaceae	Cyperus diffusus ssp. buchholzii	G rh	1	1	0	1	1	0	1	1
Cyperaceae	Cyperus distans	G rh	0	0	0	1	0	0	1	0

Cyperaceae	Cyperus fertilis	G rh	1	1	0	1	0	1	1	1
Cyperaceae	Fimbristylis hispidula	G rh	0	0	0	0	0	0	1	0
Cyperaceae	Mapania macrantha	G rh	1	1	1	1	0	0	0	0
Cyperaceae	Mariscus alternifolius	G rh	0	0	0	1	1	0	1	1
Cyperaceae	Scleria boivinii	G rh	0	1	1	1	1	1	1	1
Cyperaceae	Scleria racemosa	G rh	0	0	0	1	0	0	0	0
Davalliaceae	Davallia chaerophylloides	ep	0	1	0	1	1	1	1	1
Davalliaceae	Nephrolepis biserrata	Thd	1	1	1	1	1	1	1	1
Dennstaedti	Lonchitis currori	Thd	0	1	0	0	0	0	0	0
Dennstaedti	Microlepia speluncae	Thd	1	1	1	1	1	0	1	1
Dennstaedti	Pteridium aquilinum	Hec	0	1	0	0	0	0	1	0
Dichapetalac	Dichapetalum cymulosum	Phgr	1	1	1	1	1	1	1	1
Dichapetalac	Dichapetalum heudelotii	Phgr	1	1	1	1	1	1	1	1
Dichapetalac	Dichapetalum insigne	Phgr	0	0	0	0	0	0	0	1
Dichapetalac	Dichapetalum sp.	Phgr	0	0	0	0	0	0	1	0
Dilleniaceae	Tetracera alnifolia	Phgr	1	1	1	1	1	1	1	1
Dioscoreace	Dioscorea alata	Gt	0	0	0	1	0	0	1	0
Dioscoreace	Dioscorea bulbifera	Gt	1	1	0	1	1	0	1	1
Dioscoreace	Dioscorea cayennensis	Gt	0	1	0	0	0	0	1	0
Dioscoreace	Dioscorea cf. rotundata	Gt	0	0	0	1	0	0	1	0
Dioscoreace	Dioscorea smilacifolia	Gt	0	1	0	1	1	1	1	1
Dracaenace	Dracaena arborea	NnPh	0	0	0	0	0	0	0	1
Dracaenace	Dracaena aubryana	NnPh	0	0	1	1	0	0	0	0
Dracaenace	Dracaena camerooniana	NnPh	0	0	0	1	1	0	1	0
Dracaenace	Dracaena cerasifera	NnPh	0	0	1	0	1	0	0	0
Dracaenace	Dracaena sp.	NnPh	0	0	1	0	0	0	0	0
Ebenaceae	Diospyros bipindensis	NnPh	0	1	0	0	0	0	0	0
Ebenaceae	Diospyros cinnabarina	NnPh	0	1	0	1	0	1	0	0
Ebenaceae	Diospyros conocarpa	NnPh	0	1	0	1	0	1	0	0
Ebenaceae	Diospyros fragrans	NnPh	1	1	1	1	0	1	0	0
Ebenaceae	Diospyros hoyleana	NnPh	0	0	0	1	0	0	0	0
Ebenaceae	Diospyros simulans	NnPh	0	1	0	1	0	0	0	0
Ebenaceae	Diospyros suaveolens	McPh	0	0	0	0	0	1		
Ebenaceae	Diospyros suaveolens	NnPh	0	0	1	1	0	1	0	0
Ebenaceae	Diospyros zenkeri	NnPh	0	0	0	1	0	1	0	0
Euphorbiace	Alchornea cordifolia	NnPh	1	1	0	1	1	1	1	1
Euphorbiace	Alchornea floribunda	NnPh	1	1	0	0	0	0	0	1
Euphorbiace	Antidesma laciniatum	NnPh	0	0	1	0	0	0	0	1
Euphorbiace	Antidesma membranacea	McPh	0	1	0	0	0	0	0	0
Euphorbiace	Antidesma membranacea	MsPh	0	1	0					
Euphorbiace	Antidesma membranacea	NnPh	1	1	1	1	1	0	1	0
Euphorbiace	Argomuellera macrophylla	NnPh	0	1	1	1	0	0	0	1
Euphorbiace	Bridelia micrantha	McPh	1	1	0	1	0	1	1	0
Euphorbiace	Bridelia micrantha	MsPh	1	1	0	1	0	0	1	0
Euphorbiace	Bridelia micrantha	NnPh	1	1	0	1	1	1	1	1
Euphorbiace	Croton oligandrus	McPh	1	1	0	0	0	0	0	0
Euphorbiace	Croton oligandrus	MsPh	1	1	1	0	0	0	0	1
Euphorbiace	Croton oligandrus	NnPh	1	1	0	1	0	0	0	0
Euphorbiace	Crotonogyne manniana	NnPh	0	0	1	1	0	0	0	0
Euphorbiace	Dalechampia convolvuloides	Chc	0	1	0	1	0	0	1	1

Euphorbiace	Dichostemma glaucescens	McPh	0	1	1	0	0	0	0	0
Euphorbiace	Dichostemma glaucescens	MsPh	0	0	1	0	0	0	0	0
Euphorbiace	Dichostemma glaucescens	NnPh	0	1	1	1	0	1	1	0
Euphorbiace	Discoglypremna caloneura	McPh	0	1	0	0	0	0	0	0
Euphorbiace	Discoglypremna caloneura	MgPh	0	0	0	0	0	0	0	0
Euphorbiace	Discoglypremna caloneura	MsPh	0	1	0	0	0	0	0	0
Euphorbiace	Discoglypremna caloneura	NnPh	0	1	0	1	0	0	0	1
Euphorbiace	Drypetes aframensis	NnPh	0	0	0	1	0	0	0	1
Euphorbiace	Drypetes cf. leonensis	McPh	1	1	0	0				
Euphorbiace	Drypetes cf. leonensis	NnPh	0	1	1	1	0	0	0	0
Euphorbiace	Drypetes principum	NnPh	1	1	1	1	1	1	1	0
Euphorbiace	Elaeophorbia drupifera	McPh	0	1	0	0	0	0	0	0
Euphorbiace	Euphorbia hirta	Thd	0	0	0	0	0	0	0	1
Euphorbiace	Euphorbia prostrata	Thd	0	0	0	0	0	0	1	0
Euphorbiace	Grossera paniculata	NnPh	0	1	0	1	0	0	0	1
Euphorbiace	Hevea brasiliensis	McPh	0	1	0	0	0	0	1	0
Euphorbiace	Hevea brasiliensis	MsPh	0	1	0	0	0	0	0	0
Euphorbiace	Hevea brasiliensis	NnPh	0	1	0	1	0	0	0	1
Euphorbiace	Hymenocardia ulmoides	McPh	0	1	0	0	0	0	0	0
Euphorbiace	Hymenocardia ulmoides	MgPh	0	0	0	0	0	0	0	0
Euphorbiace	Hymenocardia ulmoides	MsPh	0	1	0	0	0	0	0	0
Euphorbiace	Hymenocardia ulmoides	NnPh	0	1	0	1	0	0	1	1
Euphorbiace	Macaranga barteri	McPh	1	1	0	1	0	1	0	0
Euphorbiace	Macaranga barteri	MsPh	0	1	0	0	0	1	0	1
Euphorbiace	Macaranga barteri	NnPh	0	1	0	1	0	1	1	1
Euphorbiace	Macaranga cf. schweinfurthii	NnPh	0	1	0	0	0	0	0	0
Euphorbiace	Macaranga hurifolia	McPh	1	1	1	1	1	1	1	1
Euphorbiace	Macaranga hurifolia	MsPh	1	1	1	1	0	0	0	0
Euphorbiace	Macaranga hurifolia	NnPh	1	1	1	1	1	1	1	1
Euphorbiace	Macaranga monandra	McPh	1	1	0	1	0	0	1	0
Euphorbiace	Macaranga monandra	MsPh	1	1	0	0	0	0	0	0
Euphorbiace	Macaranga monandra	NnPh	0	1	0	1	0	0	0	1
Euphorbiace	Macaranga spinosus	NnPh	1	0	0	0	0	0	0	1
Euphorbiace	Maesbotrya dusenii	NnPh	1	1	0	1	1	1	0	0
Euphorbiace	Maesobotrya barteri	NnPh	0	1	0	0	0	0	0	1
Euphorbiace	Maesobotrya bipindensis	NnPh	1	0	1	1	0	0	0	1
Euphorbiace	Mallotus oppositifolius	NnPh	0	0	0	0	0	0	0	1
Euphorbiace	Manihot esculenta	NnPh	0	1	0	1	1	0	1	1
Euphorbiace	Manniopyton fulvum	Phgr	0	1	0	0	0	0	0	1
Euphorbiace	Mapania mannii	G rh	0	1	0	0	0	0	0	0
Euphorbiace	Mareyopsis longifolia	NnPh	1	0	0	1	0	0	0	0
Euphorbiace	Margaritaria discoidea	McPh	0	1	0	0	0	0	0	0
Euphorbiace	Margaritaria discoidea	MgPh	0	0	0	0	0	0	0	0
Euphorbiace	Margaritaria discoidea	MsPh	0	1	0	0	0	0	0	0
Euphorbiace	Margaritaria discoidea	NnPh	1	1	0	1	0	1	1	1
Euphorbiace	Neoboutonia mannii	McPh	0	1	0	1	0	0	0	0
Euphorbiace	Neoboutonia mannii	MsPh	0	1	0	0	0	0	0	0
Euphorbiace	Neoboutonia mannii	NnPh	0	0	0	1				
Euphorbiace	Phyllanthus amarus	Thd	1	1	0	1	1	1	1	1
Euphorbiace	Phyllanthus muellerianus	Phgr	1	1	0	1	1	0	1	1

