Characteristics, Structure, and Tree Species Diversity of a Tropical Exploitation Forest after 40 Years of Regeneration

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by

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In love to Luca.

Content

Acronyms

AGB	Above Ground Biomass
BGB	Below Ground Biomass
BHD	Brusthöhendurchmesser
BA	Basal Area
β_{sim}	Lennons Measure of Species Differentiation
C	Carbon Fraction
C_{MS}	Marczewski-Steinhaus Index of Complementarity
C_N	Brain-Curtis Quantitative Similarity Index
C_S	Sørensen Index of Similarity
d	Diameter
d’	Berger-Parker Index
D	Simpson Index
dbh	Diameter at Breast Height
Doub	Doubletons, Rare Species represented by two stems
f	Form Factor
H	Tree Height
H´	Shannon Index
Ha	Hectare
H/D	Height Diameter Ratio
J`	Shannon Evenness
mc	Moisture Content
N	Number
P	Sample Plot
S	Species
Sing	Singletons, extremely rare species represented by one stem
SV	Standing Volume
TB	Total Biomass
VS	Volume Shrinkage Factor
WD	Wood Density

Abstract

Tropical forest ecosystems provide essential benefits for humanity. Forest degradation and deforestation implies the loss of biological diversity that alters complex forest ecosystems. Especially, when forests are subject to selective timber harvesting a number of times fundamental ecosystem functions and the provision of ecosystem services can profoundly be disturbed. Safeguarding forests and their biological diversity increases the forests' resilience against climate change, contributes to the mitigation of global warming and maintains livelihoods benefits.

Against this backdrop this study examines the state of a tropical exploitation forest in regeneration with particular focus on the question whether the forest ecosystem can return to its original state or will change to a new equilibrium.

For this purpose, ground-based measurements recorded during a field survey in the evergreen coastal rainforests of Mondah, near the majof city of Gabon, were analyzed. The forests were protected against subsequent exploitation during the last 40 years.

At this stage, signs of previous exploitations are still existent in the forest stand structure. The study estimates of woody biomass and forest carbon stock per hectare rank below the local potential. There is evidence that the ligneous diversity is reduced compared to former levels.

At the same time the assessment found that basic forest characteristics fit to the range given for matured forest in the region. The comparison with field data from 1993 proves the proceeding forest recovery. The study concludes that a repeatedly exploited forest stand can restore many aspects of its primary characteristics when it is protected against subsequent logging. The natural regeneration of woody plant species seems to be impeded due to the human induced local disturbances of wildlife. Based on these findings it is suggested that the forest stand under investigation cannot return to its original state but changes to a new equilibrium. Further investigations are needed to gain more substantiated knowledge on the extent of forest ecosystem alteration.

Special focus of the analysis was placed on the contribution of small-sized stems ($1cm \leq dbh < 10cm$) usually neglected in tropical forest inventories to the study's outcome. This study suggests that its systematic survey has to be included in forest assessment protocols because their involvement influences the assessment results in excess of 5%.

The results reveal, that the assessment of ligneous plants smaller than 10cm dbh is only negligible in terms of their contribution to volume, woody biomass, and -carbon stock. In all other cases the exclusion of small-sized stems leads either to an under- or overestimation of the stand parameters under investigation beyond the 5% threshold.

Abstract (German)

Tropische Regenwälder sind dynamische Ökosysteme. Für die Aufrechterhaltung ihrer dynamischen Stabilität ist größtmögliche biologische Artenvielfalt essentiell. Die Bewahrung ihrer Diversität erhöht die Resilienz der Wälder gegen Störungen und sichert die Bereitstellung wesentlicher Ökosystemdienstleistungen (z.B. Minderung des Klimawandels, Subsistenz). Waldschädigungen durch wiederholte Exploitationen implizieren Artenschwund und folglich die Störung der Funktionen und Leistungen des komplexen Ökosystems.
Vor diesem Hintergrund untersucht die vorliegende Studie einen mehrmalig exploitierten Regenwaldbestand nach 40 Jahren geschützter Regeneration.
Das Untersuchungsgebiet ist der immergrüne Küstenregenwald Mondahs nahe Libreville, der Hauptstadt Gabuns. Auf Basis von Feldaufnahmen wurden charakteristische Kennwerte, Struktur und Artenvielfalt der hölzernen Vegetation analysiert.
Die Ergebnisse der Arbeit ergeben ein differenziertes Bild. Die Auswirkungen früherer Exploitationen sind in der Bestandsstruktur noch erkennbar. Biomasse und Kohlenstoffgehalt der hölzernen Vegetation pro Hektar liegen unter dem lokalen Potential. Die Artenvielfalt der hölzernen Vegetation hat aufgrund anthropogener Störungen des Waldökosystems abgenommen. Gleichzeitig nähern sich die numerischen Werte der charakteristischen Bestandsvariablen jenen alter Waldbestände des Kongobeckens an. Desweiteren belegt der Vergleich mit Daten aus dem Jahr 1993 den fortschreitenden Regenerationsprozess des Waldes. Die Studie zu dem Schluss, dass die Erholung eines mehrmalig exploitierten Waldes möglich ist, jedoch scheint im vorliegenden Fall die natürliche Regeneration der hölzernen Artenvielfalt aufgrund der lokal stark gestörten Flora und Fauna eingeschränkt. Die Rückkehr des Waldökosystems in sein ursprüngliches Gleichgewicht ist damit unwahrscheinlich. Weiterführende Untersuchungen sind notwendig, um das Ausmaß und die Implikationen der Veränderung des Ökosystems genauer abschätzen zu können.
Der Fokus vorliegender Analyse liegt auf dem Einfluss der in gängigen tropischen Forstinventuren vernachlässigten Stammfraktion $1cm \leq BHD < 10cm$ auf das Untersuchungsergebnis. Es wurde untersucht, ob ihre systematische Erfassung in die Bestandsaufnahme inkludiert werden sollte, da ihr Ausschluss die Resultate um mehr als 5% verändert. Tatsächlich erscheint die Erhebung des Dünnholzes nur in Hinblick auf Bestandsvolumen, Biomasse und Kohlenstoffgehalt vernachlässigbar, der Einfluss auf alle anderen bestandsbezogenen Kennzahlen übersteigt 5%.

1. Introduction

1.1. The Forests of the Congo Basin

Beside Amazonia and South-East Asia, the Congo Basin is one of the three rainforest basins on earth. Situated in central Africa it spans as a belt north and south of the equator from the Atlantic Coast to the western foothills of the Ruwenzori Mountains which are located on the border between Uganda and the Democratic Republic of Congo. After the Amazon the forests of the Congo Basin represent the second largest and contiguous rainforest block on Earth (Corlett and Primack 2011) and constitute approximately up to one quarter of the world's tropical forests (WWF s.a.). The forested area nears 2 million square kilometers (Billand et al. 2006). The forest ecosystems give home to an immense wealth of biological diversity and contain 25% of the total carbon stored in tropical forests on Earth (European Commission 2012; FAO and ITTO 2011). The dense forests span the boundaries of Equatorial Guinea, Cameroon, Central African Republic, Republic of Congo, Gabon and the Democratic Republic of Congo, the latter hosting more than half of the forests (Corlett and Primack 2011; White 1983). With a forest cover in excess of 80% of the national territory, Gabon is the most forested country of the Congo Basin (FAO 2010; Campell et al.; Wasseige et al. 2008; Ministere des Eaux et Forets, Gabon 1999; Cabinet du Président de la République Gabon, s.a.; FAO and ITTO 2011). It is considered as one of the biological most diverse countries of Africa. Although the following specifications refer to the particular situation in Gabon, it can be transferred to other Congo Basin countries in the majority of cases.

1.2. Threats and Impacts on the Forest Ecosystems

1.2.1. Threats

In the past, the overall low population density, high level of urbanization, an underdeveloped agricultural sector, difficult to access terrain in the interior and relative national wealth of fossil energy resources have contributed to the protection of the Gabonese forests. Recently, national development and economic diversification lead to increasing threats on the forest ecosystems (General Direction of Environment and Nature Protection Gabon 2008).

Deforestation is mainly driven by socio-economic factors including the expansion of slash- and burn agriculture, firewood extraction and charcoal production (FAO and ITTO 2011) in the local surrounding of human settlements. Large-scale agricultural projects, opening up of

the country due to infrastructure development (roads, railways, sea ports), and industrial mining activities contribute to deforestation on the national level.
Illegal timber exploitation combined with increasing commercial logging activities are considered as major reasons for forest degradation (General Direction of Environment and Nature Protection Gabon 2008; Makana and Thomas 2006).
While the high level of urbanization have contributed to safeguarding the forests in wide, quasi uninhabited parts of Gabon, the high population densities in urban regions threaten the forests located near the cities and roads (General Direction of Environment and Nature Protection Gabon 2008). The rapid urban population growth intensifies the pressure on neighboring forests ecosystems and its resources (UNEP 2002) setting the continuity of those forests at risk. At the present stage, the region around the capital city of Gabon, Libreville, is identified as deforestation area (General Direction of Environment and Nature Protection Gabon 2008).

1.2.2. Impacts

Biological diversity is the stabilizing factor of ecosystem functions and the driver behind the provision of livelihood benefits for forest-dependent communities and global society (Cardinale et al. 2012). In the case of Libreville one of the major impacts of rapid and uncontrolled urbanization is its spread into forest ecosystems (Cardinale et al. 2012). The overuse of forest resources and services, its degradation, and clearing result in changes and loss of biological diversity (Makana and Thomas 2006). This loss is seen as a highly critical issue as it alters the structure and functioning of ecosystems (Cardinale et al. 2012).
Especially, when the forest is subject to repeated selective timber harvesting fundamental functions of complex forest ecosystem can profoundly be disturbed and their ability to provide goods and services for society reduced (Cardinale et al. 2012). In addition, repeated forest logging might alter dimensional forest stand characteristics and implies lasting changes in horizontal and vertical stand structure impacting the amount of forest biomass and carbon stored. By trapping carbon dioxide forests play a major role in mitigating climate change. When degraded or destroyed forests release carbon into the atmosphere and contribute to global warming at the same time as its ability to sequester carbon is profoundly impacted (FAO 2006).
The forests of Mondah situated in the north of Libreville are characterized by a long story of human exploitation. The history of repeated selective timber logging in the region dates back to the beginning of the last century (Lanteigne and Hamelin 2011). Intensive exploitation is documented for the epoch before 1930, the early 1930ies and two more times between 1950 and 1970 (Pietsch 2000). The forest was classified as protected area in 1951 and its usage was legally restricted by the government (Pietsch 2000). During the last decades numerous

areas of the forests were successively declassified. Originally occupying 10,200 ha the protected area today measures 5206 ha in size (Figure 1). Wide, formally forested areas were cleared. The high rate of forest regression in the region is caused by the accelerating sprawl of urban development and augmented clearing and cultivation of forested areas for subsistence agriculture or plantations. Occupations of land for living or speculative reasons spread from the southern part of the forest, which borders the periphery of Libreville, pressurizing the remaining forest stands. Timber extraction for charcoal production, sand mining and limestone quarrying further degrade the forest (AGP 2011; Lanteigne and Hamelin 2011). Practices of this kind are illegal, but were tolerated by the forest agency (Pietsch 2000). The result is a landscape mosaic of various landscapes existing next to each other. Within a few kilometers, recently cleared areas, agriculturally used areas and plantations, fallows, forests in the first stage of succession and older forests in different stages of regeneration alternate (own observation, Sept. 2011).

1.3. State of the Forest and Forest Regeneration

In general, little is known about the forest ecosystems of the Congo Basin. Large areas are still unexplored and research in the past remains insufficient. Instead of being unified under a common framework, research activities by different stakeholders or interest groups are both poorly coordinated and disparate. The resulting data gaps include essential information such as forest characteristics, biological diversity and forest carbon stocks. On the other hand, reliable forest data are needed to produce accurate reports on the state and dynamics of the forest. Particularly in regard to emerging market mechanisms seeking for the compensation of forest ecosystem services substantiated reports are needed (FAO and ITTO 2011). In terms of global carbon cycling the assessment of forest carbon stocks and its changes is considered as increasingly important (Brown 1997). Further, the lack of adequate forest system knowledge negatively impacts the effective implementation of any conservation project (FAO and ITTO 2011).

To gain robust information on the impact of forest disturbance and to evaluate positive effects of forest conservation the assessment of repeatedly degraded forest ecosystems and its recovery process appears important. Against this backdrop this study intends to produce informed knowledge on the state and regeneration of a repeatedly exploited rainforest under protection. In this context, it is of particular interest to investigate the extent and degree of the recovery capacity of the forest and to assess if the forest ecosystem can return to its original state or will change to a new equilibrium.

In the Mondah forests some spatially well-defined forest areas exist that are effectively protected against current environmental degradation in the region. These sites are covered with potentially natural heterogeneous coastal evergreen lowland rainforest. Its forest stands have undergone an uninterrupted natural recovery process since the last exploitation activities terminated approx. 40 years ago. These forests provide favorable conditions to research the state and recovery of an exploited rainforest stand and the impact of human disturbances on both.

1.4. Forest Conservation

To conserve biological diversity and thus, forest carbon stocks is essential for society (Phelps et al. 2012) as it bolsters the dynamic stability of ecosystems, increases forest resilience against climate change and supports the regeneration process of degraded forest stands (Milz 2009). Thus, biodiversity conservation seems essential for the maintenance of livelihood benefits. Further, forest ecosystems "[…] store more carbon than any other terrestrial ecosystems and [thus], are an important 'brake' on climate change (Gibbs et al. 2007, p1). Safeguarding forests and (re)storing its forest biomass and carbon stock bound in the forest structure contributes to climate change mitigation. Actually, Gabon is taking a leading position among Congo Basin countries in reference to forest conservation. It stands out due to its voluntary policies and forest governance applied by the government. Since the early nineties the forest policy is characterized by clear commitments towards conservation of its tropical forests (General Direction of Environment and Nature Protection Gabon 2008).

1.5. Surveying Biodiversity

The term biodiversity has experienced an amazing proliferation in popularity. The growing popularity comes along with an increasing dilution of the meaning. A disambiguation of the concept is considered necessary for the scope of this work.
The widely accepted definition of the United Nations Environment Program describes biodiversity as

> *"the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (United Nations 1992, Art. 2)."*

Based on this definition biological diversity can be categorized into three basic forms: qualitative diversity (between biotic entities), quantitative diversity (quantity of biotic entities) and functional diversity (terrestrial diversity or ecological complexity) represented by biotic objects in a spatial or temporal reference area (Beierkuhnlein 2003).

A remark is to be made regarding the use of the terms species or biological diversity and species richness. Species diversity is a comprehensive concept that includes several aspects and can be assessed in terms of richness (number of unique species), evenness (equitability among species in an assemblage), and heterogeneity (species complementarity in the sample area) (Cardinale et al. 2012; Beierkuhnlein 2003; Magurran 2004).
Biological diversity can be assessed within or between geographical scales. In this context Magurran (2004) distinguishes between inventory diversity (within habitat) and differentiation diversity (between habitats). In addition, Gray (2000) suggests an unambiguous notation of a logical series of scales. He recognizes four scales of inventory diversity given in Table 1.
The most important distinction between differentiation diversity and inventory diversity is that the former does not represent a logical order in scale. Since beta or differentiation diversity in its original perception does not relate to spatial scales, Gray (2000) recommends using the term turnover diversity to describe spatial or temporal changes in species composition (see Table 1).

Table 1: Notation of inventory and turnover diversity in relation to scale, Source: (Magurran 2004) and (Gray 2000).

Scale	**Inventory diversity**	**Turnover diversity**
Within sample	Point species richness	
Between samples, within habitat		Pattern diversity
Within habitat	Sample species richness	
Between habitats, within landscape		β diversity
Within landscape	Large area species richness	
Between landscapes		δ diversity
Large area species richness	Biogeographical province species richness	

This study uses the terminology proposed in Table 1 to describe inventory diversity. To avoid confusion the variability in species occurrence between spatial units is termed turnover diversity. This study focuses on the organismal level of biological diversity and refers to single countable objects represented by single plant individuals (Magurran 2004; Hubbell 2001). Biological diversity is defined as the biotic plant diversity of ligneous vegetation. The concept is used as measure to assess qualitative and quantitative species abundance and composition in a defined area at a given point in time.

1.6. Forest Assessment

The analysis of the present study was carried out on the basis of an on-site forest assessment. The assessment was used as concept to collect data and information on the quality and quantity of the woody forest vegetation in place (Köhl et al. 2006) in order to

assess basic forest stand characteristics, forest structure and the ligneous plant species diversity. In this context, the forest assessment is considered a static process (Gordon and Newton 2006) the outcome of which can provide information on the state and dynamics of the forest (Dallmeier 1992).
Data from ground-based field measurements collected in forest assessments are the most useful for the calculation of tree carbon content and the estimation of forest carbon stock (Gibbs et al. 2007; Magnussen and Reed 2004; Brown 1997; GOFC-GOLD 2010).
Since the above ground biomass of the forest vegetation is supposed to be the largest carbon pool in tropical forests, biomass estimation derived from tree-specific parameters is regarded as a fundamental step for the quantification of tree carbon content and changes in forest carbon stock (Gibbs et al. 2007). Further, vegetation surveying is the basic requirement for any forest diversity assessment.

1.7. Working Objectives and Hypothesis

This thesis aims to examine the state of the forest, assessing forest regeneration and investigating the human impact on the forests by analyzing forest characteristics, stand structure and tree-species diversity in place. This objective is composed of three working objectives:

A. The first objective is to assess and evaluate the actual state of a repeatedly exploited tropical rainforest after 40 years of regeneration. In order to determine the state of the forest the data collected during the on-site assessment are analyzed according to the following scheme:
    1. Important forest characteristics and estimates are calculated including
        a. Stem density
        b. Basal area
        c. Standing volume of the growing stock
        d. Above ground biomass density
        e. Above ground forest carbon stock.
    2. The forest stand structure is to be assessed in regard to
        a. Horizontal stand structure
        b. Vertical stand structure
        c. Species structure.
    3. Tree-species diversity is estimated using different diversity indices. Thereby, two types of measures are to be distinguished
        a. Measures to assess within habitat diversity and
        b. Measures to assess between habitat diversity.

In order to evaluate the present state of the forests the analysis' results are compared to reference values given in literature and the findings of other forest assessments.

B. The second objective is to ascertain the progression in the forest regeneration process. This examination is based on the comparison of the present findings with field data recorded in 1993 in the study area.
C. The third objective is to identify anthropogenic impacts on the actual state of the forest as they are detectable by changes in the tree-species diversity.
   This investigation is carried out based on information from publications and studies, personal communication with stakeholders, and own knowledge gained during field work.

To complement the study's outcome site-specific characteristics and information are included in the assessment results and discussion.