Euphorbiace	Plagiostyles africana	McPh	1	1	1	0	0	0	0	0
Euphorbiace	Plagiostyles africana	MsPh	1	1	1	0	0	0	0	0
Euphorbiace	Plagiostyles africana	NnPh	0	1	1	0	0	0	0	0
Euphorbiace	Ricinodendron heudelotii	McPh	0	0	0	0	1	0	0	0
Euphorbiace	Ricinodendron heudelotii	MgPh	0	0	0	0	0	0	0	0
Euphorbiace	Ricinodendron heudelotii	MsPh	0	1	1	0	0	0	0	0
Euphorbiace	Ricinodendron heudelotii	NnPh	0	1	0	1	1	0	0	1
Euphorbiace	Shirakopsis ellipticum	NnPh	0	1	0	1	0	0	1	0
Euphorbiace	Spondianthus preussii	NnPh	0	1	1	0	0	0	0	0
Euphorbiace	Tetrochidium didymostemon	McPh	1	1	1	1	0	0	0	0
Euphorbiace	Tetrochidium didymostemon	MsPh	0	1	1	0	0	0	0	0
Euphorbiace	Tetrochidium didymostemon	NnPh	0	1	1	1	1	0	1	1
Euphorbiace	Uapaca acuminata	NnPh	0	1	0	0	0	0	0	0
Euphorbiace	Uapaca guineensis	McPh	1	1	1	0	0	0	1	0
Euphorbiace	Uapaca guineensis	NnPh	0	1	1	1	1	0	1	1
Flacourtiace	Dasylepis sp.	NnPh	0	0	0	0	0	1	0	0
Flacourtiace	Homalium letestui	McPh	0	0	0	1	0	0	0	0
Flacourtiace	Homalium letestui	MsPh	0	0	0	1	0	0	0	0
Flacourtiace	Homalium letestui	NnPh	1	1	0	1	1	1	1	1
Flacourtiace	Oncoba dentata	NnPh	0	1	0	1	0	0	0	0
Flacourtiace	Oncoba glauca	McPh	1	1	0	0	0	0	1	0
Flacourtiace	Oncoba glauca	MsPh	0	0	0	0	0	0	0	0
Flacourtiace	Oncoba glauca	NnPh	1	1	1	1	1	0	1	1
Flacourtiace	Oncoba welwitschii	McPh	0	1	0	1	0	1	0	0
Flacourtiace	Oncoba welwitschii	MsPh	0	0	0	0		1	0	0
Flacourtiace	Oncoba welwitschii	NnPh	0	1	0	1	0	1	1	0
Flagellariace	Flagellaria guineensis	Chc	0	0	0	0	0	1	1	0
Gnetaceae	Gnetum africanum	Thc	1	1	0	0	0	0	1	1
Graminae	Acroceras zizanioides	Thd	1	1	0	1	1	0	1	1
Graminae	Axonopus compressus	Thd	0	0	0	0	1	1	1	1
Graminae	Bambusa vulgaris	NnPh	0	0	0	1	0	0	0	0
Graminae	Centotheca lappacea	Thd	1	1	0	1	1	1	1	1
Graminae	Cyrtococcum chaetophoron	Thd	0	1	0	1	1	0	1	1
Graminae	Guaduella densiflora	Hec	0	1	0	1	0	0	0	0
Graminae	Leptaspis cochleata	Hec	0	1	1	0	0	0	0	0
Graminae	Olyra latifolia	Hec	1	1	0	1	0	0	0	1
Graminae	Oplismenus hirtellus	Thd	1	1	0	1	1	1	1	1
Graminae	Panicum brevifolium	Chd	0	1	0	1	0	0	1	1
Graminae	Panicum lukwangulense	Chd	0	0	0	0	0	0	0	1
Graminae	Panicum maximum	Thd	0	0	0	0	1	0	1	1
Graminae	Paspalum conjugatum	Chd	0	0	0	0	1	0	1	1
Graminae	Paspalum paniculatum	Thd	0	0	0	0	1	0	1	0
Graminae	Pennisetum polystachion	Chd	0	0	0	0	0	0	1	0
Graminae	Setaria megaphylla	Thd	0	0	0	0	1	0	1	0
Graminae	Streptogyne crinita	Hec	1	1	1	0	0	1	0	0
Guttiferae	Allanblackia floribunda	McPh	0	1	1	1	0	0	1	1
Guttiferae	Allanblackia floribunda	NnPh	0	1	0					
Guttiferae	Garcinia cf. epunctata	NnPh	0	0	1	1	0	0	0	0
Guttiferae	Garcinia cf. mannii	McPh	0	0	0	0	0	1		
Guttiferae	Garcinia cf. mannii	MsPh	0	0	0	0	0	1		

Guttiferae	Garcinia cf. mannii	NnPh	0	0	0	0	1	1	0	0
Guttiferae	Garcinia gnetoides	NnPh	0	0	0	0	0	1	0	0
Guttiferae	Garcinia mannii?	NnPh	0	0	0	0	0	1	0	0
Guttiferae	Harungana madagascariensis	McPh	0	0	0	1	1	0	1	1
Guttiferae	Harungana madagascariensis	NnPh	1	1	1	1	1	1	1	0
Guttiferae	Symphonia globulifera	NnPh	0	1	1	1	1	1	0	0
Guttiferae	Vismia guineensis	NnPh	0	1	0	0	0	0	0	0
Humiriaceae	Saccoglottis gabonensis	MgPh	0	0	0	0	0	1	0	0
Humiriaceae	Saccoglottis gabonensis	NnPh	0	0	1	1	0	1	1	0
Icacinaceae	Alsodeiopsis mannii	NnPh	0	1	1	0	0	0	0	0
Icacinaceae	Lasianthera africana	NnPh	1	1	1	1	1	1	1	1
Icacinaceae	Lavigeria macrocarpa	Phgr	1	1	1	1	1	1	1	1
Icacinaceae	Leptaulus daphnoides	NnPh	0	1	0	0	0	0	0	0
Icacinaceae	Polycephalium lobatum	Phgr	0	0	0	0	0	0	0	1
Icacinaceae	Pyrenacantha lebrunii	Phgr	0	1	0	0	0	0	0	0
Irvingiaceae	Desbordesia glaucescens	McPh	0	1	1					
Irvingiaceae	Desbordesia glaucescens	MsPh	0	0	0					
Irvingiaceae	Desbordesia glaucescens	NnPh	0	1	1	1	1	0	1	1
Irvingiaceae	Irvingia gabonensis	McPh	0	0	0	0	0	0	0	0
Irvingiaceae	Irvingia gabonensis	MgPh	0	0	0	1	0	0	0	0
Irvingiaceae	Irvingia gabonensis	Msph	0	1	0	1	0	0	0	0
Irvingiaceae	Irvingia gabonensis	NnPh	0	0	0	0	1	1	1	0
Irvingiaceae	Irvingia grandifolia	NnPh	0	0	0	1	0	0	0	0
Irvingiaceae	Klainedoxa gabonensis	McPh	0	1	0	1	0	0	0	0
Labiatae	Clerodendrum atlanticum	Phgr	0	0	0	1	0	0	0	0
Labiatae	Clerodendrum buchholzianum	Phgr	0	1	0	1	0	0	1	1
Labiatae	Clerodendrum splendens	Phgr	1	0	0	1	1	1	1	1
Labiatae	Leucas martinicensis	Hec	0	1	0	0	0	0	0	0
Labiatae	Plectranthus sp.	Hec	0	0	0	0	1	0	0	0
Labiatae	Solenostemon monostachyus	Thd	0	0	0	1	0	0	0	0
Labiatae	Vitex grandifolia	McPh	0	0	0	0	0	0	0	0
Labiatae	Vitex grandifolia	MsPh	1	0	0	0	0	0	0	0
Labiatae	Vitex grandifolia	NnPh	0	1	0	1	1	0	1	0
Labiatae	Vitex myrmecophila	Phgr	0	1	0	0	0	0	0	0
Lauraceae	Cinnamomum zeylanicum	NnPh	0	0	0	1	0	0	0	0
Lauraceae	Hypodaphis zenkeri	NnPh	0	0	1	1	1	0	0	0
Lauraceae	Persea americana	McPh	1	1	0	1	0	0	0	0
Lauraceae	Persea americana	MsPh	1	0	0	1	0	0	0	0
Lauraceae	Persea americana	NnPh	1	0	0	0	0	0	1	0
Lecythidace	Napolaeona vogelii	NnPh	0	1	1	1	1	0	1	1
Lecythidace	Petersianthus macrocarpus	McPh	1	1	0	0	0	0	0	0
Lecythidace	Petersianthus macrocarpus	MsPh	0	1	0	0	0	0	0	1
Lecythidace	Petersianthus macrocarpus	NnPh	1	1	1	0	0	1	0	1
Leguminosa	Afzelia bipindensis	NnPh	0	1	0	1	1	0	0	0
Leguminosa	Amphimas ferrugineus	McPh	0	1	0	0				
Leguminosa	Amphimas ferrugineus	NnPh	0	1	0	0	0	0	0	0
Leguminosa	Anthonotha macrophylla	McPh	0	1	0	1	0	1	1	0
Leguminosa	Anthonotha macrophylla	MsPh	0	1	0	0	0	0	0	0
Leguminosa	Anthonotha macrophylla	NnPh	1	1	1	1	1	1	1	1
Leguminosa	Aphanocalyx sp.	NnPh	0	1	0	1	0	0	0	0

Leguminosa	Baphiopsis parviflora	NnPh	0	0	0	1	0	0	0	0
Leguminosa	Berlinia auriculata	McPh	0	0	0	0	0	1	0	0
Leguminosa	Berlinia auriculata	MsPh	0	0	0	0	0	1	0	0
Leguminosa	Berlinia auriculata	NnPh	1	0	0	0	0	1	1	0
Leguminosa	Berlinia bracteosa	NnPh	0	1	0	0	0	0	1	1
Leguminosa	Dialium dinklagei	NnPh	0	1	1	0	0	0	0	0
Leguminosa	Dialium pachyphyllum	Msph	0	1	0	1	0	1	0	0
Leguminosa	Dialium pachyphyllum	NnPh	0	1	1	1	0	1	1	1
Leguminosa	Distemonanthus benthamianus	McPh	0	1	0	0	0	0	0	0
Leguminosa	Distemonanthus benthamianus	Msph	0	1	0	1	0	0	0	0
Leguminosa	Distemonanthus benthamianus	NnPh	0	1	0	0	0	0	0	1
Leguminosa	Duparquetia orchidacea	Phgr	1	1	0	1	1	1	1	1
Leguminosa	Erythrophleum ivorense	McPh	0	0	0	0	1	0	0	0
Leguminosa	Erythrophleum ivorense	Msph	0	1	0	0	0	0	0	0
Leguminosa	Erythrophleum ivorense	NnPh	0	1	0	0	1	1	1	0
Leguminosa	Gilbertiodendron brachystegioides	NnPh	1	0	0	1	0	1	0	0
Leguminosa	Gilbertiodendron limba	McPh	0	0	1	0	0	0	0	0
Leguminosa	Guibourtia ehie	NnPh	0	1	1	1	1	1	1	0
Leguminosa	Hylodendron gabunense	NnPh	0	1	1	1	1	0	0	0
Leguminosa	Hymenostegia afzelii	MsPh	0	0	0	0	0	1	0	0
Leguminosa	Hymenostegia afzelii	NnPh	0	1	0	1	0	1	1	0
Leguminosa	Leonardoxa africana	McPh	0	0	0	0	0	1	0	0
Leguminosa	Leonardoxa africana	NnPh	0	1	0	0	0	1	0	0
Leguminosa	Pellegriniodendron diphyllum	NnPh	0	0	0	0	0	0	1	0
Leguminosa	Stachyothyrsus staudtii	MsPh	0	1	0	0	0	0	0	0
Leguminosa	Stachyothyrsus staudtii	NnPh	0	0	0	0	0	1	0	0
Leguminosa	Acacia kamerunensis	Phgr	1	1	0	1	0	0	0	1
Leguminosa	Albizia adianthifolia	McPh	1	1	1	0	0	0	1	1
Leguminosa	Albizia adianthifolia	MsPh	1	1	1	1	0	0	0	0
Leguminosa	Albizia adianthifolia	NnPh	1	1	1	0	0	1	1	1
Leguminosa	Albizia zygia	McPh	1	1	1	0	0	0	1	0
Leguminosa	Albizia zygia	NnPh	0	1	0	0	0	0	1	1
Leguminosa	Calpocalyx heitzii	McPh	1	1	0	1	0	0	0	0
Leguminosa	Calpocalyx heitzii	MgPh	0	0	0	0	0	0	0	0
Leguminosa	Calpocalyx heitzii	MsPh	0	0	0	1	0	0	0	0
Leguminosa	Calpocalyx heitzii	NnPh	1	1	1	0	0	0	1	0
Leguminosa	Inga edulis	NnPh	0	0	0	0	0	0	0	1
Leguminosa	Mimosa pudica	Hec	0	0	0	0	1	0	1	1
Leguminosa	Pentaclethra macrophylla	McPh	1	1	0	1	0	0	0	1
Leguminosa	Pentaclethra macrophylla	MsPh	0	1	0	1	0	0	1	0
Leguminosa	Pentaclethra macrophylla	NnPh	1	1	1	1	1	0	1	1
Leguminosa	Piptadeniastrum africanum	McPh	0	1	0	1	0	0	0	0
Leguminosa	Piptadeniastrum africanum	MgPh	1	0	0	0	0	0	0	0
Leguminosa	Piptadeniastrum africanum	MsPh	1	0	0	0	0	0	0	1
Leguminosa	Piptadeniastrum africanum	NnPh	0	1	1	1	1	1	1	1
Leguminosa	Tetrapleura tetraptera	McPh	1	1	0	0	0	0	0	0
Leguminosa	Tetrapleura tetraptera	MsPh	0	0	0	1	0	0	0	0
Leguminosa	Tetrapleura tetraptera	NnPh	1	1	0	0	0	0	0	1
Leguminosa	Angylocalyx sp.	McPh	0	0	0	0	0	1		
Leguminosa	Angylocalyx sp.	NnPh	0	1	1	1	0	1	0	0