In addition to the three working objectives above, the special purpose of the present study is to investigate the impact of a minimum diameter requirement eqal to 10cm dbh on the forest assessment results. Based on the common assumption that the ligneous vegetation dbh<10cm counts for less than 5% of the forest characteristics of interest, most tropical forest assessments report to a minimum diameter requirement equal to dbh<10cm (or even larger). Small-sized stems and understory vegetation are excluded from sampling or merely surveyed on a very low level (Voluntary Carbon Standard 2010; Brown 1997).
The thesis at hand casts the previous supposition into doubt. It suggests that especially in forest stands characterized by a high proportion of small sized stems juveniles and small trees potentially contribute more than the critical 5% to forest characteristics and estimates. This study proposes the hypothesis that for young or degraded forest stands in regeneration, a minimum diameter below 10cm dbh should be chosen. The complete census of all ligneous stems with a minimum dbh≥1cm is considered a prerequisite to capture the maximum of ligneous stand diversity and to develop robust stand estimates. Thus, this study aims to show the effect of excluding small-sized stems from surveying. It is suggested that surveying trees to a minimum diameter at breast height equal to or larger than 10cm implicates

A. substantial loss of information in regard to ligneous plant species diversity because
   1. Certain species rarely grow beyond 10cm dbh
   2. Young-growth forest vegetation is excluded from the assessment.
B. The underestimation of important forest estimates (e.g. basal area, standing volume, forest living biomass, forest carbon stock) in excess of the critical 5% threshold relative to the total. Since these variables cannot be measured directly

in the field but usually are estimated from dimensional measures (dbh, height) the exclusion of small-sized stems leads to an underestimation.

The effect of defining a minimum dbh equal to 10cm on the forest assessments' outcome shall be quantified by contrasting the results resulting from two different minimum diameter requirements. For this purpose two data sets were created. Data set 1 includes all ligneous vegetation dbh≥1cm. Data set excludes small-sized stems, i.e. it only contains trees dbh≥10cm. By reporting the contribution of the ligneous vegetation 1cm ≤ dbh <10cm to basic forest estimates, forest structure, and tree species diversity it shall be assessed if its systematic survey has to be included in forest assessment protocols because it exceeds the 5% significance threshold.

2. Materials and Methods

2.1. Study Area - La Forêt classée de la Mondah

The „Forêt classée de la Mondah“ (Mondah forest) is located on the Central African Atlantic coast to the west of the Congo Basin in the province of Estuaire in the department of Komo-Mondah. It is situated on a peninsula that borders on the Baie de Mondah in the north. Between Cap Esterias in the northwest and Cap Santa Clara in the southwest the land runs along approximately 15 km of frequently indented Atlantic coastline. In the south the Mondah forests are directly adjacent to the urban area of Libreville (Pietsch 2000; Hughes and Hughes 1992).

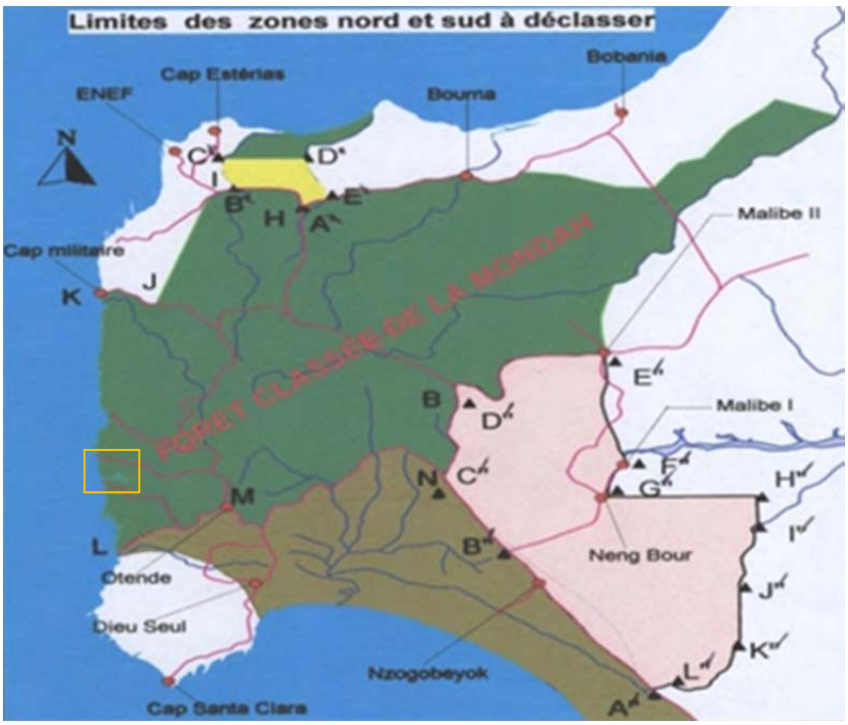

Figure 1: The peninsula Mondah und Forêt classée de la Mondah. Blue = Atlantic Ocean; Yellow = declassified zone, Project Technopôlet (100ha); Rosa = declassified zone (2000ha); Brwon = Project Marina; Dark Green = remaining classified forest area (5206 ha); Red line = road; Blue line = river. yellow rectangle = Location of the study site. Source: Realized and taken from the Laboratoire de Géomatique de L`ENEF, under the direction of Calvin Dikongo Ndjomba - Modified. Scale 1:170 000

2.1.1. Relief and Soil Characteristics

The peninsula of Mondah is located in the northwest of Gabon´s narrow coastal plain that extends from the Atlantic coast along the estuaries and plains of the big rivers towards the interior to the foots of the Cristal Mountains and the Chaillu Massif. The low-lying plain is typified by estuaries and lagoons. The altitude of the coastal plain can vary from 0 to 100 meters above sea level (Gardinier 1992; CIA 2012; Ministere des Eaux et Forets, Gabon 1999). The terrain of Mondah rises steeply from the shallow sandy coast to ridges and plateaus of more than 50m a.s.l. The heavily fragmented relief near the coast of the Mondah

forests is dominated by narrow depressions, bold hillsides and up to 90% sloping cliff lines to the seaside. At the steep coast the thick layer of beige-yellow sandstone, which overlays a limestone basement, becomes visible (Pietsch 2000). Solved iron emerges along cracks in the cliffs and colors the rock brown-red.The soil texture is characterized by sabulous and clayey formations (Ministere des Eaux et Forets, Gabon 1999).
The region is drained by numerous rivers and small watercourses. The good water capacity of the soil, a high groundwater table and numerous depressions with deficient subsurface drainage provide permanent soil wetness. Coarse silt and clay assure sufficient water supply during all seasons even on ridges and more elevated plateaus. Water stress during dry seasons is negligible and has no significant ecological impact on the vegetation. Sufficient water supply allows for continued growth throughout the year. Thus, the forest appears evergreen and humid even at the end of the long dry seasons.

2.1.2. Local Climate

The peninsula of Mondah lies within the equatorial climate zone and possesses a uniformly hot tropical climate and high relative humidities all year round (Gardinier 1992; CIA 2012). Temperature fluctuations are low and vary around 24°C – 27°C.
The local climate is marked by four distinct seasons: two wet seasons and two relatively dry ones of different severity, each one long and one short. The shorter dry interval from December to February is not truly arid but marked by relatively low monthly rainfall with constant precipitation less than 2000mm. The longer dry season from June to September is much more arid with virtually no rain and only interrupted by short heavy rain at its beginning and end. During the wet seasons abundant rainfall occurs and average monthly precipitation is close to 3500mm and especially in the longer ones rainfalls can exceed this level. The annual average precipitation nears 2700mm. Non-permanent insolation due to frequently occurring overclouding guarantees high humidities even during the drier seasons. Thus, relative humidity shows only little fluctuation and remains between 80-88% with evaporation and evapotranspiration rates of 1300mm and 1400mm. Annual insolation amounts to 1400 hours. Average wind velocity is low with 5m/s (Ministere des Eaux et Forets, Gabon 1999).

2.1.3. Vegetation

The Mondah forests belongs to the lower Guinea phytogeographical sub-region and is classified as hygrophilous coastal evergreen Guineo-Congolian equatorial rainforest of the Gabonese-Cameroonian floristic region (Pietsch 2000; Campell et al.*;* Pietsch 2000; Ministere des Eaux et Forets, Gabon 1999). The vegetation of the Gabonese-Cameroonian region is seen as the most species-rich of Africa´s tropical forests. Characterized by a high number of plant- and animal species it is assumed to be one of the most diverse heritages in

the Congo Basin (Cabinet du Président de la République Gabon, s.a.; General Direction of Environment and Nature Protection Gabon 2008). The coastal zone hosts a variety of forest formations and the floristic composition of these forests is regarded as especially rich and variable from place to place. Azonal formations like plantation forests, fallows and secondary forest at different stages of growth are dispersed throughout the coastal region (Nasi 2001; Wasseige et al. 2008; White 1983; Hughes and Hughes 1992; CIA 2012)
Locally difficult to access forest zone with narrow depressions and steep slopes made it possible to preserve some islands of nearly intact forests (Ministere des Eaux et Forets, Gabon 1999).

2.2. Study Site

The study was carried out on the terrain of the l´Aquaferme de Mondah. The parcel covers an area of 50 hectares in size. Beside dense tropical rainforest stands, the terrain encloses approximately 500 m Atlantic coastline and a large freshwater lake that drains to the sea (Figure 1). The forest walks reveal that the terrain of the study site is characterized by drastically changing topographic conditions within a few meters. Depending on the terrain surface the prevalent vegetation varies. The coastline is edged with salinity tolerant (esp. Cocos nucifera and brush vegetation) and littoral forest vegetation. Scattered mangroves can be found at the interface between the Atlantic Ocean or lagoons and land, in brackish water, stagnant water bodies and on inundated and marshy grounds. In these transitional zones between the coastal vegetation and dense forest stands the small spiny palmier (Phoenix reclinata) was recorded, that often appears together with dominant mangrove species (Rizophera Racemosa). The freshwater lake is lined with a belt of dense mangroves. Forests formations typical for periodically inundated and hydromorphic soils was found in wet depressions.

Dense evergreen rainforest vegetation occupies most parts of the study site.
Most plant species are ligneous and exceed the number of herbaceous species (Pietsch 2000; White 1983). The majority of tree species is characterized by slender trunks, branches near the top and often buttresses at the base with increasing stem diameter. Some tree species are cauliflorous. Apart from clearings, the crowns of the understory build a dense cover. The canopy layer is opened, emergents are loosely scattered through the forest. Most of the leaves are dark green and lanceolate or elliptic in shape. Leaf size varies considerably from a few millimeters to more than half a meter (White 1983).
Lianas and vines of different age occur abundantly throughout the forest indicating repeated natural or anthropogenic disturbances. In particular, rattan is rampant and overgrows mature trees of the canopy layer or occupies complete clearances as meters high impenetrable

thicket. Old skidding trails of different age are visible all over the area verifying selective timber harvesting practices.
Numerous huge and partly well-preserved stumps at different stages of organic weathering attest previous exploitations. Based on their wood characteristics some of the stumps could be identified including Douka (Tieghemella Africana) and Moabi (Baillonella toxiperma).
In addition to large tree species inventoried inside the sample plots a variety of tree species reaching huge diameter could be recorded by walking the forest including: one unknown species characterized by a strongly channeled stem, Ehombe, Moubamba rouge (Aneulophus africanus B.), Faro (Daniellia spp.), Londo (botanical nomination unknown), Sorro (Scyphocephallum mannii), Alep (Desbordesia glaucescens), Niové (Staudtia stipitata), and Mbaza (Parkia bicolor).

2.3. Forest Assessment

The forest assessment was carried out at local scale in the forests situated on the l´Aquaferme de Mondah. The terrain occupies 50ha within the Mondah forests.

2.3.1. Sample Plot Establishment

Forest mensuration and data collection was carried out on a total sample area of 1 hectare. Measurements were collected at sample locations, referred to as sample plots or sample points. Numerous plot designs exist in practice but there neither is a standard plot shape nor size (Kleinn and Bhandari 2004). A fundamental distinction is to be drawn between fixed area and variable size plots. Surveys based on fixed area are frequently applied, and for many situations the most practical, efficient and easiest to process sample methods for all kind of forest assessments (Condit 1998; Gordon and Newton 2006; Nzogang 2009; Kleinn and Bhandari 2004). Due to dense understory and consequently, difficult forest access and reduced visibility in regenerating tropical forests the demarcation of squared and rectangular plots proved to be easier (Köhl et al. 2006) and are also recommended to efficiently measure dense stands with small trees and variables associated with small diameter classes (Kangas and Maltamo 2009; Kleinn and Bhandari 2004).
For the purpose of the present forest assessment seven square plots of two different fixed sizes were established within the territory of the L´Aquaferme de Mondah. Each plot was counted as one sample point. The sum of sample points is called the sample.
The site selection for plot establishment was based on previous forest walks and field verification undertaken to investigate the prevalent forest vegetation within the study area. To capture different prevalent forest variations the plots were laid out in a fashion considering topographic and vegetation variations across the sample area. Mangrove forests and other

riverine vegetation formations at the lakeside, swampy and inundated areas and seashore vegetation were considered as distinct forest ecosystems and explicitly excluded from surveying.

The distribution of all seven sample plots throughout the study area is illustrated in Figure 2. Three plots covering each 50m × 50m were established in three locations representing different topographical terrains and thus, forest variations.

Plot 1 (P1) is established in proximity to the coast but does not include salt-tolerant vegetation. The north-west corner of the plot is located at the edge of a valley.

Plot 2 (P2) lies behind the freshwater lake outside the permanently or partially inundated areas. One part of the plot rests on bright plain plateau. On the western border the terrains slopes nearly -40° down to a valley bottom. The northern border runs along a steep gradient, and crosses a ridge before it sharply inclines to another valley. An old skidding road is situated on the ridge.

Plot 3 (P3) represents the interior of the coastal region. The terrain inclines from the eastern to the western border. Inside the plot the stump of a giant Moabi (Baillonella toxisperma) could be identified. Corresponding to the terrain elevation and lightning the vegetation changes within the plot from the eastern to western direction.

In addition, four plots 25m × 25m in size (P4, P5, P6, P7) were located every 75m along a 400m long east-west transect from the coastline to the interior. The course of the transect is described in Figure 2. Number and position of the metering points are given in Annex A, Table 20. The terrain cross section of this transect is drafted in Appendix A, Figure 24.

Plot 4 (P4) is situated on a valley bottom. The valley is oriented east to west, and gives a dark, misty and humid impression.

Plot 5 (P5) is completely situated on the bottom of a long valley, oriented north to south. The valley is characterized by bright lighting conditions, sand emerges on the surface, and signs of temporary surface discharge are visible.

The terrain of Plot 6 (P6) is characterized by the origin of an east to west oriented gorge. The hills of the gorge slope more than 30°. The loose forest stand around the gorge leads to high insolation in parts of the plot. To the south of the plot numerous old trees including Colatier (Cola acuminata), Okoumé (Aucumea kleineana), Dabema (Piptadeniastrum africanum), and Faro (Daniellia spp.) could be found. Three naturally toppled and huge trees further open the dense forest stand and provide increased light incident.

Plot 7 (P7) is located on the first elevated plain behind the coastal strip and adjacent marshy, brackish soils. Approximately one third of the plot is dominated by meters high and tight rattan lianas which repress all other vegetation.

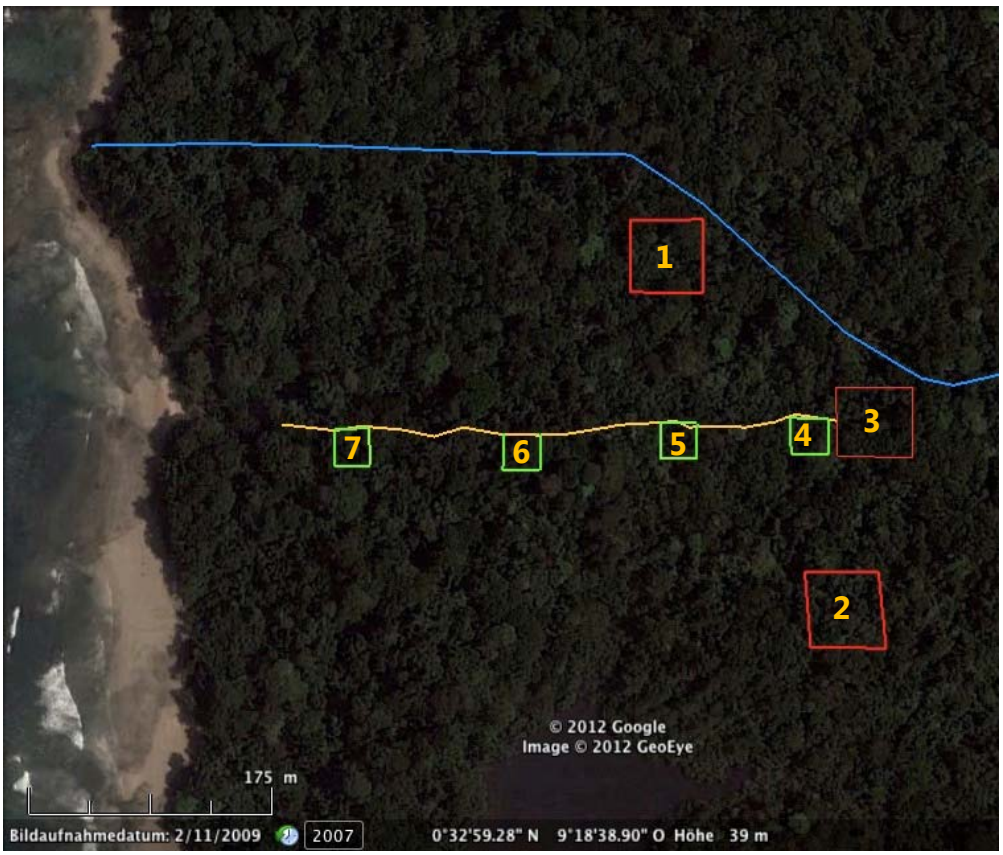

Figure 2: Study Area: L´Aquaferme de Mondah. Blue line = approximate course of a forest road; yellow line = course of the forest transect; red quadrats = 0.25ha plots; green quadrats = 0.0625ha plots. Source: Picture: Google Earth; line and plot positions added by the author based on GPS data.

All plot quadrates were surveyed to the cardinal directions. Surveying of a quadrate started from south-east corner point. Corner stakes were established exactly at each quadrate corner. Quadrate sites were demarcated working from the first corner stake along the cardinal direction to the next corner point. Due to heavy terrain and bad visibility 20 meters is the longest distance that can be accurately surveyed in dense forest (Sunderland et al. 2004). Thus, exact horizontal distance was measured using additional stakes that were placed along the borders of each plot.

These stakes were also used to facilitate general orientation in the field and to determine if an individual is located inside the sample plot (Dallmeier 1992).