Leguminosa	Arachis hypogea	Thd	0	0	0	0	0	0	1	1
Leguminosa	Baphia laurifolia	NnPh	0	0	0	1	0	0	0	1
Leguminosa	Baphia nitida	NnPh	0	1	0	1	0	1	1	1
Leguminosa	Baphia sp.	NnPh	0	0	0	0	0	0	1	0
Leguminosa	Dalberbia hostilis	Phgr	0	0	0	0	1	0	1	0
Leguminosa	Dalbergia afzelii	Phgr	0	1	1	1	1	1	1	1
Leguminosa	Dalbergia grandibracteata	Phgr	1	0	0	0	0	0	1	0
Leguminosa	Desmodium adscendens	Chd	1	1	0	1	1	1	1	1
Leguminosa	Desmodium tortuosum	Chd	0	0	0	0	0	0	1	0
Leguminosa	Dolichos reflexa	Phgr	0	0	0	1	0	0	1	1
Leguminosa	Erythrina excelsa	MsPh	0	1	0	0	0	0	0	0
Leguminosa	Leptoderris oxytropis	Phgr	0	1	0	1	1	1	1	0
Leguminosa	Milletia hypolampra	Phgr	0	1	1	1	0	0	1	0
Leguminosa	Milletia macrophylla	McPh	0	1	1		1			
Leguminosa	Milletia macrophylla	NnPh	1	1	1	1	1	1	1	1
Leguminosa	Milletia mannii	NnPh	1	1	1	0	0	0	1	0
Leguminosa	Milletia sp.	NnPh	0	1	0	1	0	0	1	1
Leguminosa	Mucuna flagellipes	Phgr	0	1	0	1	1	0	1	1
Leguminosa	Newtonia griffoniana	Phgr	1	1	1	1	0	0	0	0
Leguminosa	Pterocarpus soyauxii	McPh	0	1	1	1	0	0	0	0
Leguminosa	Pterocarpus soyauxii	MsPh	1	0	0	1	0	0	0	0
Leguminosa	Pterocarpus soyauxii	NnPh	1	1	1	1	1	0	0	1
Leguminosa	Pueraria phaseleoides	Thc	0	0	0	1	1	0	1	0
Lepidobotry	Lepidobotrys staudtii	NnPh	1	1	0	0	0	0	0	0
Liliaceae	Gloriosa simplex	Chc	0	0	0	0	0	0	1	0
Linaceae	Hugonia obtusifolia	Phgr	0	1	1	0	1	0	0	0
Loganiaceae	Anthocleista schweinfurthii	McPh	1	1	0	1	1	1	1	1
Loganiaceae	Anthocleista schweinfurthii	MsPh	1	1	0	1	0	1	1	0
Loganiaceae	Anthocleista schweinfurthii	NnPh	1	1	0	1	1	1	1	1
Loganiaceae	Mostuea brunonis	NnPh	0	1	0	1	0	0	0	0
Loganiaceae	Strychnos sp.	Phgr	1	1	0	1	0	1	0	0
Lomariopsid	Bolbitis acrostichoides	ep	0	1	0	0	1	0	0	0
Lomariopsid	Lomariopsis guineensis	ep	1	1	1	0	0	0	0	0
Loranthacea	Globimetula sp.	para	0	0	0	0	0	0	1	0
Lycopodiace	Lycopodium cernum	Chd	1	1	0	0	0	0	1	0
Malvaceae	Hibiscus afer	NnPh	0	0	0	0	0	0	1	0
Malvaceae	Sida acuta	Chd	0	0	0	0	0	0	1	1
Malvaceae	Sida alba	Chd	0	0	0	0	0	0	1	1
Marantacea	Ataenidia conferta	G rh	0	1	0	0	0	0	0	0
Marantacea	Haumania danckelmanniana	Phgr	1	1	1	1	1	1	1	1
Marantacea	Hyselodelphys zenkeriana	Phgr	1	1	0	0	0	0	0	0
Marantacea	Marantochloa holostachya	G rh	0	1	0	1	0	1	0	1
Marantacea	Megaphrynium macrostachyus	G rh	1	1	1	1	0	0	0	1
Marantacea	Sarcophrynium prionogonium	G rh	0	1	1	0	0	0	1	1
Marantacea	Trachyphrynium braunianum	G rh	1	1	0	1	0	1	0	0
Melastomat	Dichaetanthera africana	NnPh	0	1	0	0	0	0	0	0
Melastomat	Dissotis minutiflora	Chd	0	1	0	0	0	0	1	1
Melastomat	Dissotis rotundifolia	Chd	0	0	0	1	1	0	1	1
Melastomat	Tristemma camerooniana	NnPh	1	1	0	1	1	1	1	1
Meliaceae	Carapa sp.	McPh	1	1	0	0		1		

Meliaceae	Carapa sp.	NnPh	1	1	1	1	1	1	1	1
Meliaceae	Guarea glomerulata	NnPh	0	1	0	0	0	0	0	0
Meliaceae	Heckeldora leptotricha	NnPh	0	1	0	0	0	0	0	1
Meliaceae	Heckeldora staudtii	NnPh	0	1	0	0	0	0	0	0
Meliaceae	Khaya ivorensis	NnPh	0	1	0	0	0	0	0	0
Meliaceae	Lovoa trichilioides	McPh	0	0	0	1				
Meliaceae	Lovoa trichilioides	NnPh	0	1	0	0	0	0	0	0
Meliaceae	Pterorhachis zenkeri	NnPh	0	1	0	0	0	0	0	0
Meliaceae	Trichilia preuriana	MsPh	0	1	0	0	0	0	0	0
Meliaceae	Trichilia rubescens	NnPh	0	1	1	1	1	1	1	1
Meliaceae	Turraea heterophylla	Phgr	0	1	0	0	0	0	0	0
Meliaceae	Turraeanthus africanus	McPh	0	1	0	0	0	0	0	0
Melianthace	Bersama paullinioides	NnPh	0	1	0	0	0	0	0	0
Menisperma	Cissampelos owariensis	Chc	0	1	0	1	0	1	1	1
Menisperma	Dioscoreophyllum cumminsii	Chc	1	1	0	1	1	0	0	1
Menisperma	Epinetrum cordifolium	Phgr	0	1	0	0	0	0	0	1
Menisperma	Jateorhiza macrantha	Thc	1	1	0	1	1	0	1	1
Menisperma	Kolobopetalum auriculatum	Thc	1	1	1	1	0	1	1	1
Menisperma	Penianthus longifolius	NnPh	0	1	1	1	0	0	1	0
Menisperma	Penianthus zenkeri	NnPh	1	1	1	1	0	0	1	1
Menisperma	Triclisia gilletii	Phgr	1	1	1	1	1	1	1	1
Monimiacea	Glossocalyx brevipes	NnPh	0	0	0	1	1	0	0	0
Moraceae	Dorstenia sp.	Thd	0	0	0	1	0	0	0	0
Moraceae	Ficus cf. kamerunensis	NnPh	0	0	0	0	0	0	0	1
Moraceae	Ficus exasperata	McPh	1	1	0	1	0	0	1	1
Moraceae	Ficus exasperata	MsPh	1	1		1	0	0	0	1
Moraceae	Ficus exasperata	NnPh	1	1	0	1	0	1	1	1
Moraceae	Ficus kimuenzensis	NnPh	0	0	0	0	0	0	1	0
Moraceae	Ficus mucuso	McPh	1	1	1	1	1	0	0	0
Moraceae	Ficus mucuso	MsPh	1	1	0	0	0	0	0	1
Moraceae	Ficus mucuso	NnPh	1	1	0	1	1	0	1	1
Moraceae	Ficus sp.	MsPh	1	0	0	0	0	0	0	1
Moraceae	Ficus sur	McPh	1	0	0	1	0	0	0	1
Moraceae	Ficus sur	NnPh	1	1	0	1	0	0	0	1
Moraceae	Milicia excelsa	McPh	0	1	0	1	0	1	0	1
Moraceae	Milicia excelsa	MgPh	0	1	0	0	0	0	0	0
Moraceae	Milicia excelsa	MsPh	0	1	0	0	0	0	0	0
Moraceae	Milicia excelsa	NnPh	0	1	1	1	1	1	1	1
Moraceae	Scyphocyse manniana	NnPh	0	1	0	0	0	0	0	0
Moraceae	Treculia acuminata	NnPh	0	1	0	1	1	0	1	1
Moraceae	Treculia africana	NnPh	0	1	1	1	0	0	1	0
Moraceae	Treculia obovoidea	McPh	0	1	0	0	0	0	0	0
Moraceae	Treculia obovoidea	MsPh	0	1	1	1	0	0	0	0
Moraceae	Treculia obovoidea	NnPh	0	0	0	0	0	0	0	
Moraceae	Trilepisium madagascariensis	McPh	0	1	0					
Moraceae	Trilepisium madagascariensis	NnPh	1	1	1	1	0	0	0	0
Musaceae	Musa paradisiaca	NnPh	1	1	0	1	1	0	1	1
Musaceae	Musa sapientum	NnPh	1	1	0	1	0	0	1	1
Myristicacea	Coelocaryon preussii	McPh	1	1	0	1	0	0	0	0
Myristicacea	Coelocaryon preussii	MsPh	1	1	0	0	1	0	0	1