2.3.2. Data Collection

Field studies were undertaken with a team of two to six people. The team was built up by at least one local tree finder and one researcher carrying out measurements and data records. The work in the field was divided and allocated depending on manpower availability. Researchers were responsible for planning and conducting forest mensuration and manual data recording in the field.

Tree finders primarily performed tree identification in the field. When necessary they assisted the instrument operator and laborers or carried out data recording.
Principle tasks of the forest laborers included clearing the way through the forest as well as the ground of the sample plots in order to make access, surveying, and mensuration possible.
A professional hand bearing compass (Suunto KB-14) was used to exactly determine the geographic alignment of the plots. The surveying of tree height, surface, horizontal distances and inclination was carried out with the Vertex IV Hypsometer and transponder T3 (Haglöf Sweden).
Measurements were restricted to lively and free standing ligneous vegetation. Lianas were explicitly excluded from the assessment. In the actual phase of regeneration they could be found abundantly throughout the forest. With proceeding regeneration their proportion typically diminishes significantly. Thus, their inclusion in forest analysis is assumed to bias results of estimated forest variables.
The field survey of the present forest assessment is based on the complete census of the sample plots. Sample trees were selected satisfying two criteria: they must be located inside the sample plot and meet the minimum size limit. The minimum size limit was expressed as minimum diameter and minimum height: The assessment protocol includes any ligneous individual in each sample plot with dbh≥1cm at minimum height 1.3 meters.

2.4. Forest Mensuration

Qualitative and quantitative attributes were surveyed for both topography of census plots and ligneous vegetation. Vegetation mensuration and identification began as soon as the sample plots were established and preparation for survey work had been terminated. In order to take measurements of all the ligneous plants that are defined as sample trees the field crew walked the quadrate in approx. 10 meter wide stripes, starting at one of the corner points. Recording was performed in a four-step process: measuring the plant for both dbh and top height, identifying the species, manual recording of data and finally marking the tree with colored spray.
Site-specific data were collected separately for each plot and recorded manually.

2.4.1. Site-Specific Data

To describe the specific site qualities of each census plot several data were collected.
The general hillside exposure (aspect), topographic depressions and the orientation of valleys were determined for each site. The altitude a.s.l. was recorded for quadrate corners and additional metering points along the borderlines. The slope of the relief was measured

along the quadrate borders. Specific factors like old logging roads and skip trails were notated. The collected information was recorded manually in corresponding forms. For a better visualization schematic diagrams of the plots were drafted.

2.4.2. Tree-Specific Data and Characteristics

For each ligneous plant located within the sample pots that met the minimum diameter requirement, the diameter at breast height (dbh), tree height and species were determined and recorded according to the following procedures.

2.4.2.1. Diameter at Breast Height

Diameter at breast height is defined as measurement of a tree's girth standardized at 1.3 meters above ground. During surveying all ligneous plants dbh≥1cm were measured to the nearest millimeter using a caliper for individuals with dbh<2cm and a cloth diameter tape for individuals dbh≥ 2cm. The measurements were taken avoiding any protrusion or lianas growing on the trunk. Vines, moss, loose bark, etc. are to be removed prior to measurement in order to obtain precise and consistent measurements (Dallmeier 1992).

2.4.2.2. Height

All saplings and trees that met the lower diameter and height limit for inclusion were measured for total height. Total height for the purpose of this study is defined as the vertical distance between the base of the stem and the topmost tip of the tree (Köhl et al. 2006). Measurements were recorded to the nearest decimeter. Broken tops were notated.

2.4.2.3. Species Identification and Characteristics

Individual trees were identified in the field. Species identification was accomplished through terrestrial survey and conducted by one or two native tree finders. Native tree finders are often only familiar with local names of tree species, respectively species were predominantly identified in the local languages Nzebi, Bakota, Benga and Fang. In some cases the tree´s pilot name was known. A systematic collection of herbarium vouchers was not carried out. For tree identification morphological and anatomical characteristics were employed (leaves, bark, roots, fruits, resin). Beside visual characteristics the tree finders identify a tree by tasting, smelling and feeling it. Most of the species could be identified directly in the field. Only in few cases field identification was not possible. In these instances leaf and bark samples were taken to experienced elderly who possess an astonishing knowledge of the species.

Species were recorded in a sheet, listing their local appellations and when ascertainable their common pilot and botanical species names.

In addition to the species name further remarkable characteristics were recorded, e.g. use of tree components for subsistence or medical purposes, exceptional attributes, noticeable form and color of bark and leaves, cognation to other trees.
If known botanical species identification was derived from common pilot names. Botanical species identification derived from local tree names is a difficult and iterative process of research. Astonishing collections of Central African tropical vegetation in numerous local languages in combination with a multitude of plant descriptions can be found in the works of (Wilks and Issembé 2000; Walker and Sillans 1961). Together with different databases, translation lists of former inventories and vegetation studies in the Congo Basin these two works serve as basis for the translation. Thus, numerous trees were identified using the local species names together with characterizing features.

2.5. Data Clearing and Gap Filling

Gaps or faults in existing data records were to be filled or cleared.
Faulty data were identified using the tree-specific Height/Diameter ratio (H/D value). Each Height-Diameter pair exhibiting H/D>5 and H/D<0.5 was checked for plausibility. Absent or suspicious height and diameter values were corrected using the species-specific height diameter relationship. For each species, represented by a reasonable number of individuals, a species-specific height curve (two parameter log model) was calculated using the equation:

$$\boldsymbol{y = a * ln(x) + b} \qquad (1)$$

Where y = total tree height, x = diameter at breast height, and a and b = constant model parameters estimated using regression analysis. Based on the species-specific height curves missing or faulty height records could directly be extrapolated.

Absent or suspicious diameter data were computed with the reverse growth function:

$$\boldsymbol{x = e^{\frac{(y-b)}{a}}} \qquad (2)$$

Where x = diameter at breast height, y = total tree height, and a and b constant model parameters equal to the parameters used above.
In cases where no meaningful species-specific height diameter relationship could be established missing values were replaced using the general growth equation estimated calculated for the forest stand under investigation. Evidently forgotten comma in the data were added during data digitalization.
Out of 3649 recorded trees, the data of 201 trees were incomplete due to missing or false values of either dbh or tree height. Respectively, missing data was completed and suspicious

values corrected for 5.5 % of all surveyed individuals. In sum, unquoted comma account for 1% of the entire data set. Broken tops were recorded for 76 trees and respectively, 2% of all individuals.
Non-uniform and arbitrary orthography of species names in local languages must be standardized. In cases where no official or common diction of the species' name could be found the nomenclature and spelling was defined by the research team. For data analysis each species was recorded by a code combining the standardized notation ("working title") and sequence number. The "working title" serves as coding and does not necessarily coincide with common or established spelling.

2.6. Data Analysis

Principle component of the analysis was the partitioning of data into two data sets: In order to investigate the contribution of small trees to forest characteristics, stand structure and woody plant species diversity in place the complete data set including all ligneous vegetation with dbh≥1cm was portioned into two data sets, herein after referred to as "data set 1" and "data set 2". Data set 1 comprises all inventoried woody vegetation that meets the minimum diameter requirement of dbh≥1cm. Data set 2 excludes small trees and only contains trees with dbh≥10cm. The data analysis was carried out separately for both data sets.
Forest parameters of interest were estimated for both single individuals and on aggregated levels. Since diameter and height were measured on every individual located within the sample plots, associated cross sectional area, standing volume, biomass and carbon content were estimated for each woody plant. These values were aggregated for further analysis. Here, aggregation is understood as the combination of individuals into groups based on particular characteristics in order to obtain aggregate level estimates of the forest characteristics of interest. Trees were grouped by demographics (diameter classes, height classes) and species/families.
The aggregation by demographics combines plant individuals of similar sizes for data summaries. Aggregation by diameter is probably the most common method of aggregation and in the present context used to analyze the horizontal stand structure of the forest stand. For that purpose all trees of data set 1 (dbh<1cm) and data set 2 (dbh<10cm) were grouped into 10 cm diameter classes. Additionally the resolution of the smallest diameter class of data set 1 (dbh<10cm) was refined into 1cm diameter classes.
Combination of trees by height class was carried out to investigate the vertical stand structure of the forest stand. Two schedules of height classes were developed: The first schedule grouped the stand into two meter height classes. Thereafter, the second schedule was developed dividing the forest stand into height classes that represent the vertical stand

zonation (understory-, intermediate- and, overstory layer including emergent trees). The aggregation of data by species and families was used to investigate stand species structure and single species importance.
Where necessary, values were scaled to the common unit of one hectare. Mean values were calculated on the level of sample units or the complete sample area of one hectare.
The state of the forest under analysis is evaluated and discussed on the basis of data given in literature. Since the values and data given in literature are commonly only valid for trees dbh≥10cm, the comparison of the study site in the Mondah forest with literature is based on the data of data set 2 (dbh≥10cm). Thus, when no further specifications are given, the comparison includes trees dbh≥10cm and all findings are standardized to the area of one hectare.

2.7. Forest Stand Characteristics

2.7.1. Number of Individuals

The number of individuals was counted per hectare on the entire sample area, each sample unit and for all aggregation groups (species, diameter- and height classes). It is considered as an important component to compare structure and diversity of different samples or assessments.
The stand density can be expressed in terms of stem count, volume, or biomass per unit area (Köhl et al. 2006). In tropical forest stands stem count per unit is considered to provide an informative estimate of density (Köhl et al. 2006). In the context of this study, the number of individuals is referred to as density/hectare if the number of stems is used as structural parameter. The terms stand density and stem density are used as equivalents.
Further, the number of individuals per species can be used as basic diversity measurement. In this context the number of individuals is referred to as abundance.

2.7.2. Number of Species

The number of species serves as an important parameter for numerous structural and diverse analysis components. The total number of species was determined for data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm), species occurrence and distribution was investigated across the diameter and height classes of each set. Family structure was analyzed counting the number of species and species abundance of botanically identified species per family. Proportional species estimations were computed for forest variables under investigation described below (e.g. the percentage of abundant species that provide 50% of total standing volume in relation to total species).

2.7.3. Diameter and Height

In order to compare the present stand data with other forest assessment carried out in the region both arithmetic and quadratic mean values were calculated for the forest stand under investigation.

In addition, the mean height of Lorey was calculated because in contrast to the arithmetic and quadratic mean values it weights the contribution of trees to the stand height by their basal area:

$$\boldsymbol{H_L = \frac{\sum g*h}{\sum g}} \qquad (3)$$

Lorey's mean height is estimated multiplying the tree height (h) by its basal area (g), and then dividing the sum of this calculation by the total stand basal area.

The diameter height relationship was modeled for the forest stand based on the data of all surveyed trees. Species-specific height diameter relationships were investigated and mapped for each species represented by a reasonable number of individuals. Trees with broken tops were excluded from the investigation. Stand as well as species-specific height curves were estimated assuming a logarithmic/concave growth model described by equation 4:

$$\boldsymbol{y = a * ln(x) + b} \qquad (4)$$

Where y = total tree height, x = diameter at breast height, and a and b = constant model parameters estimated using regression analysis.

All height diameter relationships under investigation were graphically illustrated in scatter plots of tree height against corresponding tree diameter. Based on the height diameter relationship the stand height curve as well as species-specific height curves were estimated.

2.7.4. Cross Sectional Area

The cross sectional area (basal area) of a tree is defined as the area it covers in its cross section at breast height (Köhl et al. 2006). For model calculation the basal area is assumed to be a circular. Consequently, it can be directly estimated from the dbh of any individual tree. The estimated area is given in square meters. The individual tree basal area was computed for every individual according to equation 5:

$$\boldsymbol{ba_i = \pi \frac{dbh^2}{4}} \qquad (5)$$

Where dbh = diameter of breast height of a tree.

The total stand basal area per hectare (BA) was calculated as the sum of individual basal area (ba_i):

$$\boldsymbol{BA = \sum ba_i} \quad (6)$$

2.7.5. Standing Volume

Volume is usually estimated for standing trees and expressed quantitatively as a function of diameter at breast height. For the scope of this work it is defined as the above-stump volume of all trees alive (dbh≥1cm), measured over-bark to the tree top height excepting branches (Garzuglia and Saket 2003). Standing volume is used as input variable for further estimations such as biomass and carbon content. For the purpose of the present study above, standing volume (compact wood over 7cm at the smaller end) of free standing living ligneous plants was estimated for every recorded individual. The estimated volume is given in cubic meters.

The tree shape essentially influences the standing volume of each tree. In order to estimate the volume of a tree its form is described by a theoretical solid, often a cylinder. Since the true shape of a tree does not correspond to the cylinder a form factor is needed defining the relationship between the stem volume and the cylinder. The timber form factor (f) for the present analysis was set at 0.6 (Channell 1984). Respectively, above stump volume of every tree was estimated according to the formula:

$$\boldsymbol{sv_i = ba_i * h * f} \quad (7)$$

Where ba_i = Basal area of a tree, h = total height of a tree and f = 0.6.

The total volume over 7cm at the smaller end per hectare was the sum of tree-specific standing volume:

$$\boldsymbol{SV = \sum sv_i} \quad (8)$$

2.7.6. Living Biomass

Here, biomass refers to above ground woody biomass of ligneous plants and trees with dbh≥1cm and is defined as the total amount of above ground living organic matter expressed as oven dry kg (biomass) or oven dry kg per unit area (biomass density) (Brown 1997; Garzuglia and Saket 2003). Biomass can be expressed as a function of tree dimensions (diameter and height) or as function of stand level variables such as basal area or volume. It is referred to as biomass when given on the level of individual plants or biomass density when given as mass per unit area (Brown 1997).

Biomass of the forest stand under investigation was calculated using field data. Since the primary data refer to individual trees, corresponding biomass was calculated for each individual and summed up to biomass density for the sample area. Estimates were derived from volume data and calculated for each tree multiplying the individual´s volume by the species wood density (WD) (Garzuglia and Saket 2003) according to the formula (Gautam and Pietsch 2012):

$$\boldsymbol{agb_i = sv_i \times WD_{0\%}} \quad (9)$$

Where agb_i = above ground biomass in kg per individual, SV_i = individual standing volume, and $WD_{0\%}$ = species-specific wood density at 0% moisture content. The above ground biomass density per hectare was calculated as the total sum of agb_i:

$$\boldsymbol{AGB = \sum agb_i} \quad (10)$$

The total biomass density per hectare was calculated as sum of above and below ground biomass:

$$\boldsymbol{TB = AGB + BGB} \quad (11)$$

Where TB = Total biomass, AGB = above ground biomass and BGB = below ground biomass. The below ground biomass was estimated according to Saachi et al. (2011) as a function of the above ground biomass (equation 12):

$$\boldsymbol{BGB = 0.489 AGB^{0.89}} \quad (12)$$

Where BGB = below ground biomass and AGB = above ground biomass.

Species-specific wood density in kg/m^3 was derived from literature and existing databases. Wherever applicable species-specific oven-dry wood density at 0% moisture content ($WD_{0\%}$) was taken. When wood density was given at 12% moisture content ($WD_{12\%}$) wood density at 0% moisture content of corresponding tree species was calculated according to the following formula (Kollmann et al. 1968):

$$\boldsymbol{WD_{0\%} = WD_{mc} \times \left[100 + \left(\frac{VS}{30} \times mc\right)\right] \times \frac{1}{(100+mc)}} \quad (13)$$

Where Ni = number of individuals in ith species, WD_{mc} = wood density (kg m^3) at moisture content (mc%), mc = moisture content in wood, and VS = volumetric shrinkage of the species.

Missing data were replaced by a weighted mean wood density based on known species. The weighted mean wood density (WD_{avg}) was estimated separately for each sample plot according to the formula (Gautam and Pietsch 2012):

$$\boldsymbol{WD_{avg}} = \frac{\sum \boldsymbol{N_i \rho_i}}{\sum \boldsymbol{N_i}} \qquad (14)$$

Where N_i = number of individuals in i^{th} species and ρ_i = wood density of i^{th} species. The calculated value was assigned to all individuals of the corresponding plot for which species-specific data were not available.

2.7.7. Tree Carbon Content and Forest Carbon Stock

For the purpose of the present analysis the above ground carbon content of living ligneous vegetation was calculated for each individual dbh≥1cm. The evaluation of growing carbon stock was based on plant-specific biomass estimation computed beforehand by multiplying plant-specific biomass (oven-dry) with species-specific wood carbon content (Magnussen and Reed 2004) according to the formula (Gautam and Pietsch 2012):

$$\boldsymbol{abc_i} = \frac{(\boldsymbol{abg_i} \times \boldsymbol{C})}{\boldsymbol{100}} \qquad (15)$$

Where AGC = above ground carbon content of living woody vegetation, AGB = above ground biomass (oven-dry)(kg), and C = species-specific wood carbon fraction (%). The forest carbon stock per hectare was calculated as sum of tree individual carbon contents:

$$\boldsymbol{ABC} = \sum \boldsymbol{abc_i} \qquad (16)$$

Whenever available species-specific wood carbon fraction (C%) was derived from previous investigations of forest stands in Gabon (Gautam and Pietsch 2012). Missing values were replaced by a weighted mean wood carbon content derived from known species. The weighted mean carbon fraction (Cavg) was estimated separately for each sample plot according to the formula (Gautam and Pietsch 2012):

$$\boldsymbol{C_{avg}} = \frac{\sum \boldsymbol{N_i C_i}}{\sum \boldsymbol{N_i}} \qquad (17)$$

Where Ni = number of individuals in ith species, and Ci = wood carbon fraction of ith species. The calculated value was assigned to all individuals of the corresponding plot for which species-specific data were not available.

2.8. Biodiversity and Diversity Assessment

2.8.1. Diversity Assessment

For the purpose of this study the assessment of the biological diversity in place is restricted to the living woody vegetation dbh≥1cm, exempt from lianas and other vines. The assessment of biological diversity is divided into the analysis of inventory diversity on the one hand and turnover diversity on the other hand.
Inventory diversity is a quantitative characterization of a defined spatial unit and can respectively be expressed in discrete terms, i.e. number of species (Beierkuhnlein 2003) while turnover diversity is a qualitative measure of change assessing directly the compositional similarity between a number of samples (Jost 2007). It refers to the type and not to the number of species that can be found within two different spatial units.
It will increase in heterogeneous regions, in which few species are shared by single sample units, and decline in homogenous ones where the species´ composition of sample units is more or less identical (Magurran 2004).
Inventory diversity is reported as sample species richness for data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm). Turnover diversity is analyzed on the level of pattern diversity, i.e. the variability in the composition of species between point samples within the sample area (Gray 2000; Beierkuhnlein 2003). For further detail see chapter 1.5.