Myristicacea	Coelocaryon preussii	NnPh	1	1	1	1	1	1	1	1
Myristicacea	Pycnanthus angolensis	McPh	1	1	0	1	0	0	0	1
Myristicacea	Pycnanthus angolensis	MgPh	0	0	0	0	0	1	0	1
Myristicacea	Pycnanthus angolensis	MsPh	1	1	1	1	1	0	0	1
Myristicacea	Pycnanthus angolensis	NnPh	1	1	0	1	0	1	1	1
Myristicacea	Scyphocephalium mannii	McPh	0	0	0	1	0	0	0	0
Myristicacea	Staudtia kamerunensis	MsPh	1	0	0	1	0	0	0	0
Myristicacea	Staudtia kamerunensis	NnPh	0	0	0	0	0	0	0	
Myrtaceae	Psidium guajava	McPh	0	0	0	1	0	1	0	1
Myrtaceae	Psidium guajava	NnPh	0	0	0	1	1	1	1	1
Myrtaceae	Syzygium guineensis	NnPh	0	1	0	0	0	0	0	0
Ochnaceae	Campylospermum dybowskii	NnPh	0	1	0	0	0	0	0	1
Ochnaceae	Campylospermum elongatum	NnPh	1	1	1	1	0	0	0	1
Ochnaceae	Lophira alata	McPh	0	0	0	1	0	1	0	
Ochnaceae	Lophira alata	MsPh	0	0	0	0	0	1	0	0
Ochnaceae	Lophira alata	NnPh	0	1	1	1	1	1	1	1
Ochnaceae	Ouratea sp.	NnPh	0	1	1	1	0	0	0	1
Ochnaceae	Rhabdophyllum sp.	NnPh	0	1	0	0	0	0	0	0
Olacaceae	Coula edulis	NnPh	0	1	0	1	0	0	0	0
Olacaceae	Heisteria parviflora	McPh	0	0	1					
Olacaceae	Heisteria parviflora	NnPh	0	1	1	1	0	1	1	1
Olacaceae	Heisteria trillesiana	NnPh	0	1	0	1	0	0	1	0
Olacaceae	Olax latifolia	NnPh	0	1	0	1	1	0	1	1
Olacaceae	Ongokea gore	MsPh	0	0	0	0	1	1	0	0
Olacaceae	Strombosia grandifolia	McPh	0	0	1					
Olacaceae	Strombosia grandifolia	MsPh	0	0	1					
Olacaceae	Strombosia grandifolia	NnPh	1	1	1	1	0	0	0	0
Olacaceae	Strombosiopsis tetrandra	McPh	0	0	1	0	0	0	0	1
Olacaceae	Strombosiopsis tetrandra	MsPh	0	0	0	0	0	0	0	0
Ophioglossa	Ophioglossum reticulatum	Thd	0	0	0	0	0	0	1	0
Orchidaceae	Bulbophyllum	ep	0	1	0	1	0	0	0	0
Orchidaceae	Calyptrochilum emarginatum	ep	0	1	0	0	0	0	0	1
Orchidaceae	Corymborkis corymbis	Chd	1	0	0	0	0	0	0	0
Orchidaceae	Polystachya sp.	G rh	0	1	0	0	0	0	1	0
Oxalidaceae	Oxalis barrelieri	Thd	0	0	0	1	1	0	1	1
Palmae	Elaeis guineensis	McPh	0	1	0	1	0	0	1	1
Palmae	Elaeis guineensis	MsPh	1	1	0	1	0	0	1	1
Palmae	Elaeis guineensis	NnPh	1	1	1	1	1	1	1	1
Palmae	Eremospatha wendlandiana	Phgr	0	0	0	0	0	1	0	0
Palmae	Laccosperma secundiflorum	Phgr	1	1	1	1	1	0	1	1
Palmae	Podococcus barteri	NnPh	0	1	1	1	0	0	0	1
Palmae	Raphia hookeri	McPh	0	1	0	0	0	0	0	0
Palmae	Raphia monbuttorum	McPh	0	0	0	1	0	0	0	0
Palmae	Raphia monbuttorum	MsPh	0	0	0	1	1	0	0	0
Palmae	Raphia monbuttorum	NnPh	0	1	1	0	0	1	1	0
Palmae	Sclerosperma mannii	NnPh	0	1	0	0	0	0	0	0
Pandaceae	Microdesmis haumaniana	NnPh	0	1	1	1	1	1	1	0
Pandaceae	Microdesmis puberula	NnPh	1	1	1	1	0	0	1	1
Pandaceae	Panda oleosa	MsPh	0	1	0	0	0	0	0	1
Passifloraceæ	Adenia cissampeloides	Phgr	1	1	1	1	1	1	1	1

Passifloracea	Adenia mannii	Chc	0	1	0	0	0	0	0	0
Passifloracea	Barteria nigritana	McPh	0	1	0	0	0	1	0	0
Passifloracea	Barteria nigritana	NnPh	0	1	1	1	0	1	1	1
Passifloracea	Deidamia clematoides	Chc	1	1	0	1	0	0	1	1
Passifloracea	Passiflora foetida	Phgr	0	0	0	0	0	0	1	0
Phytolacacea	Hilleria latifolia	Hec	1	0	0	0	0	0	0	0
Piperaceae	Piper guineensis	Chc	1	1	0	1	1	0	1	1
Piperaceae	Piper umbellatum	NnPh	1	1	0	1	0	0	1	1
Polygalaceae	Carpolobia alba	NnPh	1	1	1	1	1	1	1	1
Polypodiace	Anapeltis owariensis	ep	0	1	0	1	0	0	1	0
Polypodiace	Microsorium punctatum	ep	1	1	1	1	0	0	1	1
Polypodiace	Phymatosorus scolopendria	ep	0	1	0	0	0	0	1	1
Polypodiace	Platycerium angolense	ep	0	0	0	0	0	0	1	0
Rhamnaceae	Gouania longipetala	Phgr	1	1	0	0	0	0	0	1
Rhamnaceae	Lasiodiscus mannii	NnPh	0	1	0	1	0	0	0	0
Rhamnaceae	Maesopsis eminii	McPh	0	1	0	1	0	0	0	0
Rhamnaceae	Maesopsis eminii	Msph	0	1	0	0	0	0	0	0
Rhamnaceae	Maesopsis eminii	NnPh	1	1	0	1	1	0	1	1
Rubiaceae	Aidia micrantha	McPh	1	1	1	1	0	0	0	
Rubiaceae	Aidia micrantha	MsPh	0	1	1	1	0	0	0	0
Rubiaceae	Aidia micrantha	NnPh	1	1	1	1	0	0	0	1
Rubiaceae	Aulacocalyx caudata	NnPh	0	1	0	0	0	0	0	1
Rubiaceae	Bertiera aequatorialis	NnPh	0	1	1	1	0	1	1	1
Rubiaceae	Bertiera aethiopica	NnPh	1	1	0	1	0	0	1	1
Rubiaceae	Bertiera bracteolata	NnPh	0	1	0	1	0	0	1	1
Rubiaceae	Bertiera elabensis	McPh	0	0	0	1	0	0	0	0
Rubiaceae	Bertiera elabensis	NnPh	1	1	0	1	1	1	1	0
Rubiaceae	Bertiera retrofracta	NnPh	1	1	1	1	0	0	1	1
Rubiaceae	Canthium campylacantha	Phgr	0	1	0	0	0	0	0	0
Rubiaceae	Chassalia bipindensis	NnPh	0	0	0	1	0	0	0	0
Rubiaceae	Chassalia cristata	Phgr	0	1	1	1	0	0	0	1
Rubiaceae	Chassalia sp.	NnPh	0	1	0	1	0	0	0	0
Rubiaceae	Chassalia sp. nov.	NnPh	0	1	0	0	0	0	0	1
Rubiaceae	Chassalia zenkeri	NnPh	0	1	0	1	0	0	1	0
Rubiaceae	Chazaliella sciadephora	NnPh	1	1	1	0	0	1	0	1
Rubiaceae	Craterispermum laurinum	NnPh	0	0	0	1	0	0	0	0
Rubiaceae	Diodia sarmentosa	Chd	0	0	0	0	0	0	1	1
Rubiaceae	Diodia scandens	Chd	0	1	0	1	1	0	1	0
Rubiaceae	Euclinia longiflora	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Gaertnera longevaginalis	NnPh	0	0	0	0	0	1	0	0
Rubiaceae	Geophila afzelii	Chd	0	1	1	1	0	1	1	0
Rubiaceae	Geophila cordifolia	Chc	0	1	0	1	0	0	1	0
Rubiaceae	Hallea ciliata	NnPh	0	0	0	1	0	0	0	0
Rubiaceae	Heinsia crinita	NnPh	1	1	1	1	1	0	1	1
Rubiaceae	Hekistocarpa minutiflora	NnPh	0	0	0	0	0	1	0	0
Rubiaceae	Hymenocoleus sp.	Chd	0	0	0	1	0	0	0	0
Rubiaceae	Hymenocoleus sp. TB 3223	Chd	0	1	0	0	0	0	0	0
Rubiaceae	Keetia sp.	Phgr	1	1	1	1	0	0	1	0
Rubiaceae	Leptactina arnoldiana	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Leptactina involucrata	MsPh	0	1						