2.8.2. Measuring Inventory Diversity

In chapter 1.5, inventory diversity is defind as tree species diversity found within the study area. Inventory diversity statistics is divided into two subcategories of measurements: species richness measures and heterogeneity measures (Magurran 2004).
On the most elementary level biological inventory diversity is equated with the number of species (species richness) within a defined study area (Gray 2000).
A diversity index is a single statistic that combines richness and evenness components (Magurran 2004). Diversity parameters generated by such indices are information tools, summarizing data to provide additional information on proportional species abundance and distribution (Köhl et al. 2006; Gray 2000) No index exists that perfectly captures all components of biological diversity but different groups of indices measuring different aspects of diversity – for that reason six indices are used here emphasizing different components of inventory diversity.
Below a brief overview of the indices used for analysis of forest inventory diversity is given.

2.8.2.1. Heterogeneity Measures of Inventory Diversity

Fisher´s alpha (α): Fisher´s alpha is a parametric diversity measure of the log series model investigating the relationship between the number of species and the number of individuals in those species. Single prerequisite for the application is that species abundance data have the form of discrete numbers of individuals.
According to Magurran (2004) α can be obtained from the equation 18 (Magurran 2004):

$$\boldsymbol{\alpha = N(1 - x)x} \qquad (18)$$

x can be estimated from the iterative solution of:

$$\boldsymbol{\frac{S}{N} = \left[\frac{(1-x)}{x}\right] \times [-ln(1 - x)]} \qquad (19)$$

Where N = total number of individuals and S = total number of species.

Shannon (H´): The Shannon index assesses the diversity of an assemblage based on the relation of abundance and dominance of species taking into account the number of individuals as well as the number of taxa. The nonparametric index has its origins in information theory and is sometimes referred to as Shannon entropy. As a heterogeneity measure the index assesses the degree of evenness in species abundance using the formula (Magurran 2004):

$$\boldsymbol{H` = -\sum p_i \, log \, p_i} \qquad (20)$$

Where p_i = the proportion of individuals found in the i^{th} species. The true value of p_i is assumed to be unknown and therefore computed by the maximum likelihood estimator n_i/N, where n_i is the number of individuals of the i^{th} species and N the total number of individuals found in the study area. For reasons of computational simplicity the natural logarithm (log_e, equivalent to ln) is often used. The natural logarithm is assumed to be ecologically just as valid as other log formations.
The maximum value that can be obtained for an assemblage under consideration if all species are equally distributed is given by H_{max} (see equation 25) (Magurran 2004).

2.8.2.2. Dominance Measures of Inventory Diversity

Diversity measures emphasizing dominance use the richness of species as indicator for the diversity of the study site. Widely known indices are those of Berger-Parker and Simpson.
Berger-Parker (d'): The Berger-Parker index expresses the relative importance of the most abundant species in the sample as the ratio of the number of individuals to the most

abundant species (N_{max}) and the total number of individuals (N). The formula is given in Magurran (2004) as follows:

$$\boldsymbol{d' = \frac{N_{max}}{N}} \quad (21)$$

The reciprocal (1/d) is used to describe an increase in diversity, i.e. decreasing dominance, with an increase in the index value.

Simpson (D): The index calculates the probability of any two individuals drawn at random from an infinite large community belonging to the same species using the equation (Magurran 2004):

$$\boldsymbol{D = \sum p_i^2} \quad (22)$$

Where p_i represents the proportion of individuals in the i^{th} species.

In order to assess finite communities the index can be modified to (Magurran 2004):

$$\boldsymbol{D = \left[\frac{n_i(n_i-1)}{N(n-1)}\right]} \quad (23)$$

Where n_i = number of individuals in the ith species and N = total number of individuals.

2.8.2.3. Evenness Measures for Inventory Diversity

Evenness measures aim to assess the difference of the observed pattern from the expected pattern in a hypothetical assemblage (Magurran 2004). This study uses the Shannon-Evenness (J´) as measure of species equitability in a community. The index is normalized to the maximum diversity that could possibly occur within an assemblage H_{max}. Variations of the equation to estimate the Shannon Evenness exist in literature. Here the formula given by Magurran (2004) is used:

$$\boldsymbol{J` = \frac{H`}{H_{max}}} \quad (24)$$

H_{max} is calculated from:

$$\boldsymbol{H_{max} = ln(S)} \quad (25)$$

Where S = the total number of species found in the sample.

2.8.2.4. Rare Species

To quantify the number and proportion of rare and extremely rare species, species solely represented by a single (singleton) or two (doubleton) individuals were counted.

Their proportion in relation to species found in the study area were estimated with the formulas:

$$\boldsymbol{R_{sing}} = (\frac{\boldsymbol{S_{sing}}}{\boldsymbol{S}}) \times \mathbf{100} \quad (26)$$

and

$$\boldsymbol{R_{doub}} = (\frac{\boldsymbol{S_{doub}}}{\boldsymbol{S}}) \times \mathbf{100} \quad (27)$$

Where S_{sing} / S_{doub} = number of species represented with one / two individuals and S = total number of species.

2.8.3. Measuring Turnover Diversity

In chapter 1.5 turnover diversity is defined as a measure analyzing species replacement or change in species composition between sample points along temporal or spatial environmental gradients. The indices developed for the measurement of species turnover can be divided into three categories:
The first category comprises measures that investigate differences in species richness between spatial units in relation to the total species richness of the study area (Magurran 2004). The second category entails indices that analyze changes in species composition amongst spatial units and thereby evaluate biotic distinctness. They are defined as measures for similarity/dissimilarity, or complementary measures (Magurran 2004). The third category examines the species-area relationship and evaluate species turnover in relation to species accumulation of the area. The last category will be excluded from the analysis of this study.

2.8.3.1. Proportional Species Richness of single spatial Units

Measures of species turnover that relates the species richness of single spatial units to the total species richness of the study are perhaps the best known and sometimes explicitly suggested as measures for between habitat diversity. Whittaker´s original measure of beta diversity (β_w) belongs to this category (Magurran 2004). Because of its simplicity, publicity and solid performance it will be applied here to assess the species turnover across the sample site as a whole. According to Gray (2000) β_w can be calculated from the formula:

$$\boldsymbol{\beta_W} = \frac{\boldsymbol{\gamma}}{(\boldsymbol{\alpha})} \quad (28)$$

Where γ = the total number of species in the surveyed system (i.e. γ diversity) (Magurran 2004) and α is the number of species in a sample unit.

Since there is usually more than one measurement of point diversity, it is sensible to use the mean point diversity for the estimation of β_w of the complete sample (Gray 2000).

2.8.3.2. Assessment of Complementarity between single Sample Plots

Complementarity in that sense refers to the difference of spatial units in terms of the species they contain (Magurran 2004). Similarity indices can be used to assess similarities/dissimilarities, and respectively, complementarity between sites. The more complementary two sites are, the higher is their turnover diversity. The indices of Sørensen and Jaccard estimate the similarity between two sites in consideration of species composition (inventory diversity) of single sample points that are to compare. Subtracting the estimated value from 1 (i.e. $1 - C_J$; $1 - C_S$) modify both indices into intuitively meaningful diversity measure. A low value then indicates a decrease in diversity.
The Jaccard similarity index can be computed according to the following equation (Magurran 2004):

$$\boldsymbol{C_J = \frac{a}{a+b+c}} \qquad (29)$$

Where a = the total number of species found in both sample units, b = the number of species only found in sample unit 1, and c = the number of species only found in sample unit 2. The transformation of the Jaccard index to its complement is the equivalent of the Marczewski-Steinhaus measure of complementarity (Magurran 2004):

$$\boldsymbol{C_{MS} = 1 - \frac{a}{a+b+c}} \qquad (30)$$

In addition to the Jaccard or Marczewski-Steinhaus index as simple measure for similarity, the Sørensen similarity index is assumed to emphasize the proportion of shared species between to sample units.
It can be calculated from the equation (Magurran 2004):

$$\boldsymbol{C_S = \frac{2a}{(2a+b+c)}} \qquad (31)$$

Where a = the total number of species recorded in both sample units, b = the number of species present only in sample unit 1, and c = the number of species present only in sample unit 2.

In the 1950s Bray and Curtis developed a modified version of the Sørensen index based on quantitative data. It can be calculated from the equation (Magurran 2004):

$$\boldsymbol{C_N = \frac{2jN}{(Na+Nb)}} \qquad (32)$$

Where Na = the total number of individuals present in sample unit 1, Nb = the total number of individuals present in sample unit 2, and jN = sum of the lower of the two species abundances found in both sites. That is, when a species can be found in sample unit 1 and sample unit 2, the lower sum of individuals of this species shared by both sample units would be used to calculate jN. By doing so, the effective number of individuals that represent a particular species is included in the assessment of turnover diversity. As its predecessor the index produces high values for similar and respectively, less diverse, samples. To reflect an increase in differentiation diversity with an increase in the index value the index´ complement ($1\text{-}C_N$) should be used.

Derived from Simpson Lennon et al. introduce a new turnover measure β_{sim} in 2001. In contrast to the former indices, this index should capture the assumption that turnover is high when the proportion of species shared between two sample points is low and the proportion of loss and gain from one to the other is similar (Magurran 2004; Koleff et al. 2003). Koleff (2003) gives the formula as follows:

$$\boldsymbol{\beta_{sim} = 1 - \left(\frac{a}{a+min(b,c)}\right)} \qquad (33)$$

Where a = the total number of species represent in both sample units, b = the number of species in sample unit 1, and c = the number of species in sample unit 2.

This index reflects gain and loss, taking into account differences caused by unequal species numbers (Magurran 2004; Koleff et al. 2003). Any difference in species richness inflates either b or c. By using the smallest of these two values in the denominator, the impact of imbalances in species richness should be reduced.

3. Results

3.1. State of a tropical Exploitation Forest after 40 Years of Regeneration

In order to evaluate the present state of the forest, the assessment results produced by data analysis were analyzed and set in relation to data given in literature. Since the values given in literature are commonly only valid for trees dbh≥10cm, the comparison of the present study site with literature is based on data set 2 that only includes trees with dbh≥10cm. When no further specifications are given all findings are standardized to the area of one hectare.

3.1.1. Key Forest Characteristics and Estimates

Table 2 describes the assessment results of the key forest characteristics under examination for data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm).

Table 2: Key forest characteristics and estimates of data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm)

Forest characteristics			**Data set 1**	**Data set 2**
Surveyed parameters	**Equation**	**Unit**		
Stand Density (abundance)		stems/ha	3649	486
Species		nr/ha	151	85
Diameter sum		cm/ha	23772.9	11539.2
Mean diameter		cm	6.5	23.7
Mean quadratic diameter		cm	11.85	30.49
Mean height		m	6.9	15.8
Mean quadratic height		m	8.64	17.79
Lorey´s height	(3)	m	26	28.5
Estimated variables				
Stand basal area	(6)	m^2/ha	40.23	35.49
Total volume	(8)	m^3/ha	628.35	607.98
Above ground biomass	(10)	kg/ha	356463.76	343703.15
Below ground biomass	(12)	kg/ha	46214.53	44739.2
Total biomass	(11)	kg/ha	402678.29	388442.35
Above ground carbon stock	(16)	kg/ha	170269.59	164254.64

Since the size of all sample plots add up to one hectare, the stand density per hectare equals the total number of trees (abundance) found in the sample area. The stem density per hectare decreased rapidly with increasing tree size. It adds up to 3649 stems/ha dbh≥1cm, declines to 486 stems/ha with dbh≥10cm, further drops down to 108 stems/ha dbh≥30cm dbh and solely counts for 25 stems/ ha that grow beyond 60 cm dbh (general minimum ripeness for cutting in Gabon).

Globally, tree densities in tropical rainforest vary from 300 to 1000 stems (dbh≥10cm) per hectare.Tropical African forests tend to range on the lower end of the scale and typically exhibit stem densities between 300 to 600 trees per hectare (Corlett and Primack 2011).

When stems dbh≥1cm are included into consideration the stand density potentially counts up to 10 times more compared to the number of stems dbh≥10cm/ha (Pietsch 2000). The forests of Mondah comply with the range given for mature tropical African forests in literature: The study site hosts 486 stems dbh≥10cm/ha. When individuals with dbh≥1cm are included into analysis the stem density per hectare is nearly eight times higher and consequently, fits to the range introduced above.

Analogous to the tree density the stand basal area/ha and total volume/ha declines when only larger diameter are considered in analysis. Table 3 gives the mean stand basal area/ha, mean tree density/ha and the mean diameter/ha calculated for different vegetation assessment sites in Gabon. It illustrates that the tree density of stems dbh≥10cm/ha found in Mondah is comparable to other primary or mature forests in Gabon. Among the vegetation assessment included into comparison only the forest sites in the Mbé National Park, Cristal Mountains had clearly more trees dbh≥10cm/ha than the Mondah forest (see Table 3). All other study sites under comparison exhibit lower stem densities. Similar findings are made in regard to the stand mean diameter/ha. Only the primary forest in Makokou exhibits a higher quadratic mean diameter than the present study area in Mondah. Even the mean diameter determined for the mature forests situated in the Mbé National Park near the Mondah forests ranks 1cm below these of the Mondah forests.

Table 3: Comparison of Mean Basal Area (m^2/ha). Stem density/ha and Mean Diameter of four study sites in Gabon. Data are taken from: (Pietsch 2000; Balinga 2006; Sunderland et al. 2004; Sassen and Wan 2006). [1]including lianas; [2] arithmetic mean; [3] calculated from the mean values given by the authors

Study Site	**Mean Basal Area (m^2/ha)**	**Average Stem density/ha**	**Mean Diameter (cm)**
Mondah Forest (1993)	29.71	485	27.9 (22.3)[2]
Mondah Forest (2011)	35.49	486	30.49 (23.7)[2]
Waka National Park	33.0	413	28.71
Mbé National Park (old)	37.34	539	29.48
Gamba Complex	38.0[1,3]	467[3]	
Rabi-Toucan (disturbed)	32.67[1,3]	445[3]	
Loango	44.5[1,3]	489[3]	
Moukalaba-Doudou (old)	41.0[1,3]	487[3]	
Mokokou Primary Forest	39.56[3]	384[3]	31.01[3]
Makokou Secondary Forest	18.34[3]	263[3]	24.81[3]

The stand basal area/ha occupied by all trees dbh≥10cm recorded on the present study site in the Mondah forests ranks above the once of other secondary or disturbed forest stands in the region. At the same time the forest of the study site exhibits a lower mean basal area than less disturbed or primary forests in Gabon (Table 3).

The above ground biomass was calculated for each tree from its individual standing volume and species-specific wood density at 0% moisture content (see equation 9).
Species-specific wood density could be determined from literature for 53 species represented by 1980 individuals (see Annex B, Table 21).
The values of species-specific wood density derived from literature vary from 211 kg/m^3 to 975 kg/m^3 at 0% moisture content. The overall mean specific wood density including all individuals dbh≥1cm was calculated as 617 kg/m^3 at 0% moisture content. The plot-specific weighted average mean densities including all individuals dbh≥1cm range between 592 kg/m^3 and 714 kg/m^3 at 0% moisture content (see Table 4). These values are consistent with the specifications in literature, which defines mean wood density of African forest stands at 561 kg/m3 with variations between 500 kg/m^3 und 790 kg/m^3 (Brown 1997; Garzuglia and Saket 2003).

Table 4: Plot-specific weighted average mean wood density (kg/m^3) and plot-specific weighted average above ground carbon fraction (%)

Plot	WD_{avg}(kg)	C_{avg}(%)
P1	608	46.67
P2	633	47.17
P3	592	48.89
P4	640	48.65
P5	714	46.65
P6	630	46.61
P7	684	47.32

The sum of the tree-specific above ground biomass (agb_i) adds up to the above ground biomass density per hectare (AGB/ha). The below ground biomass density per hectare (BLB/ha) was calculated as fraction of the AGB/ha (see equation 12). The total living biomass density density per hectare (TLB/ha) is composed of the above and below ground biomass density/ha (see equation11).
According to Brown (1997) the average above ground biomass density in Gabon amounts to 339000 kg/ha in disturbed forest stands and to 375000 kg/ha in undisturbed forests. The above ground biomass density including all trees dbh≥1cm in the study site amounts to 356463.76 kg/ha. This value ranks in the middle of the range between undisturbed and disturbed forest biomass density estimates. The above ground biomass density for stems dbh≥10cm was calculated as 343703.15 kg/ha and thus, comes close to Brown´s estimate for disturbed forests.

According to Saatchi et al. (2011) only a few regions on earth exhibit above ground biomass densities greater than 350000 kg/ha. The results reveal that the region of Mondah and the forests of the study site are characterized by such high above ground biomass densities and consequently, can be accounted to the highest biomass class found on earth.

The above ground Carbon Content of each tree (abc_i) was calculated from tree-specific above ground biomass (abg_i) and species-specific carbon fraction (see equation 15). The species-specific carbon fraction could be derived from literature for 24 species represented by 958 individuals (see Annex A, Table 21). Magnussen and Reed (2004) assumed that the carbon fraction of oven dry biomass at 0% moisture content is relatively constant and typically ranges between 45% and 50%. The specific values found for the species represented in Mondah correspond to this assumption, i.e. the species-specific carbon fraction of oven dry biomass at 0% moisture content calculated for the species represented in Mondah varies betweem 45.14% to 49.67%.
The calculated plot specific weighted average mean carbon fraction varies in a narrow range between 46.61% and 48.89% (see Table 4).
The sum of tree specific carbon content (abc_i) adds up to the above ground carbon stock per hectare (ABC/ha) (see equation 16).
The carbon stock of the study site stored in the living above ground biomass of all trees dbh≥10cm is calculated at 164t/ha (Table 2). This value increases to 170t/ha when all stems dbh≥1cm are included into the assessment. In order to compare the carbon stock of the study site with reference values given in literature the total biomass carbon stock was calculated as the sum of the carbon fraction stored in above and below ground biomass (equation 11). For that purpose, the total biomass carbon stock is estimated as 50% of the total biomass given in Table 2 (Saatchi et al. 2011). According to this estimation the biomass carbon density in the study site equates 192t/ha when all trees dbh≥10cm are considered. Due to its potentially high living biomass densities the forest of Mondah are assumed to store on average between 200 t/ha and 250t/ha of carbon in its living biomass. Both, the several hundred years old forest stands and the prevalence of the fast growing tree species Okoumé contribute to this high potential (Saatchi et al. 2011; Valla Finch 2011).Thus, at the present stage the biomass carbon density estimated for the present study site remains below its local potential (Saatchi et al. 2011).

3.1.2. Stand Structure

3.1.2.1. Tree-Species and -Family Structure

In data set 1 (dbh≥1cm), a total of 151 species represented by 3649 individuals were identified and recorded in local languages. In data set 1 the botanical identification was possible for 61 species (40% of all species). In data set 2 (dbh≥10cm), a total of 86 species represented by 486 individuals were identified and recorded in local languages. In data set 2 the botanical identification was possible for 44 species (50% of all species). The complete lists of binominal species names for data set 1 and data set 2 are given in Annex B, Table 24 and Annex B, Table 25. In data set 1 (dbh≥1cm), the botanically identified species were assigned to 31 families. In data set 2 (dbh≥10cm), the botanically identified species were assigned to 26 families.