Rubiaceae	Leptactina involucrata	NnPh	1	1	0	1	0	0	0	1
Rubiaceae	Massularia acuminata	NnPh	1	1	1	1	1	1	1	1
Rubiaceae	Morinda lucida	McPh	0	0	0	0	0	0	0	1
Rubiaceae	Morinda lucida	Msph	0	1	0	0	0	0	0	0
Rubiaceae	Morinda lucida	NnPh	0	0	0	1	1	0	1	1
Rubiaceae	Morinda morindioides	Phgr	0	0	0	0	0	0	1	0
Rubiaceae	Mussaenda arcuata	Phgr	0	1	0	1	1	0	0	0
Rubiaceae	Mussaenda erythrophylla	Phgr	0	0	0	1	0	0	0	0
Rubiaceae	Nauclea diderrichii	McPh	0	1	0	0	0	0	0	
Rubiaceae	Nauclea diderrichii	Msph	0	0	0	0	0	0	0	0
Rubiaceae	Nauclea diderrichii	NnPh	1	1	0	1	0	0	0	0
Rubiaceae	Oldenlandia lancifolia	Chd	0	0	0	0	0	0	1	1
Rubiaceae	Oldenlandia sp.	Chd	0	0	0	0	0	0	1	0
Rubiaceae	Otomeria guineensis	Chd	0	1	0	0	0	0	0	1
Rubiaceae	Oxyanthus gracilis	NnPh	0	0	1	0	0	0	0	0
Rubiaceae	Oxyanthus speciosus	NnPh	0	1	0	0	0	0	0	1
Rubiaceae	Oxyanthus unilocularis	NnPh	1	1	0	1	0	1	1	1
Rubiaceae	Pauridiantha efferata	McPh	0	1	0	1	0			
Rubiaceae	Pauridiantha efferata	NnPh	0	1	0	1	1	0	1	1
Rubiaceae	Pausynistalia macroceras	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Pavetta camerooniana	NnPh	0	0	0	1	0	0	0	1
Rubiaceae	Pavetta sp.	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Pavetta TB 3186	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Poecilocalyx schumanniana	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Porterandia cladantha	McPh	0	0	0	1				
Rubiaceae	Porterandia cladantha	NnPh	0	1	0	1	1	0	1	1
Rubiaceae	Psychotria globiceps	NnPh	1	1	1	1	0	0	0	0
Rubiaceae	Psychotria peduncularis	NnPh	1	1	1	1	1	1	1	1
Rubiaceae	Psychotria psychotrioides	NnPh	0	1	0	1	0	0	1	1
Rubiaceae	Psychotria sp.	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Psychotria venosa	McPh	0	1	0	0	0	1	0	0
Rubiaceae	Psychotria venosa	NnPh	0	1	0	1	0	1	1	1
Rubiaceae	Psydrax palma	McPh	1	1	0	0	0	0	0	1
Rubiaceae	Psydrax palma	MsPh	0	1	0	0	0	0	0	0
Rubiaceae	Psydrax palma	NnPh	0	1	0	0	0	1	1	1
Rubiaceae	Psydrax subcordata	Msph	0	0	0	0	0	0	0	0
Rubiaceae	Psydrax subcordata	NnPh	0	1	0	1	0	1	0	0
Rubiaceae	Rothmannia hispida	NnPh	0	1	0	1	0	1	0	0
Rubiaceae	Rothmannia lateriflora	NnPh	0	1	0	0	0	0	0	1
Rubiaceae	Rothmannia longiflora	NnPh	0	1	0	0	0	0	1	0
Rubiaceae	Rothmannia octomera	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Rothmannia whitfieldii	NnPh	0	1	0	1	0	0	0	1
Rubiaceae	Rutidea hispida	Phgr	0	1	0	1	0	0	0	0
Rubiaceae	Rytigynia umbellulata	NnPh	1	1	0	0	0	1	0	1
Rubiaceae	Sabicea calycina	Phgr	0	1	0	1	0	0	1	1
Rubiaceae	Sabicea medusala	Phgr	0	1	0	0	0	0	0	0
Rubiaceae	Sabicea pilosa	Phgr	0	1	1	1	1	0	1	1
Rubiaceae	Sabicea sp.	Phgr	1	1	0	1	0	1	1	1
Rubiaceae	Schumanniophyton magnificum	NnPh	1	0	0	0	0	0	0	0
Rubiaceae	Sherbounia zenkeri	Phgr	1	1	1	1	1	1	1	1

Rubiaceae	Spermacoce monticola	Chd	0	0	0	0	0	0	1	1
Rubiaceae	Tricalysia atherura	NnPh	0	1	0	0	0	0	0	0
Rubiaceae	Tricalysia cf. anomala	NnPh	0	0	0	0	0	0	1	0
Rubiaceae	Tricalysia gossweileri	NnPh	1	1	1	1	0	1	0	1
Rubiaceae	Vanguériopsis sp.	NnPh	0	0	0	1	0	0	0	1
Rutaceae	Citrus grandis	NnPh	0	1	0	1	0	0	0	0
Rutaceae	Zanthoxyllum cf. dinklagei	NnPh	0	1	0	0	0	0	0	0
Rutaceae	Zanthoxyllum gilletii	McPh	1	1	0	0	0	0	0	0
Rutaceae	Zanthoxyllum gilletii	Msph	0	1	1	0	0	0	0	
Rutaceae	Zanthoxyllum gilletii	NnPh	1	1	0	1	1	0	1	1
Rutaceae	Zanthoxyllum heitzii	McPh	0	1	1	0	0	0	0	0
Rutaceae	Zanthoxyllum heitzii	Msph	1	1	0	0	0	0	0	
Rutaceae	Zanthoxyllum heitzii	NnPh	1	1	0	1	0	0	0	1
Sapindaceae	Allophylus africanus	McPh	1	0	0	0	0	0	0	0
Sapindaceae	Allophylus africanus	NnPh	1	1	0	0	0	0	1	1
Sapindaceae	Chytranthus gilletii	McPh	0	1	1	1	0	1	0	
Sapindaceae	Chytranthus gilletii	Msph	0	0	1	1	0	0	0	
Sapindaceae	Chytranthus gilletii	NnPh	1	0	1	1	1	1	1	1
Sapindaceae	Chytranthus setosus	NnPh	0	1	0	1	0	0	0	1
Sapindaceae	Eriocoelum macrocarpum	McPh	0	1	1	0	0	0	0	0
Sapindaceae	Eriocoelum macrocarpum	Msph	0	1	0	0	0	0	0	0
Sapindaceae	Eriocoelum macrocarpum	NnPh	1	1	0	1	1	1	1	1
Sapindaceae	Laccodiscus ferrugineus	NnPh	0	1	0	0	0	0	0	0
Sapindaceae	Laccodiscus pseudostipularis	NnPh	0	1	0	0	0	0	0	0
Sapindaceae	Leptonychia lasiogyne	NnPh	0	1	0	1	0	1	0	0
Sapindaceae	Leptonychia pallida	NnPh	0	1	0	0	0	0	0	0
Sapindaceae	Paullinia pinnata	phgr	1	1	0	0	0	0	0	1
Sapotaceae	Delpydora macrophylla	NnPh	0	0	0	1	0	0	0	0
Sapotaceae	Englerophytum stelecanthum	NnPh	0	0	0	0	0	1	0	0
Sapotaceae	Gambeya sp.	NnPh	0	0	1	1	0	0	0	0
Sapotaceae	Tridemostemon omphalocarpoides	NnPh	0	0	1	0	0	0	0	0
Schyziaceae	Lygodium smithianum	Phgr	1	1	0	1	0	0	1	1
Scytopetalac	Pierrina zenkeri	NnPh	0	1	0	0	0	0	0	1
Selaginellace	Selaginella myosorus	Chd	0	0	0	1	1	0	1	0
Selaginellace	Selaginella vogelii	Chd	1	1	0	1	0	0	0	1
Simarubacea	Hannoa klaineana	NnPh	0	1	0	0	0	0	1	0
Simarubacea	Quassia africana	NnPh	0	1	0	1	0	1	1	1
Smilacaceae	Smilax kraussiana	Phgr	1	1	1	1	1	0	1	1
Solanaceae	Capsicum frutescens	Chd	0	0	0	1	0	0	0	1
Solanaceae	Schweinkia americana	Chd	0	0	0	0	0	0	1	0
Solanaceae	Solanum incanum	NnPh	0	0	0	0	0	0	0	1
Solanaceae	Solanum nigrum	NnPh	0	0	0	1	0	0	0	0
Solanaceae	Solanum torvum	NnPh	0	0	0	1	0	0	1	1
Sterculiacea	Cola acuminata	MsPh	0	0	1					
Sterculiacea	Cola acuminata	NnPh	0	0	1	0	0	1	1	0
Sterculiacea	Cola caricaefolia	NnPh	0	1	1	0	1	0	1	0
Sterculiacea	Cola cauliflora	NnPh	0	1	0	0	0	0	0	1
Sterculiacea	Cola cf. verticillata	NnPh	0	0	0	0	0	1	0	0
Sterculiacea	Cola chlamydantha	NnPh	1	1	1	1	0	0	1	1
Sterculiacea	Cola digitata	NnPh	0	0	1	0	0	0	0	0

Sterculiacea	Cola ficifolia	McPh	0	0	1	0	0	0	0	0
Sterculiacea	Cola gabonensis	NnPh	0	0	0	1	0	0	0	0
Sterculiacea	Cola heteromerus	NnPh	0	1	0	0	0	0	0	0
Sterculiacea	Cola lateritia	NnPh	0	1	0	0	0	0	0	1
Sterculiacea	Cola marsupium	NnPh	0	1	0	0	0	0	0	1
Sterculiacea	Cola nitida	NnPh	0	1	0	0	0	0	0	0
Sterculiacea	Cola sp.	NnPh	0	1	0	1	0	1	0	0
Sterculiacea	Eribroma oblongum	McPh	0	1	0	1	0	0	0	0
Sterculiacea	Eribroma oblongum	Msph	0	1	0	1	0	0	0	1
Sterculiacea	Eribroma oblongum	NnPh	1	1	0	1	0	0	1	0
Sterculiacea	Scaphopetalum sp.	NnPh	0	1	0	1	0	1	0	0
Sterculiacea	Scaphopetalum thonneri	NnPh	1	1	1	1	0	0	1	1
Sterculiacea	Scaphopetalum zenkeri	NnPh	0	0	0	1	0	1	0	0
Sterculiacea	Sterculia tragacantha	McPh	1	1	1	0	0	0	1	0
Sterculiacea	Sterculia tragacantha	MsPh	0	1	0	0	0	0	0	
Sterculiacea	Sterculia tragacantha	NnPh	1	1	1	1	1	0	1	1
Sterculiacea	Theobroma cacao	NnPh	1	1	0	1	0	0	0	1
Tecophyllac	Cyanastrum cordifolium	G b	1	1	1	1	0	0	0	0
Thelypterida	Cyclosorus striatus	Chd	1	1	0	1	0	0	1	1
Thymeleace	Craterosiphon scandens	Chc	0	1	0	0	0	1	0	0
Thymeleace	Dicranolepis disticha	NnPh	0	1	0	0	0	0	0	0
Tiliaceae	Clappertonia ficifolia	NnPh	0	0	0	0	0	0	1	0
Tiliaceae	Desplatsia dewevrei	NnPh	1	1	0	1	1	0	1	1
Tiliaceae	Desplatsia subericarpa	NnPh	0	1	0	1	0	0	0	1
Tiliaceae	Duboscia viridifolia	NnPh	0	1	0	0	0	1	0	0
Tiliaceae	Glyphaea brevis	NnPh	1	1	0	1	1	0	1	1
Tiliaceae	Grewia barombiensis	Phgr	0	1	1	1	1	1	1	1
Tiliaceae	Microcos coriacea	McPh	1	1	0	1	0	0	0	0
Tiliaceae	Triumfetta cordifolia	NnPh	0	0	0	1	0	0	1	1
Ulmaceae	Celtis gomphophylla	NnPh	1	0	0	0	0	0	0	0
Ulmaceae	Celtis mildbraedii	NnPh	0	1	0	0	0	0	0	0
Ulmaceae	Celtis tessmannii	McPh	0	1	0	0	0	0	0	0
Ulmaceae	Celtis tessmannii	Msph	0	1	1	0	0	0	0	0
Ulmaceae	Celtis tessmannii	NnPh	0	1	0	0	0	1	0	0
Ulmaceae	Trema orientalis	McPh	1	1	0	1	0	0	0	1
Ulmaceae	Trema orientalis	Msph	0	1	0	0	0	0	0	
Ulmaceae	Trema orientalis	NnPh	1	1	0	1	1	0	1	1
Unknown	Indeterminee	McPh	0	0	0	0	0	1	1	0
Unknown	Indeterminee	Msph	0	1	0	0	0	0	0	0
Urticaceae	Laportea aestuans	Chd	0	0	0	1	0	0	0	0
Urticaceae	Laportea ovalifolia	Chd	1	1	0	0	0	0	0	1
Urticaceae	Pouzolzia guineensis	Chd	0	0	0	1	0	0	0	0
Urticaceae	Urera cf. cordifolia	Phgr	0	1	0	1	0	0	0	0
Urticaceae	Urera sp.	Phgr	1	1	0	1	0	1	0	1
Verbenacea	Lantana camara	NnPh	0	0	0	1	0	0	1	0
Verbenacea	Stachytarpheta cayennensis	Chd	0	1	0	1	1	0	1	1
Violaceae	Rinorea albidiflora	NnPh	0	1	0	0	0	0	0	0
Violaceae	Rinorea campoensis	NnPh	1	1	1	1	1	1	1	1
Violaceae	Rinorea dentata	NnPh	0	0	1	1	1	0	0	0
Violaceae	Rinorea lepidobotrys	NnPh	0	0	0	1	0	0	0	0

Vitaceae	Ampelocissus bombycina	Phgr	1	1	1	1	1	1	1	1
Vitaceae	Cissus aralioides	Phgr	1	1	0	1	0	0	1	1
Vitaceae	Cissus barbeyana	Phgr	0	1	0	1	0	0	1	1
Vitaceae	Cissus dinklagei	Phgr	1	1	1	1	0	0	1	1
Vitaceae	Cissus leonardii	Phgr	0	1	0	1	0	0	1	0
Vitaceae	Leea guineensis	NnPh	1	1	0	1	0	1	1	1
Vittariaceae	Vittaria guineensis	ep	0	0	0	0	0	1	1	0
Zingiberacea	Aframomum daniellii	G rh	1	1	1	1	1	1	1	1
Zingiberacea	Aframomum subsericeum	G rh	0	1	1	1	0	0	1	1
Zingiberacea	Renealmia cincinati	G rh	0	1	0	0	0	0	0	0
Zingiberacea	Renealmia congoensis	G rh	0	1	1	0	0	0	0	0

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Acac kame											+		+	+									
Acan mont																							
Achy aspe																							
Acro ziza								+										+					+
Aden ciss								+					+				+		+				
Aden mann																							
Adia voge																							
Afra dani	3						2	3	+		2	+	+	+	+	2	+						
Afra subs																							
Afze bipi																							
Agel pent													+										
Ager cony		+																				+	
Aidi *mic																							
Aidi micr							+					+	1		1	+							
Albi *adi																+							
Albi adia					+		+						+	+	+								
Albi 'adi																							
Albi zygi	1		+	+	+	+	+																
Alch cord		+			+			+			+						+	+	1	1	1	+	
Alch flor	+		+	+			+						+	+	+								
Alla flor									+														
Allo *afr												+											
Allo afri						+					+	+											
Alst boon								+				1											
Alst boon			+						+										+	+			
Alst 'boo																							
Also mann																							
Ampe bomb	+			+			+		+		+			+		+	+	+	+				+
Amph ferr																							
Anan como			+																				
Anap owar																							
Anch diff																	+	+	+	+	+	+	+
Anei beni		+								+		+		+				+					
Angy olig																							
Anni chlo																							
Anno muri																							
Anon mann																							
Anno inde																							
Anth *sch	2																						
Anth schw	+		+			+				+	+				+			+		1	4		
Anth *mac																							
Anth macr						+	+	+				+			+		+	1	+	+	+	+	+
Anti laci																							
Anti memb									+			+	+		+	+							+
Antr *kla																							
Antr klai																							
Anub bart										+		+											
Apha sp.																							
Arac hypo				+																			
Argo macr																							
Arta pier			+						+														

Asys gang														+								
Atae conf																						
Aula caud																						
Axon comp	+		+																			+
Bais bail												+			+							
Bamb vulg																						
Baph verm									+													
Baph niti																						
Baph sp.																						
Baph parv																+						
Bart nigr		+		+																		
Bego sp.																						
Bego hirs																						
Bego quad																						
Berl auri								+					+		2 +							
Berl brac																						
Bers paul																						
Bert aequ																						
Bert aeth																						
Bert brac																						
Bert elab														+			+	+	+			
Bert retr																						
Bide pilo	+																					
Bolb acro																						
Bomb *buo							1															
Bomb buon		+			+						+											
Brid *mic												2										
Brid micr		+			+			+		+			+								+	
Bulb sp.																						
Call bequ						+					+											
Calp *hei																						
Calp heit								+														
Caly emar																						
Camp dybo																						
Camp elon						+																
Cana *sch							1															
Cana schw		+								+	+	+		+				+		+		
Cant camp																						
Caps frut																						
Cara sp.			+					+				+						+				
Cari papa									+													
Carp alba			+									+										+
Ceib *pen																						
Ceib pent												+	+									
Celo trig																						
Celt mild																						
Celt *tes																						
Celt tess																						
Cent lapp			+													+						+
Chas bipi																						
Chas cris																						
Chas nov.																						