Based on the botanically identified tree species Table 5 outlines the family structure found in data set 1 and data set 2. It is worth noting that the figures illustrated below will definitely both rise and change when voucher specimens are used for botanical species identification. In general, the results regarding family composition and importance in terms of species abundance carried out for the present assessment is consistent with the literature and findings of other regional forest assessments in Gabon.

According to Gentry (1988) Rubinaceae, Euphorbiacea, and Annonaceae are among the most specious families in tropical forests; Moraceae, Sapotaceae, Myristecaceae, and Meliaceae are supposed to be other species rich families. Except for Rubinaceae and Meliaceae (both only represented by one botanically identified species and few individuals) and Moraceae (only recorded in data set 1) the findings of Mondah are consistent with Gentry (1988). Further, Gentry found that Ebenaceae virtually almost always occurs in Africa rainforest stands and can belong to the most specious families. This is especially true regarding the results of the present study. Olaceae, Sapindaceae and Stericuliaceae are identified as other important species in African forests (Gentry 1988). All these three families could be recorded in the Mondah forest. In this context Stericuliaceae takes a special position. While it is only represented by one botanically identified species, it is the most abundant family found in data set 1 (578 individuals) and the second abundant in data set 2 (43 individuals ≥ 10cm dbh).

The preliminary vegetation assessments carried out in the Mbé National Park, Monts de Cristal in 2004 (Sunderland et al. 2004) and the Waka National Park (Balinga 2006) verify Gentry's categorization (Gentry 1988). Their ranking in regard to the number of species per family is given as follows:

The most species rich families in Waka in rank and order are Euphorbiaeae, Caesalpiniacesae, Annonaceae, Rubiaceae, Sapindaceae, Olacaceae, Mimosaceae, and Burseraceae. Other species shared by the Waka National Park and the study site in Mondah are i.a. Ebenaceae, Irvingiaceae, Stericulaceae, and Rizopheraceae.
Even though the order differs (Ceasalpiniaceae, Euphorbiaceae, Rubiaceae, Olacaceae, Annonaceae, Burseraceae, and Mimosaceae), the most species rich families found in the Mbé National Park are similar to those of the Mondah forest and Waka National Park.
The comparison of the study site with the other regional assessments drawn above indicates that the assessed family structure is both on the one hand plausible and on the other hand does not substantially differ from other forests in the regions.

When taking the abundance of individuals per family as ranking criterion (instead of the number of species) the family ranking changes (Table 5). As mentioned above in data set 1 (dbh≥1cm) the most abundant family in terms of the number of stems it contains is Sterculiaceae (578 stems, represented by one family). Other families represented by 100 individuals and more are: Euphorbiaceae, Ebenaceae, Papilionaceae, Myristicaceae, and Burseraceae. In data set 2 (dbh≥10cm) the most abundant family is Burseraceae (78 individuals). In the descending order Myristicaceae, Sterculiaceae, Euphorbiaceae, Ebenaceae, Papilionaceae, Annonaceae, Sapotaceae, and Sapinadaceae are represented by more than 10 individuals.

The purpose of the following subsection is to identify species-specific relevance in terms of its contribution to stand characteristics and structural forest variables.
A comprehensive list of species occurance, abundance, dominance, frequency, as well as species-specific contribution to standing volume, above ground biomass and carbon stock is presented in Annex B, Table 22 for data set 1 and in Annex B, Table 23 for data set 2. In this subchapter, an extraction of the most important findings should be illustrated.
The distribution of the total basal area, above ground volume, biomass, and carbon content across species was assessed computing absolute and proportional counts. The abundance of one species is determined by the number of stems representing this species on one hectare. The species-specific dominance is defined as the species-specific basal area occupied by the species per hectare. Respectively, the dominance of one species equates to its total species-specific basal area.

Table 5: Family structure of data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm) indicating the number of species and individuals per family

Data set 1			**Data set 2**		
Family	**Species**	**Individuals**	**Family**	**Species**	**Individuals**
Caesalpiniaceae	5	45	Burseraceae	4	78
Euphorbiaceae	4	358	Annonaceae	4	18
Burseraceae	4	160	Myristicaceae	3	56
Annonaceae	4	99	Euphorbiaceae	3	34
Anacardiaceae	4	29	Sapotaceae	3	12
Mimosaceae	4	28	Mimosaceae	3	8
Myristicaceae	3	161	Ebenaceae	2	25
Sapotaceae	3	59	Irvingiaceae	2	7
Irvingiaceae	3	19	Caesalpiniaceae	2	6
Ebenaceae	2	322	Anacardiaceae	2	3
Combretaceae	2	104	Sterculiaceae	1	43
Sapinadaceae	2	47	Papilionaceae	1	20
Olacaceae	2	22	Sapinadaceae	1	11
Moraceae	2	12	Meliaceae	1	6
Sterculiaceae	1	578	Humiriaceae	1	5
Papilionaceae	1	177	Polygalaceae	1	5
Polygalaceae	1	95	Arecaceae	1	3
Humiriaceae	1	43	Olacaceae	1	3
Lamiaceae	1	29	Salicaceae	1	3
Fabaceae	1	25	Combretaceae	1	3
Arecaceae	1	24	Lamiaceae	1	2
Salicaceae	1	8	Ochnaceae	1	2
Meliaceae	1	6	Fabaceae	1	1
Ochnaceae	1	6	Gentianaceae	1	1
Leguminoseae	1	5	Ixonanthaceae	1	1
Clusiaceae	1	3			
Gentianaceae	1	3			
Rhizophoraceae	1	2			
Ixonanthaceae	1	1			
Rubinaceae	1	1			
Rutaceae	1	1			

Figure 3 ranks those 25 species of data set 1 that hold more than 1% of the total stand basal area according to their relative dominance (i.e. species-specific basal area/ha). In addition, their individual contribution to total abundance (stem density), standing volume, above ground biomass and carbon stock is given in percent. The species-specific contribution of these 25 most dominant species is set in relation to the accumulated contribution of the remaining 126 other species which provide less than 1% of the total basal area per species. The 25 most dominant species in data set 1 are represented by 2125 stems and respectively, provide 58.2% of all individuals. Together they hold 83% of the stand basal area. Okoumé is the most dominant species, representing 19% of the total stand basal area. It is followed by Lekaia (10%) and Colatier (6%). As highlighted in Figure 3 the individual share in the total basal area of the other 22 most dominant species are closely spaced on the range between 1% and 4%.

Regarding the relative species-specific contribution to standing volume, above ground biomass, and carbon stock the distribution pattern are similar: the 25 most dominant species found in data set 1 presented in Figure 3 hold more than 88% of the standing volume, and more than 87% of the above ground biomass and carbon stock. Again Okoumé (20%) and Lekaia (16%) provide the largest portions. In descending order Moka provide for 7% of the total volume and 9% of the total biomass and carbon content, and Talis for around 5% of both.

Together, the remaining 126 species that hold less than 1% in the total basal area/ha provide 42% of all stems and hold 18% of the stand basal area, 11% of the standing volume, and 12% of the above ground biomass and forest carbon stock.

Figure 4 ranks those 25 species of data set 2 that hold more than 1% of the total stand basal area according to their relative dominance (i.e. species-specific basal area/ha). In addition, their individual contribution to total abundance (stem density), standing volume, above ground biomass and carbon stock is given in percent. In data set 2, the 25 most dominant species together provide more than 80% of the stand basal area, standing volume, above ground biomass and forest carbon stock. The three most dominant species in rank and order are Okoumé, Lekaia, and Colatier. In sum these three species occupy 35% of the stand basal area. Consequently, their dominance within the forest stand is rated as high. In addition, Okoumé and Lekaia provide by far the percental majority of the standing volume, above ground biomass and carbon stock. While Okoumé is also the most abundant species in data set 2, belongs to the rare but important species which are represented by very few but large individuals. Like in data set 1 the third and fourth dominant species are Colatier and Etehi both characterized by comparatively high stem densities. Moka and Talis are the followers in reference to standing volume, above ground biomass and carbon stock. Both are represented by few but large individuals.

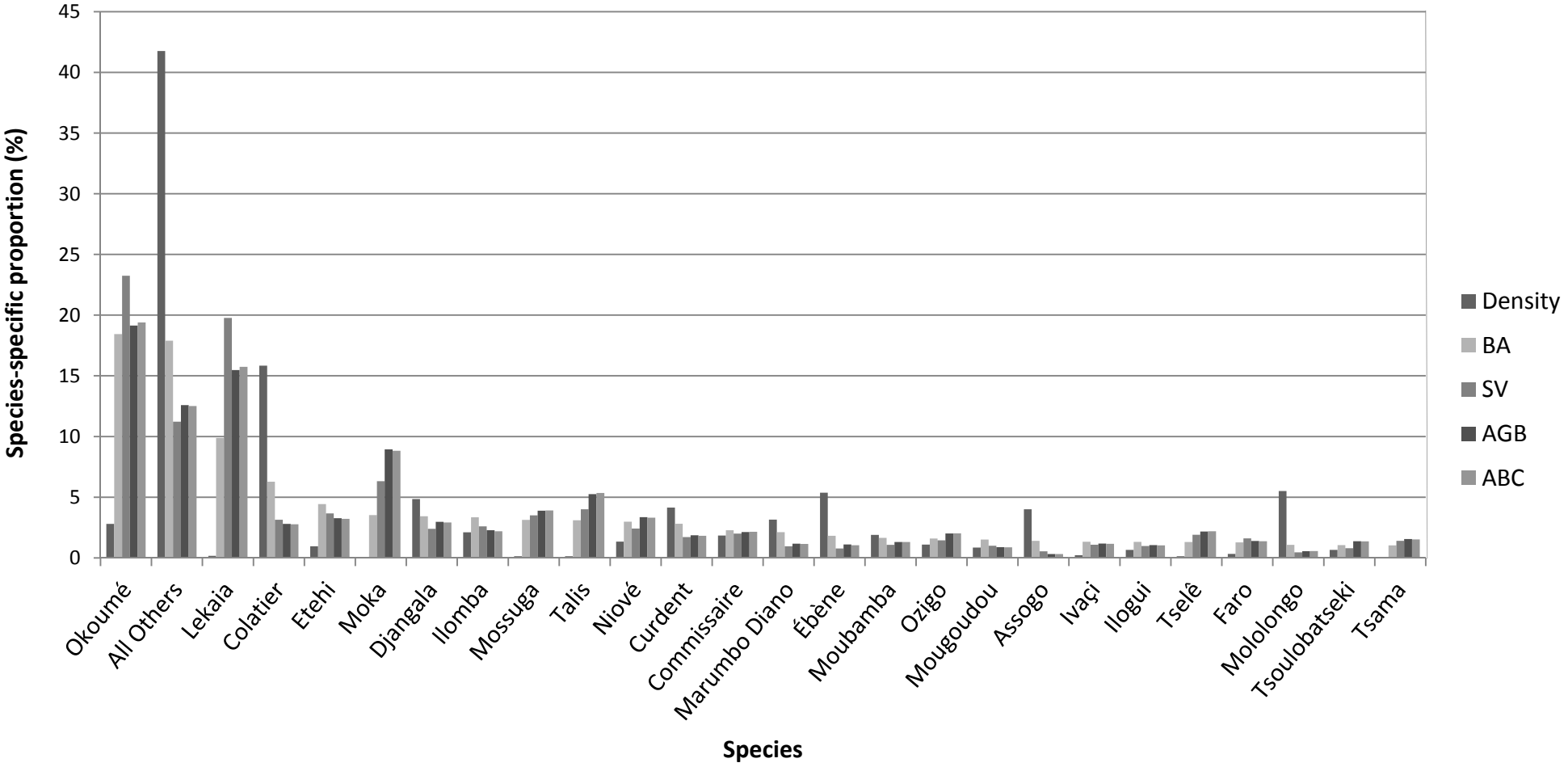

Figure 3: Species-specific contribution of the 25 species that provide at least 1% of the stand basal area/ha in data set 1 (dbh≥1cm) to: stem density (density), basal area (BA), standing volume (SV), above ground biomass (AGB), and above ground carbon stock (AGC). All values refer to 1 hectare. The species-specific contribution is set in relation to the accumulated contribution of all other species. All values refer to 1 hectare.

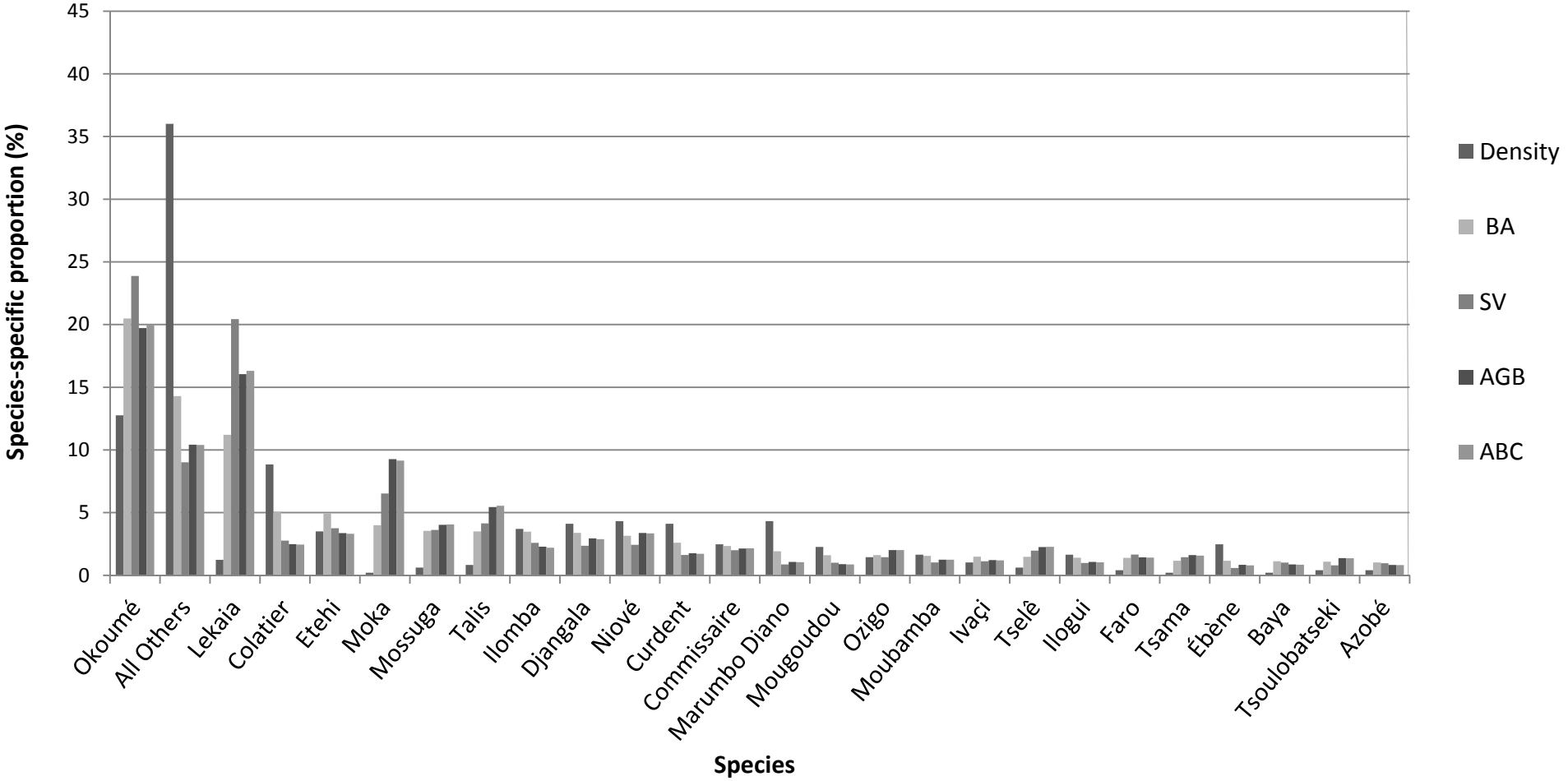

Figure 4: Species-specific contribution of the 25 species that provide at least 1% of the stand basal area/ha in data set 2 to: stem density (density), basal area (BA), standing volume (SV), above ground biomass (AGB), and above ground carbon stock (AGC). The species-specific contribution is set in relation to the accumulated contribution of all other species. All values refer to 1 hectare.

Data set 2 comprises 60 species that provide less than 1% of the total basal area. These 60 species only hold 36% of all individuals, 14.3% of the stand basal area, 9% of the standing volume, and 10.4% of the above ground biomass and carbon stock.

The previous results reveal that the species-specific dominance and contribution to forest characteristics of single species is strongly influenced by the size and not the number of the individuals which represent the species.

In contrast to the previous figures, which examined the contribution of the most dominant species, Figure 5 illustrates the contribution of the 11 most abundant species (more than 100 individuals) in data set 1 (dbh≥1cm), to stem density, stand basal area, standing volume, above ground biomass, and carbon stock. In data set 1 the 11 most abundant species together provide 55.2% of the stand density. They occupy 39.4% of the stand basal area, hold 34% of the standing volume, and 30.8% of the above ground biomass and carbon stock. The species-specific contribution of the most abundant species to forest characteristics is distributed unequally. While Okoumé exhibits the lowest abundance among the most abundant species in data set 1, it is by far the most dominant species and holds the percental majority of the standing volume, above ground biomass and carbon content. The most abundant species Colatier and Mololongo provide a comparatively small share of the forest characteristics. The individuals of all other species that are represented by less than 100 individuals account for 44.8% of the stand density. In sum these species hold the major share of the stand basal area (60.6%), standing volume (66%), and the above ground biomass and carbon stock (69.1%).

Figure 6 ranks the 13 most abundant species of data set 2 (dbh≥10cm) according to their number of individuals per species and gives their species-specific contribution to the five forest variables under consideration. With 62 trees Okoumé is the only species that holds more than 50 stems per species in data set 2 (see Table 13). The second most abundant species is Colatier (43 individuals). The contribution of the other most abundant species to the forest variables remains moderate to low and does not exceed 5% (basal area) and 4% (volume, biomass, carbon stock). The remaining 72 species with abundances lower than 10 individuals nearly hold 40% of all stems and provide 48.3% of the stand basal area, 55.5% of the standing volume, and 59% of the AGB and ABC.