Chas sp.																							
Chas zenk																							
Chaz scia															+								
Chlo orch																							
Chro odor	+	4	+		5	5			+		+			+						+	+	4	4
Chyt gill										+			+		+				+				+
Chyt seto																							
Cinn zeyl																							
Ciss owar																							
Ciss aral															+								
Ciss barb																							
Ciss dink													+		+								
Ciss leon																							
Citr gran																							
Clap fici																						+	
Clei *gla												+											
Clei glau				+													+				+		+
Cler atla																							
Cler buch																							
Cler sple	+			+							+	+				+				+	+	+	+
Cnes corn																				+	+		
Cnes ferr	+		+		+							+					+	+	+		+		
Cocc bart																							
Coel *pre								+												1			
Coel preu															+		+						
Cogn podo									+	+													+
Cola *acu																							
Cola acum		+																					
Cola cari																				+			+
Cola caul																							
Cola chla							+		+				+										
Cola digi																							
Cola fici																							
Cola gabo																							
Cola hete																							
Cola late																							
Cola mars																							
Cola niti																							
Cola vert																							
Cola sp.																							
Comb calo			+	+			+	+	+	+		+	+	+					+			+	+
Comb hisp																							
Comm beng																							
Comm capi																							
Cory cory																							
Cost afer	+		+															+	+	+	+	+	+
Cost dubi												+	+		+								
Cost luca																							
Coul edul																							
Crat laur																							
Crat scan																							
Crot *oli	+																						

Crot olig					+		+				+		+	+	+								
Crot mann																							
Cten prot																							
Culc scan		+																					
Cyan cord												+			+								
Cyan long																							
Cyat pros				+						+	+										+	+	
Cycl stri			+									+											
Cyna sp.																						+	
Cype alte																							
Cype diff		+	+	+												+							+
Cype dist																							
Cype fert														+	+								
Cyrt chae				+													+		+				
Dacr edul							+										+						
Dacr macr									2														
Dacr macr									1														
Dalb host																							+
Dalb afze																							+
Dalb gran											+				+								
Dale conv																							
Dasy sp.																							
Dava chae																						+	
Deid clem													+	+									
Delp macr																							
Desb glau																				+			
Desm adsc	+	+	+								+						+	+		+		+	
Desm tort																							
Desp dewe		+			+							+								+		+	
Desp sube																							
Dial dink																							
Dial pach																							
Dich afri																							
Dich cymu																			+				+
Dich heud															+		+	+	+	+	+		
Dich insi																							
Dich sp.																							
Dich glau																							
Dich glau																							
Dich sp.																							
Dicr dist																							
Diod sarm																							
Diod scan																					+	+	+
Dios alat																							
Dios bulb				+				+	+	+				+							+		
Dios caye																							
Dios cf.																							
Dios smil																					+		
Dios cumm																							
Dios bipi																							
Dios cinn																							
Dios cono									+														

Dios frag							+																
Dios hoyl																							
Dios simu									+														
Dios suav																							
Dios zenk																							
Disc *cal																							
Disc calo									+														
Diss minu																							
Diss rotu																							
Dist *ben																							
Dist bent																							
Doli refl																							
Dors sp.																							
Drac arbo																							
Drac aubr																							
Drac came																							
Drac cera																				+			
Drac sp.																							
Dryp afra																							
Dryp leon																							
Dryp prin																							
Dubo viri																							
Dugu stau																							
Dupa orch													+	+	+								+
Elae *gui		1		4																			1
Elae guin							+				+				+	+							
Elae 'gui		+				+			+	+											+		
Elae drup																							
Elep moll																							
Elyt marg																							
Emil cocc										+											+		+
Engl stel																							
Epin cord																							
Erem wend																							
Erib *obl																							
Erib oblo													+		+								
Erig flor																							
Erio macr																							
Erio macr			+			+						+											
Eryt ivor																							
Eryt ivor																							
Eryt exce																							
Eucl long																							
Euph hirt										+													
Euph pros																							
Ficu *exa												+											
Ficu exas	+				+					+	+			1 +	+	+							
Ficu cf.																							
Ficu kimu																							
Ficu *muc												+											
Ficu mucu	+			+					+	+	+			+						+			
Ficu sur												+											

Ficu sur							+							+	+								
Ficu *sp.																							
Ficu sp.																							
Fimb hisp																							
Flag guin																							
Funt *ela																							
Funt elas	+							+															
Funt elas																							
Gaer long																							
Gamb sp.																							
Garc cf.																							
Garc cf.																			+				
Garc gnet																							
Garc *sp.																							
Garc sp.																							
Geop afze																							
Geop cord																							
Gilb brac																							
Gilb limb																							
Glob sp.																							
Glor simp																							
Glos brev																			+				
Glyp brev		+						+													+		
Gnet afri																							
Goua long								+					+										
Gree suav													+										
Grew baro																							
Gros pani									+														
Guad dens																							
Guar glom																							
Guib ehie																	+	+	+				
Haem mann																							
Hall cili																							
Hann klai																							
Haru 'mad										+	+							4	3	1	2		1
Haum danc	2	+	+	+			+	+	+	+	+	+	+	1	3		+		+				+
Heck lept																							
Heck stau																							
Heki minu																							
Hein crin							+																
Heis parv																							
Heis tril																							
Heve *bra																							
Heve bras																							
Hibi afer																							
Hill lati											+												
Homa *let																							
Homa lete			+															+					
Hugo obtu																			+				
Hylo gabu																		+	+				
Hyme *ulm																							
Hyme ulmo																							

Hyme sp.																							
Hyme TB																							
Hyme *afz																							
Hyme afze																							
Hypo zenk																			+				
Hypo aris																							
Hyse zenk																							
Inde sp.																							
Inga edul																							
Ipom alba																				+			
Ipom bata	+									+													
Ipom invo		+		+										+				2	1	2	+	+	3
Irvi *gab																	1						
Irvi gabo																					+		
Irvi 'gab						+																	
Irvi gran																							
Jate macr									+			+	+								+	+	
Keet sp.																							
Khay ivor																							
Kige afri																							
Klai gabo																							
Kolo auri																							
Lacc ferr																							
Lacc pseu																							
Lacc secu							+		+	+		+							+		+		
Land land													+		+								
Land owar					+		+		+														
Lank eleg																							
Lann *wel																							
Lann welw																							
Lant cama																							
Lapo aest																							
Lapo oval				+																			
Lasi afri								+	+			+	+	+				+				+	+
Lasi mann																							
Lavi macr			+	+					+					+					+		+		
Leea guin															+								
Leon afri																							
Lepi stau																							
Lept arno																							
Lept invo									+							+							
Lept coch																							
Lept daph																							
Lept oxyt																							+
Lept lasi																							
Lept pall																							
Leuc mart																							
Loes apoc																				+		+	
Loma guin							+																
Lonc curr																							
Loph *ala																							
Loph alat																							

Loph 'ala																	+	+	+			+	
Lovo tric																							
Lyco cern	+																						
Lygo smit			+						+	+						+							
Maca *bar																							
Maca bart																+							
Maca 'bar																							
Maca *hur			+									1											
Maca hura	+	+	2					1	+	+	1		+				1	+	3		2	+	3
Maca 'hur																							
Maca *mon																							
Maca mona																							
Maca 'mon																							
Maca schw																							
Maca spin																							
Maes bart																							
Maes bipi																							
Maes duse												+						+					
Maes *emi																							
Maes emin	+		+		+				+										1		+		
Mall oppo																							
Mang *foe																							
Mang foet																							
Mang *ind																							
Mang indi																							
Mani escu				+					+	+								+	+	1	1	+	2
Mann fulv																							
Mapa macr							+																
Mapa mann																							
Mara holo																	+						
Mare long																							
Marg *dis																							
Marg disc						1					+				+		+						
Mari alte		+		+																	+		
Mark lute																							
Mass acum												+						+					
Mega macr							2	4					3		+		+						
Meio lepi																							
Merr aegy																							
Micr cori												+			+								
Micr haum																	+		+		+	+	+
Micr pube	+									+		+		+	+								
Micr spel														+		+							
Micr punc																							
Mika cord										+											+		+
Mili *exc																							
Mili exce										+							+			+			
Mill hypo																							
Mill macr			+	+	+	+		+		+	+	+	+	+	+	+	+		+			+	+
Mill mann																							
Mill sp.																							
Mimo pudi																							+

Momo cabr																							
Momo char											+												
Momo ciss																							
Momo foet																							
Mona klai																							
Mono myri																							
Mono *myr																							
Mori *luc																							
Mori luci																				+			
Mori mori																							
Most brun									+														
Mucu flag																		+				+	
Musa para								+	+					+			+				+	+	
Musa sapi				+	+			+		+	+												
Musa *cec			+				+		4				+	1	1	1							
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