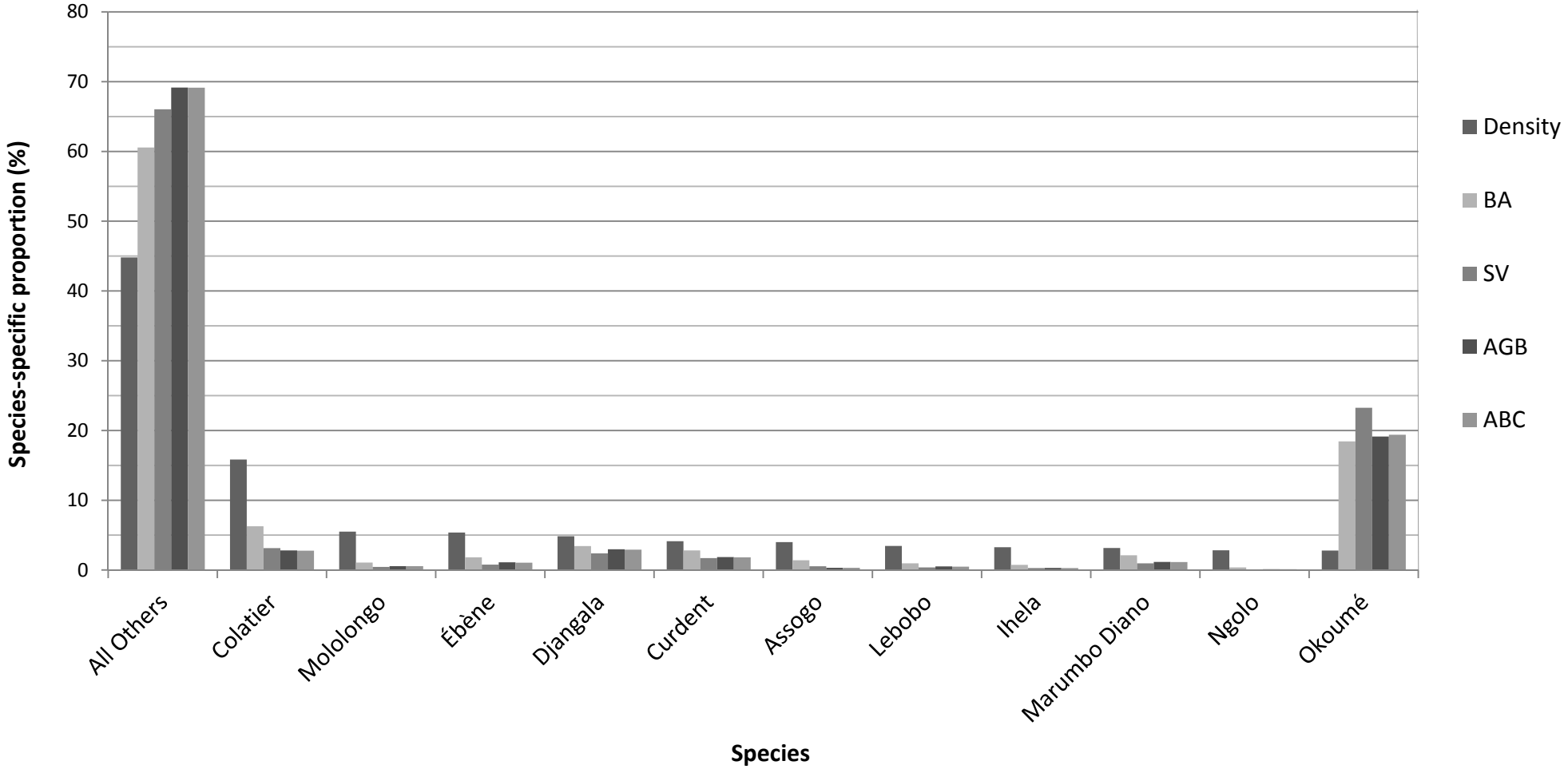

Figure 5: Contribution of the 11 most abundant species (≥100 individuals/species) in data set 1 to stem density (density), stand basal area (BA), standing volume (SV), above ground biomass (AGB), and above ground carbon content (AGC). The species-specific contribution is set in relation to the accumulated contribution of all other species. All values refer to 1 hectare.

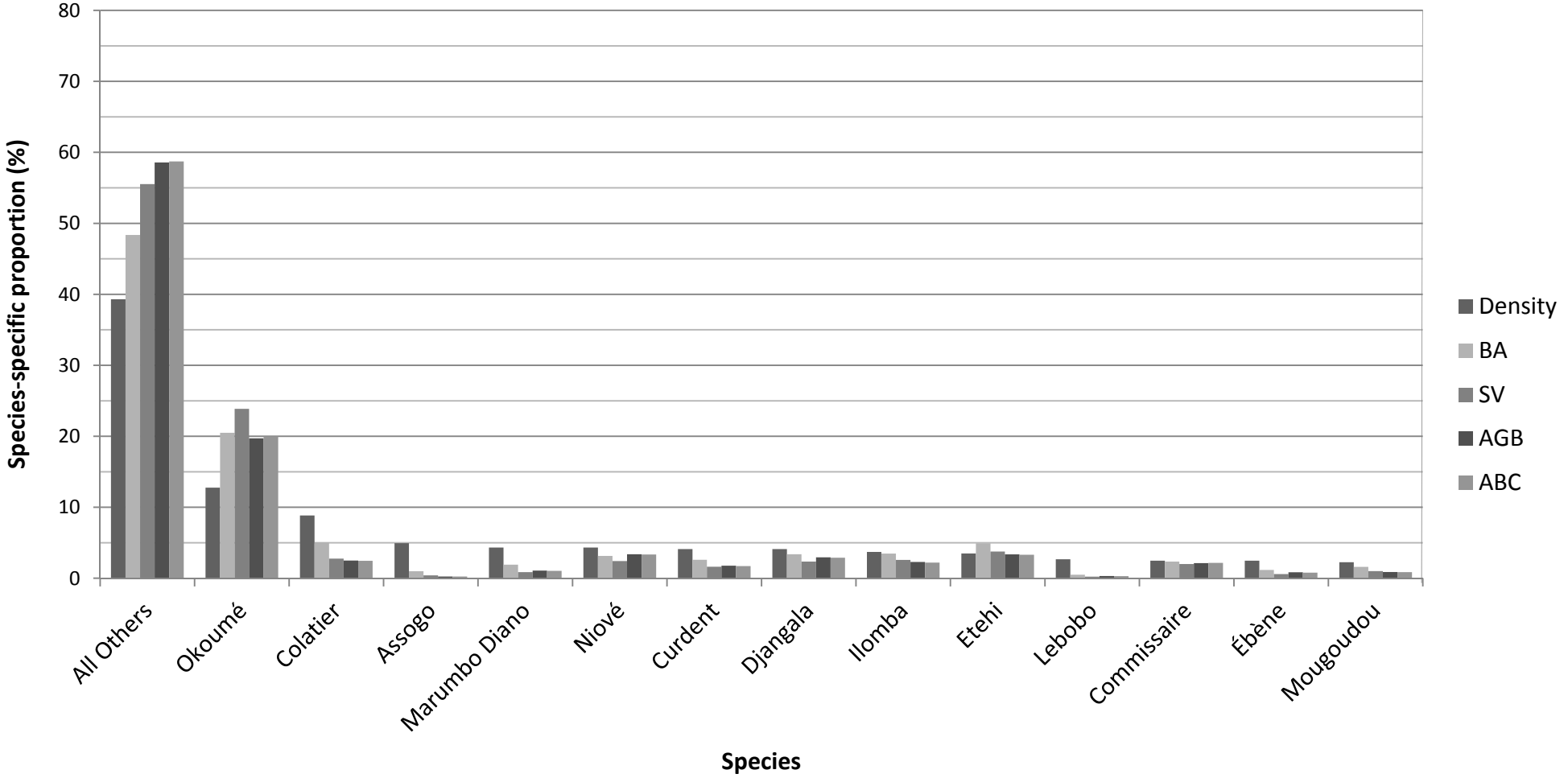

Figure 6: Contribution of the 13 most abundant species (≥10 individuals/species) in data set 2 to stem density (density), stand basal area (BA), standing volume (SV), above ground biomass (AGB), and above ground carbon content (AGC). The species-specific contribution is set in relation to the accumulated contribution of all other species. All values refer to 1 hectare.

Species frequency was determined by counting the number of sample points (plots) a species was found to occupy. It is used to measure the distribution of a species across the sample area.

Table 6 summarizes the findings for the most frequent species found in data set 1 (dbh≥1cm). Only 13 species (ca. 9%) can be found in all 7 sample plots and respectively, exhibit an absolute frequency of 100%. Another 6 species (4%) were represented in 6 sample plots (absl. frequency = 86%), 11 species (ca. 7%) in at least 5 sample plots (absl. frequency = 71%), and 15 species in 4 sample plots (absl. Frequency = 57%).

Table 6: Most frequent species in data set 1 that are represented in at least 4 sample plots. Absolute frequency $F_{absl}= p_i/P$ (p_i=Nr. of sample plots a species found to occupy)(P=total nr. of sample plots). Relative frequency $F_{rel}=Fa_{bsl}/\sum F_{abs}$

Species	Abundance (ha)	Frequency (max=7)	Absl. Frequency (%)	Rel. Frequency (%)
Colatier	578	7	100,00	1,78
Mololongo	201	7	100,00	1,78
Ébène	196	7	100,00	1,78
Djangala	177	7	100,00	1,78
Curdent	151	7	100,00	1,78
Ihela	119	7	100,00	1,78
Marumbo Diano	115	7	100,00	1,78
Ngolo	103	7	100,00	1,78
Bono	95	7	100,00	1,78
Ibodo	92	7	100,00	1,78
Ilomba	77	7	100,00	1,78
Sucari	72	7	100,00	1,78
Commissaire	67	7	100,00	1,78
Lebobo	126	6	85,71	1,53
Igoko	72	6	85,71	1,53
Somoukoé	65	6	85,71	1,53
Niové	49	6	85,71	1,53
Ozouga	43	6	85,71	1,53
Mougoudou	31	6	85,71	1,53
Mopepeda	25	6	85,71	1,53
Okoumé	102	5	71,43	1,27
Grate Corp	88	5	71,43	1,27
Moubamba	69	5	71,43	1,27
Etehi	35	5	71,43	1,27
Douka	30	5	71,43	1,27
Mougaou	24	5	71,43	1,27

Continuation Table 6				
Species	**Abundance (ha)**	**Frequency**	**Absl. Frequency (%)**	**Rel. Frequency (%)**
Mouvengui	22	5	71,43	1,27
Molologumba	18	5	71,43	1,27
Moambe Noir	16	5	71,43	1,27
Chocolatier	13	5	71,43	1,27
Azobé	6	5	71,43	1,27
Assogo	146	4	57,14	1,02
Mboudou	46	4	57,14	1,02
Ozigo	40	4	57,14	1,02
Café	36	4	57,14	1,02
Mokokosou	29	4	57,14	1,02
Ilogui	24	4	57,14	1,02
Tsoulobatseki	24	4	57,14	1,02
Noisetier	19	4	57,14	1,02
Lissesse	17	4	57,14	1,02
Faro	12	4	57,14	1,02
Iwaga	11	4	57,14	1,02
Dabema	8	4	57,14	1,02
Lebambi	8	4	57,14	1,02
Tsarassa	6	4	57,14	1,02
Talis	5	4	57,14	1,02

Figure 7 maps the relationship of relative abundance, frequency and dominance in data set 1. In its beginning the relative abundance curve clearly exceeds the relative frequency. In the continuing course it depreciates fast and drops below the relative frequency curve. The following section is characterized by volatile relative frequencies indicating less abundant but spatially very well distributed species. Peaks in the relative basal area curve originate from species with moderate to high relative frequency (except the singletons located in the last third of the curve). In the long run the development of relative frequency is strongly influenced by the species-specific abundance.

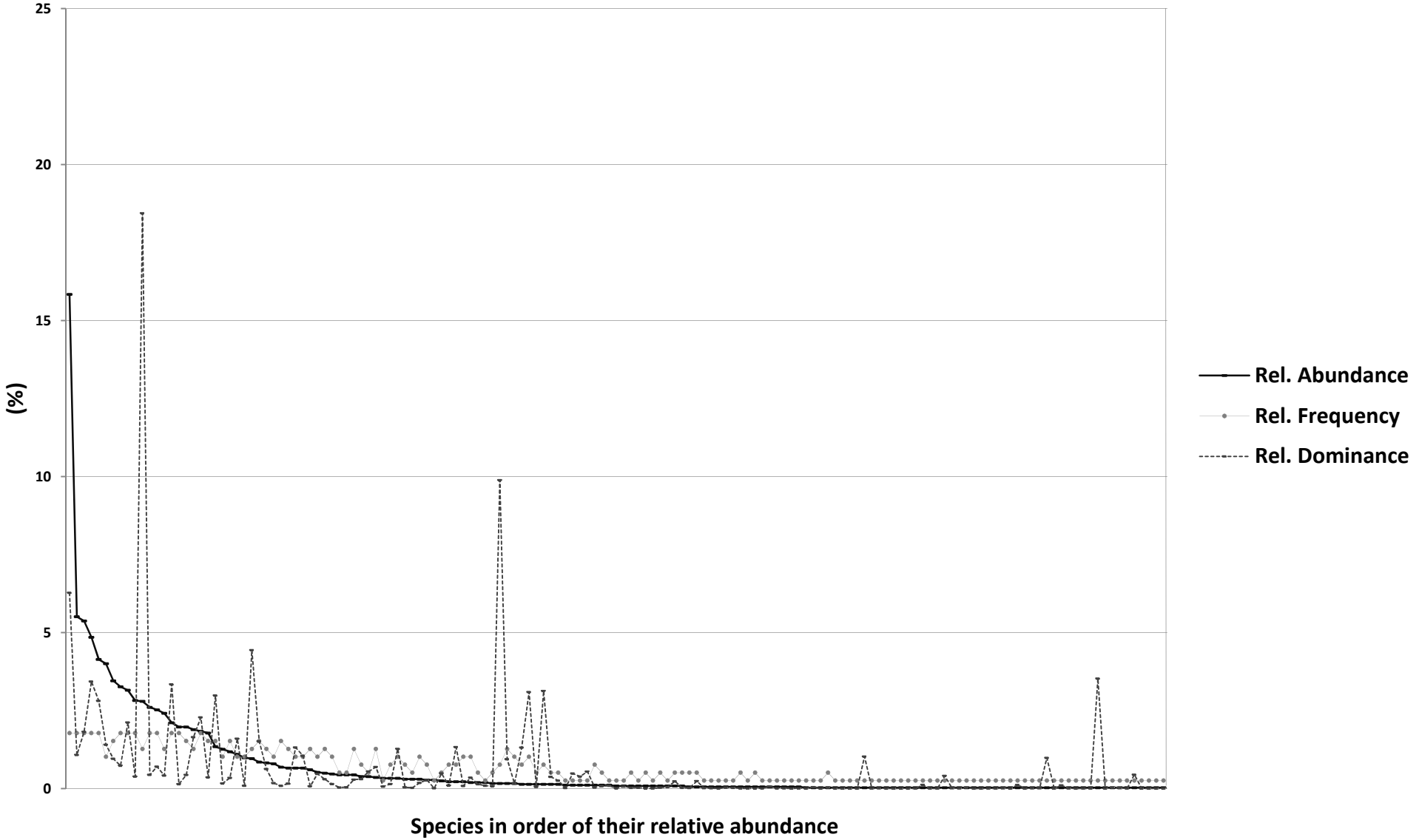

Figure 7: Relationship of relative abundance, relative frequency, and relative dominance of species in data set 1 (dbh≥1cm)

Table 7 illustrates the most frequent species found in data set 2 (dbh≥10cm). In data set 2 only two species (2%) were collected in all seven sample plots (Colatier and Commisaire), two species (2%) in six sample plots (Niové and Ilomba), and yet another three species (4%) in five sample plots (Okoumé, Moubamba, Marumbo Diano). At least 7 species occupy four sample points.

Table 7: Most frequent species in data set 2 that are represented in at least 4 sample plots. Absolute frequency $F_{absl}= p_i/P$ (p_i = Nr. of sample plots a species found to occupy)(P = total nr. of sample plots). Relative frequency $F_{rel}=F_{absl}/\sum F_{absl.}$

Species	**Density (Abundance/ha)**	**Frequency (max=7)**	**Absl. Frequency (%)**	**Rel. Frequency (%)**
Colatier	43	7	100,00	3,76
Commissaire	12	7	100,00	3,76
Ilomba	18	6	85,71	3,23
Niové	21	6	85,71	3,23
Mololongo	7	5	71,43	2,69
Marumbo Diano	21	5	71,43	2,69
Ibodo	6	5	71,43	2,69
Okoumé	62	5	71,43	2,69
Moubamba	8	5	71,43	2,69
Djangala	20	4	57,14	2,15
Curdent	20	4	57,14	2,15
Lebobo	13	4	57,14	2,15
Igoko	4	4	57,14	2,15
Mougoudou	11	4	57,14	2,15
Etehi	17	4	57,14	2,15
Chocolatier	5	4	57,14	2,15

Figure 8 describes the relationship of relative abundance, frequency and dominance in data set 2. Only in its very beginning the relative abundance curve runs above the relative frequency curve. In the following the most abundant species do not necessarily possess the highest relative frequency. The course of the curve points to less abundant but spatially well distributed species until it reaches a constant determined by the species-specific abundance.

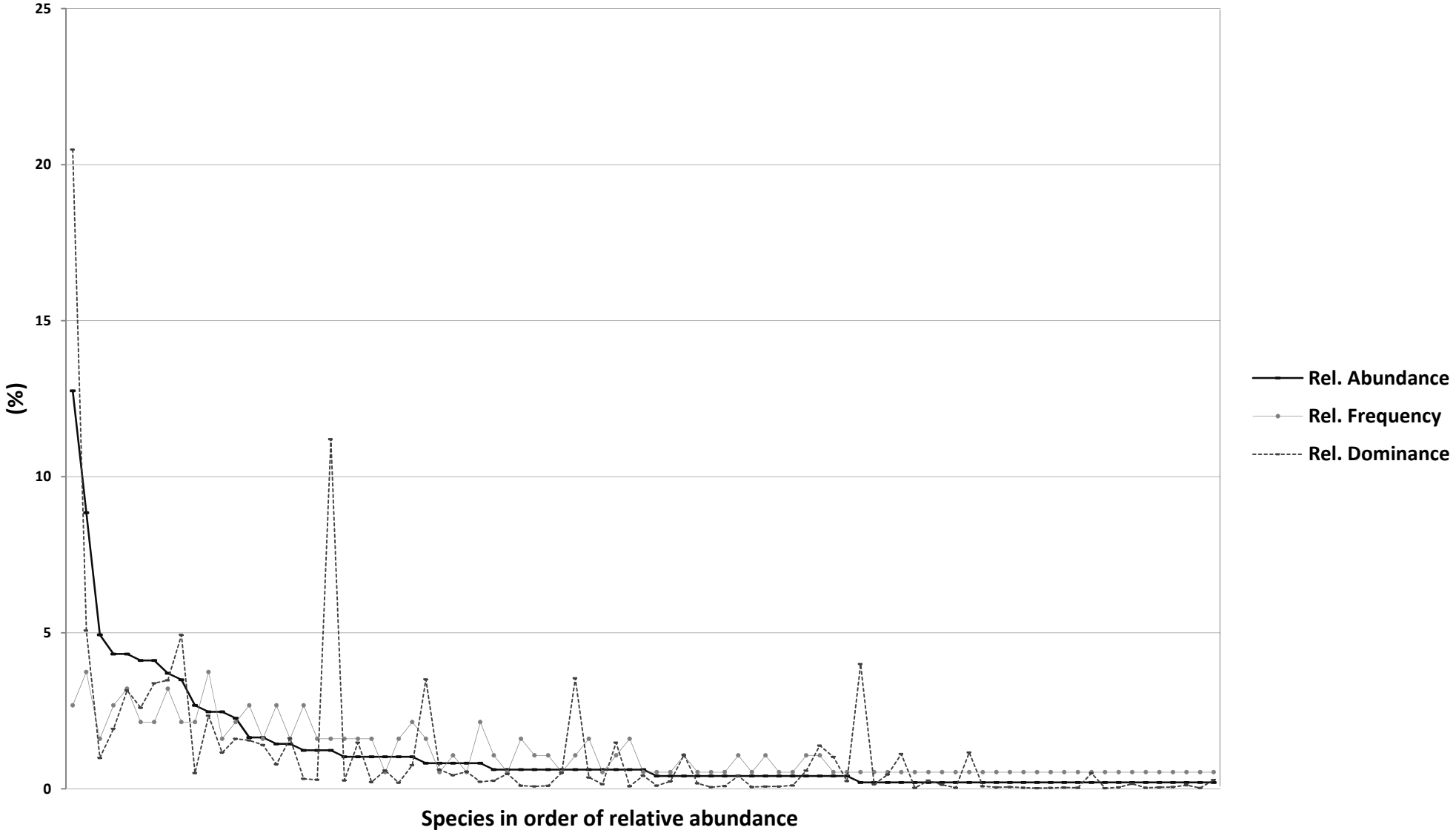

Figure 8: Relationship of relative abundance, relative frequency, and relative dominance of species in data set 2 (dbh≥10cm).

Based on the findings above the number of frequently distributed species is rated as low to very low for both data sets. Few species are ubiquitous in the Mondah forest. Only Cola and Commisaire could be recorded in all sample units of both data sets. Other frequently distributed species of data set 1 (dbh≥1cm) occupying all sample points are those species that are well represented in the understory (Mololongo, Ngolo (Terminalia superba), Djangala (Dalbergia bakeri), Ihela, Sucari) as well as widely occurring species like Ébène and Ilomba. The most abundant species also possess the highest relative frequency values. Further, the forest stand is characterized by less abundant but spatially very well distributed species. Few species show tendencies in regard to patchy or concentrated formations. Most of the low frequency values can be explained with low abundance and basal area ratios. But some species attract special attention.

Proportional to its outstanding dominance, Okoumé exhibits only moderate relative abundance and frequency values. Although it is well represented in plot P1 and P3, it is completely absent from P5 and P7 and only occurs with few scattered individuals in P2, P4 and P6.

In data set 1 (dbh≥1cm) some species show a patchy distribution, i.e. occupying only one place with a few trees. Species like Olala (12 stems), Mokoko (10 stems), Ilogo (7 stems), and Mbegou (4 Stems) are good examples in that context.

While very well distributed in data set 1 (dbh≥1cm), the abundantly occurring species Ébène could only be found in 43% of the sample points in data set 2 (dbh≥10cm). Another two noticeable species are Niga and Evesse. Although both are represented by four stems, their occurrence is concentrated one sample point. As one of the most abundant and seemingly ubiquitous species in the Mondah forest, Assogo is only present in high densities in plot P1, P2, and P2 but is completely absent from P5, P6, and P7 and extremely rare in P4.

The complete list of species-specific abundances as well as absolute and relative frequency values is given separately for data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm) in Annex B, Table 24 and Annex B,Table 25.

According to Pietsch (2000) usually 40% - 50% of the trees growing in African tropical forests stand are distributed among 10% to 15% of all species. The findings made for data set 2 comply with this categorization, i.e. approximately 10% of the species recorded in data set 2 hold toghether 50% of the trees. The stem-species distribution found in data set 1 differs from the scheme. Here, only 6% of the species are represented by 50% of the inventoried individuals. In fact, the most abundant species in data set 1 (dbh≥1cm), namely Cola, particularly influences this distribution. This species is ubiquitous in the Mondah forest and provides alone 16% of all stems. Other well represented species of the understory like Molongo (Alchonea floribunda), Ébène (Diospyros spp.) and Djangala (Dalbergia bakeri) further contribute to this effect.

3.1.2.2. Horizontal Stand Structure

To investigate the horizontal forest structure the data of data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm) was grouped into 10cm diameter classes. In addition, the resolution of the smallest diameter class in data set 1 (1cm≤dbh≥10cm) was refined into 1cm classes and analyzed separately.

Figure 9 describes the distribution of stems across 10cm diameter classes for the woody vegetation of data set 1 and data set 2. Since data set 2 is a subset of data set 1 the tree-diameter distribution of both data sets is completely identical for all trees dbh≥10cm.

The graphical illustration of the horizontal stand classification scheme given in Figure 9 shows an inverted J-shaped diameter distribution typical for uneven-aged forest. This distribution is characterized by a large number of individuals in the smaller diameter classes and decreasing stem counts in medium to larger classes.

The analysis of data set 1 (dbh≥1cm) reveals a very strong concentration of trees (87%) in the first diameter class (1cm≤dbh<10cm). The second diameter class of data set 1 contains another 8% of the stems. Consequently, in sum 94% of all surveyed individuals are represented in diameter classes smaller than 20cm dbh. The mortality rate of trees in the juvenile age is very high and corresponds to a proportional decrease of stems equal to 90% between the first (1≤dbh<10cm) and the second (10≤dbh<20cm) diameter class, i.e. while the smallest class contains a total of 3136 individuals the second class only counts 295 individuals. Usually, the medium diameter classes are characterized by a gradual decrease of stem counts with increasing diameter before a constant is reached for large diameter classes. The present data comply with this scheme until this trend suddenly stops after the diameter class 80cm≤dbh<90. That is, the percental decrease of stems between the medium diameter classes varies between 40% and 50% and reaches a constant for all trees that measure between 60cm and 90 cm dbh at around 20%. In the following course the number of trees per class abruptly drops down to zero to one stem per class. Thus, in sum four stems per hectare with dbh≤90cm could be recorded on the study site, including one giant tree with a stem greater than 200cm dbh.

As mentioned above, data set 2 (dbh≥10cm) represents a subset of data set 1 (dbh≥1cm), i.e all stems smaller than 10cm dbh are excluded from analysis. Thus, the investigation of data set 2 emphasizes the analysis of trees with increased size. The first diameter class of data set 2 (10cm≤dbh<20cm) comprises 60% of the 486 trees counted in data set 2, the second class 17%, the third one 9% (see Figure 9). Less than 2% of the all stems can be found in each diameter class between 60cm and 90cm dbh. As mentioned above, trees greater than 90cm dbh only occur occasionally.

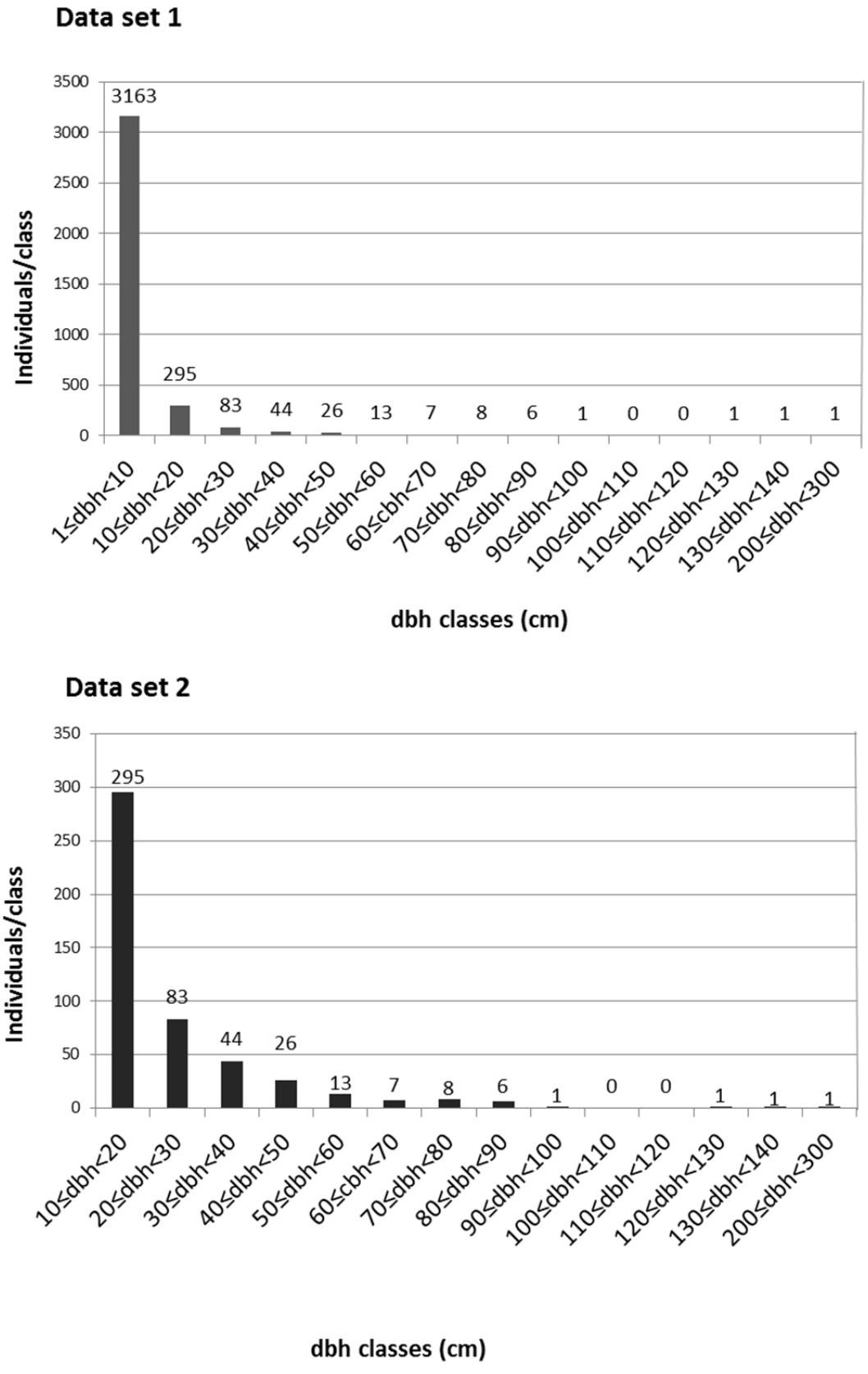

Figure 9: Tree-diameter-distribution in 10cm diameter classes across data set 1 for stems dbh≥1cm and data set 2 for stems dbh≥10cm

To analyze the sharp decrease of stems in the smallest diameter class of data set 1 (1cm≤dbh<10cm), this class is divided into 1cm diameter classes. The refined analyze scheme is graphically highlighted in Figure 10. Except the smallest diameter class (1cm≤dbh<2cm) the stem density declines continuously for 17% to 30% between the classes with increasing diameter (except a drop of 46% between the forth and fifth class). In effect, the number of stems in the first diameter class (1cm≤dbh<2cm) should exceed those of the second. It is assumed that due to inadvertences of forest workers a high number of stems between one and two centimeter dbh were cut during clearance of the dense scrub in the plots.

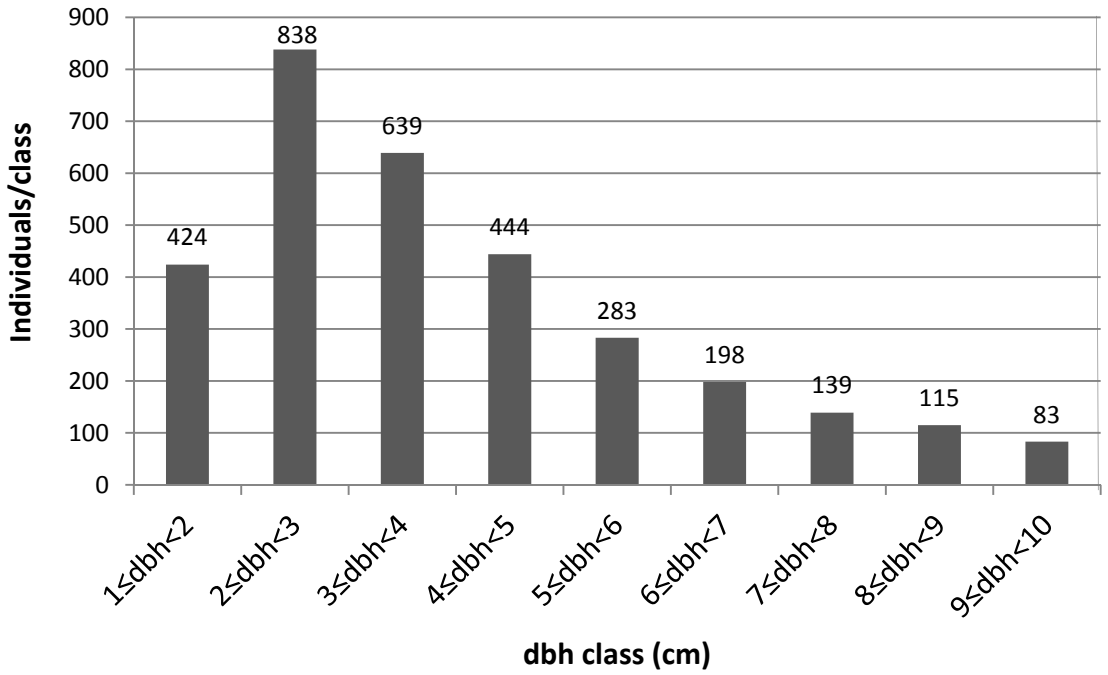

Figure 10: Tree-diameter-distribution of all stems 1cm≤dbh>10cm in data set 1 (dbh≥1cm)

The proportional distribution of stand basal area, standing volume, above ground biomass and carbon stock across diameter classes for data set 1 (dbh≥1cm) is given in Figure 11. It is remarkable that the smallest diameter class (1cm≤dbh<10cm) provides the largest percental share of the stand basal area. With increasing diameter this share oscillates between 11% and 9.5% until it declines for classes comprising trees dbh≥50cm. Contrary, the smallest diameter class contributes less than 4% to the standing volume, above ground biomass and carbon stock of the forest stand. With increasing diameter the class-specific share in these variables increases until it drops down again due to decreasing stem densities of diameter classes containing trees dbh≥50cm. However, this effect does not hold for very large trees. The diameter of giant trees overcompensates the reduced stem densities/ha. The percental contribution of one single giant tree to the total standing volume, above ground biomass density and carbon stock exceeds those of 3163 small trees dbh<10cm (Figure 11).

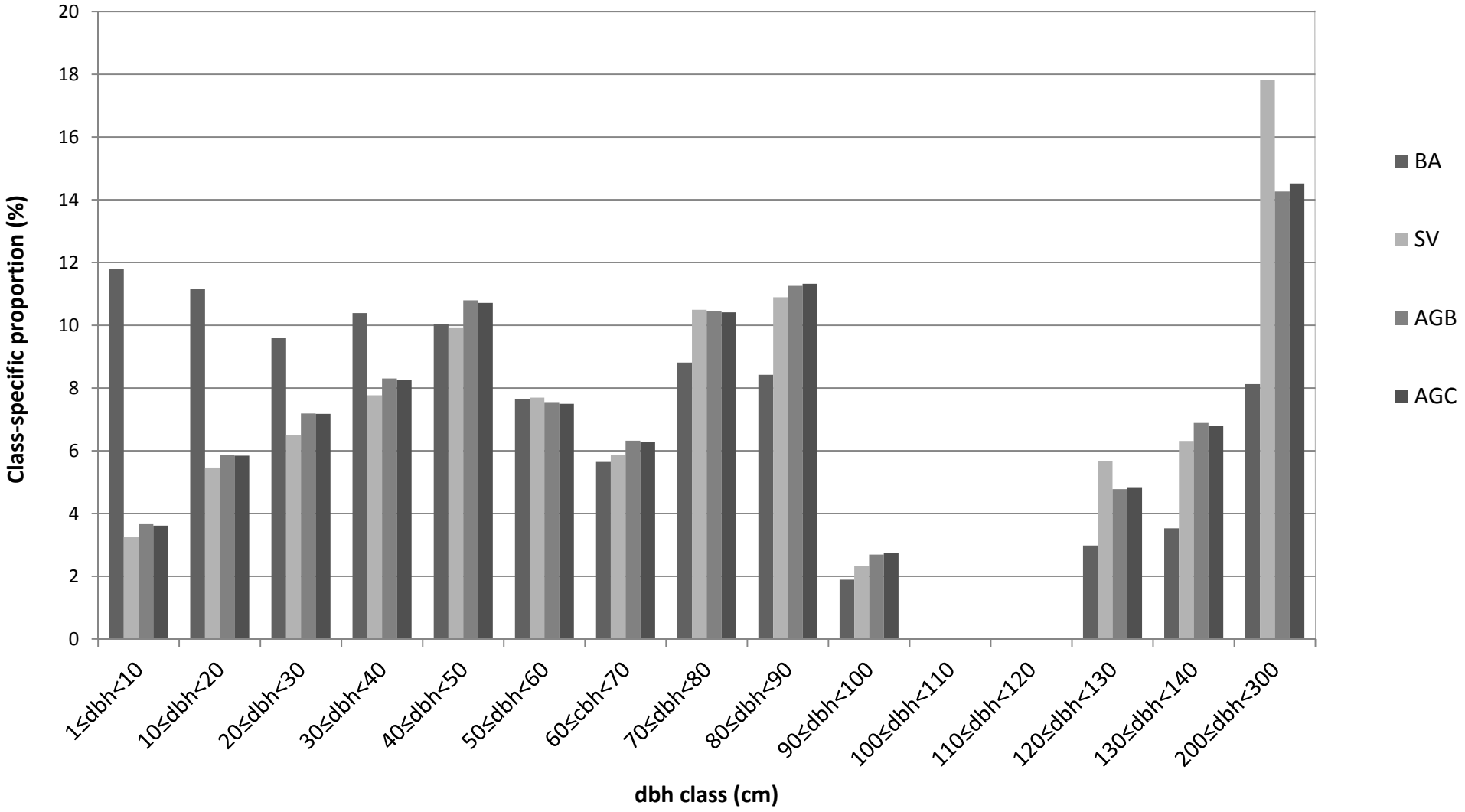

Figure 11: Proportional diameter distribution of basal area (BA), standing volume (SV), above ground biomass (AGB), above ground carbon stock (AGC) in data set 1 (dbh≥1cm) per hectare.

The proportional distribution of stand basal area, standing volume, above ground biomass and carbon stock across diameter classes for data set 2 (dbh≥10cm) is given in Figure 12. The smallest diameter class in data set 2 (here 10cm≤dbh<20cm) occupies the largest class-specific portion of the stand basal area. With increasing diameter classes the percental share in the stand basal area is linked to the stem density of each diameter class. As explained above, this is not true for giant trees. The development of the relative standing volume, above ground biomass, above ground carbon is proportional to each other. With increasing diameter it is also linked to the class-specific proportional share in the stand basal area.

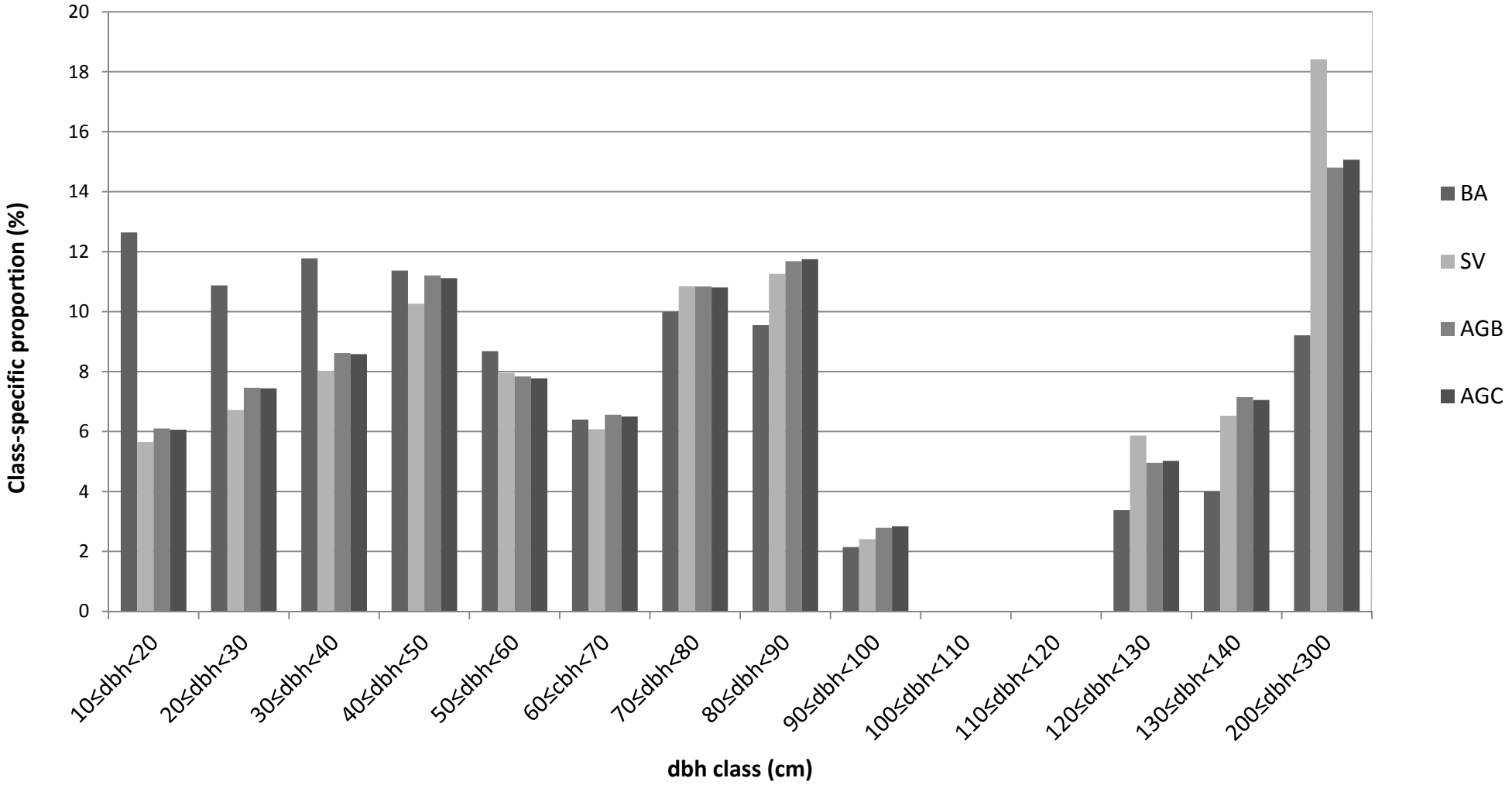

Figure 12: Proportional diameter distribution of basal area (BA), standing volume (SV), above ground biomass (AGB), above ground carbon stock (AGC) in data set 2 (dbh≥10cm) per hectare.

Figure 13 and Figure 14 give the relative species abundances in each diameter class of data set 1 (dbh≤1cm) and data set 2 (dbh≤10cm). The species-diameter distribution follows the J-shaped tree-diameter distribution. In data set 1 the first diameter class (1cm≤dbh<10cm) entails roughly 90 % of the 151 species found in the sample area. The proportion of represented species sharply declines with increasing diameter and drops to less than 1% for all diameter classes ≥ 90cm dbh.

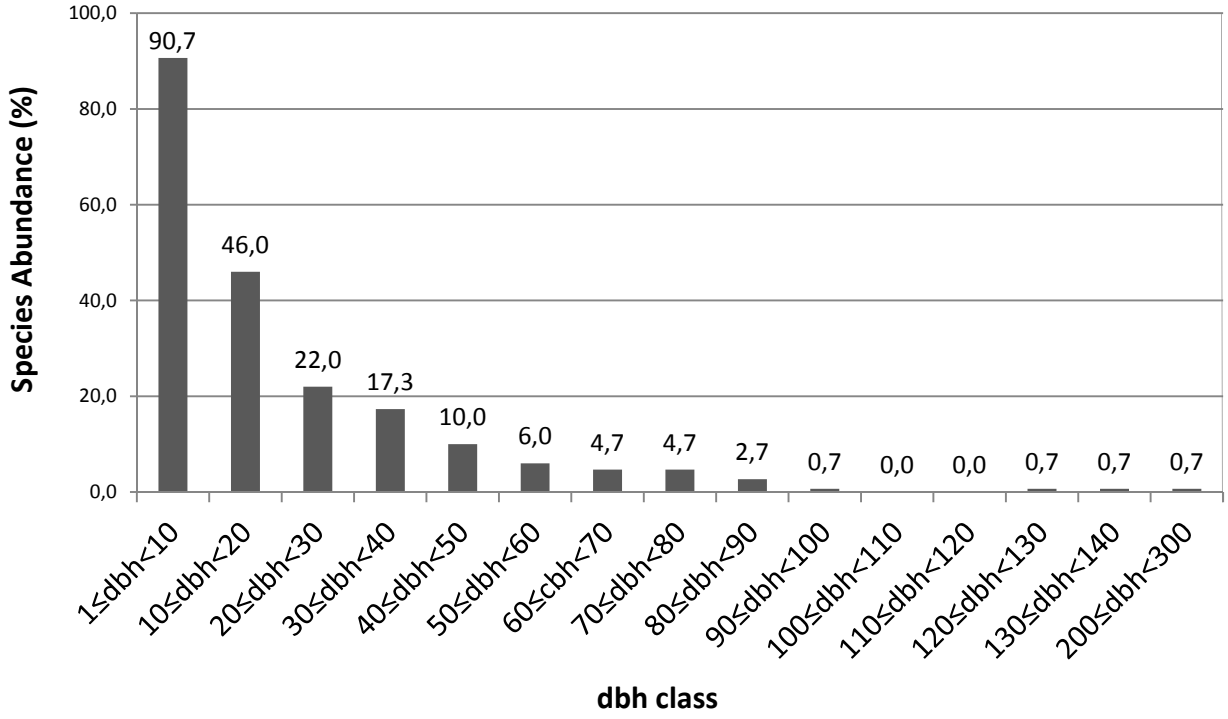

Figure 13: Relative species abundance per diameter class in data set 1 (dbh≥1cm).

Similar distribution patterns can be observed in data set 2. Most of the 85 species found in data set 2 are represented in the first diameter class (10cm≤dbh<20cm), i.e. 69 species. In the following the proportional decline of species abundance per diameter class is less extreme than in data set 1.

It is worth noting that while the majority of species is represented by smaller diameter classes, the ratio of the number of species to the number of stems changes with increasing diameter classes. On average, one species recorded in the smallest diameter class of data set 1 (1≤dbh<10cm) contains 23.3 stems and respectively, 4.7 stems in the smallest diameter class of data set 2 (10≤dbh<20cm). This ratio sharply declines with increasing diameter. Each species is represented at most by 1.5 stems in each diameter class that contains stems with dbh≥50cm.

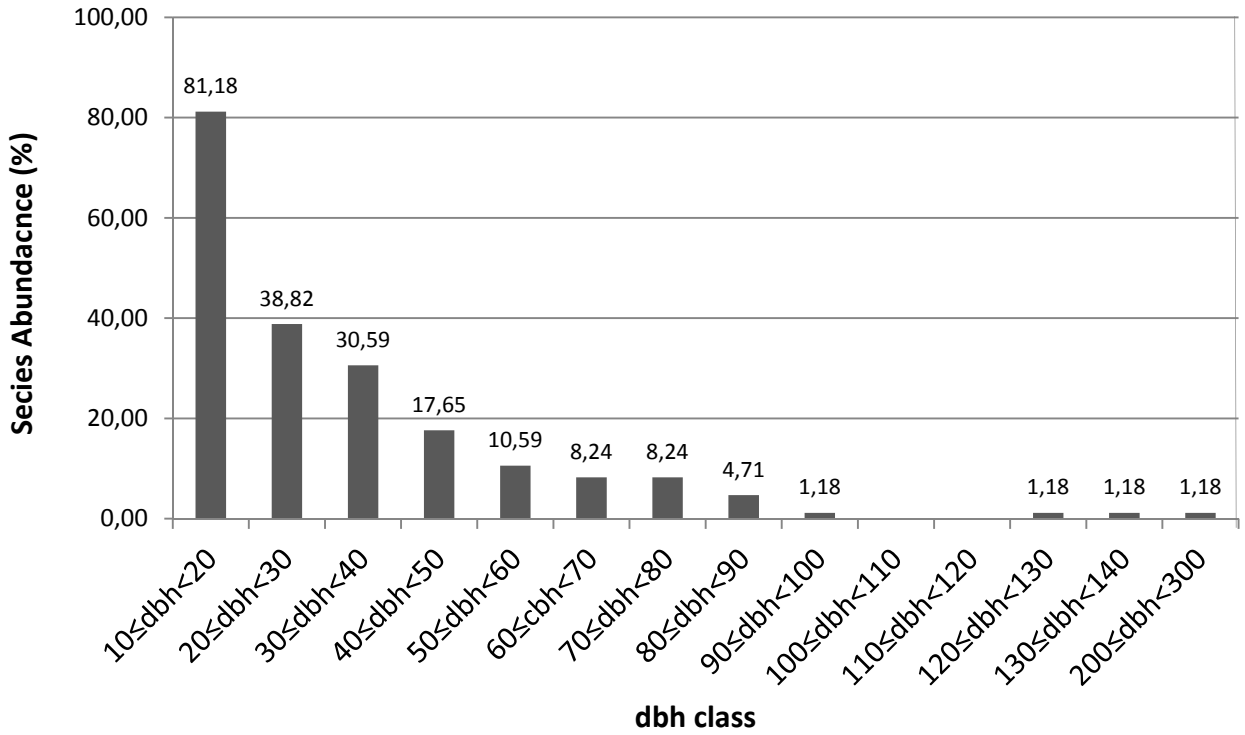

Figure 14: Relative species abundances per diameter class in data set 2 (dbh≥10cm).

The species occurrence and distribution in the horizontal classification scheme is précised in Annex C, Table 27. The detailed schedule clearly illustrates that the majority of species (110 species and respectively, 72.8% of all species) are only represented by individuals with stems smaller than 30cm dbh, whereas 60 species (39.7%) were solely recorded with stems smaller than 10cm dbh. Additionally, 25 species are represented in at least one of the three diameter classes between 30cm≤dbh<40cm and 50cm≤dbh<60cm. Well-known species that constantly occur throughout the horizontal classification scheme from the smallest diameter class to the diameter class 50cm≤dbh<60cm or greater are i.a: Faro, Ilomba, Okoumé, Talis, Tselê, Ozigo, Ébène, Colatier, and Niové. Only 16 species grow beyond the general minimum ripeness of 60cm for cutting in Gabon.

Another 15 species are only represented in diameter classes larger than 10cm dbh: the smallest individual of Ebap, Elimbi, Ilobo, Mokoute, Moussoube, Vecol, and Lekaia was recorded in the diameter class 10cm≤dbh<20cm; Gaga, Sero and Niga were found in the diameter class 20cm≤dbh<30cm, the latter with four stems at one location; Epopoko and Londo were recorded with stems 40cm≤dbh<50cm; Baya and Tsama with stems 70cm≤dbh<80cm and Moka with a stem 130cm≤dbh<140cm.

The complete relative and absolute distribution of stem counts, species occurrence, basal area, standing volume, above ground biomass and carbon content across the diameter classes in data set 1 and data set 2 is summarized in Table 8 and Table 9.

Table 8: Absolute and relative distribution of stems counts, basal area (BA), standing volume (SV), above ground biomass (AGB), above ground carbon stock (AGC), and species occurrence in data set 1 (dbh≥1cm). All values refer to 1 hectare.

dbh (cm)	Stems	Stems (%)	Species	Spec (%)	BA (m2)	BA (%)	SV (m3)	SV (%)	AGB (kg)	AGB (%)	AGC	ABC (%)
1≤dbh<10	3163	86,79	136	90,67	4,75	11,80	20,36	3,24	12760,61	3,66	6185,60	3,61
10≤dbh<20	295	8,06	69	46,00	4,49	11,15	34,33	5,46	20485,81	5,88	10004,77	5,84
20≤dbh<30	83	2,22	33	22,00	3,86	9,59	40,84	6,50	25054,08	7,19	12286,32	7,17
30≤dbh<40	44	1,21	26	17,33	4,18	10,39	48,81	7,77	28942,28	8,30	14165,13	8,27
40≤dbh<50	26	0,71	15	10,00	4,03	10,02	62,40	9,93	37638,32	10,80	18351,50	10,71
50≤dbh<60	13	0,33	9	6,00	3,08	7,66	48,34	7,69	26316,35	7,55	12836,35	7,49
60≤cbh<70	7	0,19	7	4,67	2,27	5,64	36,94	5,88	22034,10	6,32	10735,85	6,27
70≤dbh<80	8	0,22	7	4,67	3,54	8,81	65,94	10,49	36405,32	10,44	17837,06	10,41
80≤dbh<90	6	0,16	4	2,67	3,39	8,42	68,44	10,89	39233,53	11,25	19395,80	11,32
90≤dbh<100	1	0,03	1	0,67	0,76	1,89	14,65	2,33	9373,81	2,69	4689,53	2,74
100≤dbh<110	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
110≤dbh<120	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
120≤dbh<130	1	0,03	1	0,67	1,20	2,98	35,65	5,67	16648,44	4,78	8288,16	4,84
130≤dbh<140	1	0,03	1	0,67	1,42	3,53	39,67	6,31	23998,33	6,88	11641,03	6,80
200≤dbh<300	1	0,03	1	0,67	3,27	8,12	111,98	17,82	49718,79	14,26	24873,29	14,52
Total	3649	100	151*		40,23	100	628,35	100	348609,76	100	171290,38	100

* The total number of species is taken from Table 2 and not the summation over the column

Table 9: Absolute and relative distribution of stems counts, basal area (BA), standing volume (SV), above ground biomass (AGB), above ground carbon stock (AGC), and species occurrence in data set 2 (dbh≥10cm). All values refer to 1 hectare.

dbh (cm)	Stems	Stems (%)	Species	Spec (%)	BA (m2)	BA (%)	SV (m3)	SV (%)	AGB (kg)	AGB (%)	AGC	ABC (%)
10≤dbh<20	295	60,70	69	81,18	4,49	12,64	34,33	5,65	20485,81	6,10	10004,77	6,06
20≤dbh<30	83	17,08	33	38,82	3,86	10,87	40,84	6,72	25054,08	7,46	12286,32	7,44
30≤dbh<40	44	9,05	26	30,59	4,18	11,78	48,81	8,03	28942,28	8,62	14165,13	8,58
40≤dbh<50	26	5,35	15	17,65	4,03	11,37	62,40	10,26	37638,32	11,21	18351,50	11,12
50≤dbh<60	13	2,67	9	10,59	3,08	8,68	48,34	7,95	26316,35	7,84	12836,35	7,77
60≤cbh<70	7	1,44	7	8,24	2,27	6,40	36,94	6,08	22034,10	6,56	10735,85	6,50
70≤dbh<80	8	1,65	7	8,24	3,54	9,99	65,94	10,85	36405,32	10,84	17837,06	10,80
80≤dbh<90	6	1,23	4	4,71	3,39	9,55	68,44	11,26	39233,53	11,68	19395,80	11,75
90≤dbh<100	1	0,21	1	1,18	0,76	2,14	14,65	2,41	9373,81	2,79	4689,53	2,84
100≤dbh<110	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
110≤dbh<120	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
120≤dbh<130	1	0,21	1	1,18	1,20	3,38	35,65	5,86	16648,44	4,96	8288,16	5,02
130≤dbh<140	1	0,21	1	1,18	1,42	4,00	39,67	6,52	23998,33	7,15	11641,03	7,05
200≤dbh<300	1	0,21	1	1,18	3,27	9,21	111,98	18,42	49718,79	14,80	24873,29	15,07
Sum	486	100	85*		35,487828	100	607,98373	100	335849,152	100	165104,784	100

*The total number of species is taken from Table 2 and not the summation over the column.

3.1.2.3. Vertical Stand Structure

In order to obtain information indicating the occurrence and disposition of vertical stand layers the data of data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm) were divided into two meter height classes. For each class the class-specific tree density, basal area, standing volume, and above ground biomass and carbon content was calculated.
The high resolution of this schedule allows for the detailed analysis of the forest characteristic distribution. Table 10 outlines the distribution of the key forest characteristics across the vertical height classes in data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm). Broken tops were recorded for 76 trees. Since this number corresponds to 2% of all individuals, its importance is regarded as negligible for the scope of the present analysis.
In data set 1 (dbh≥1cm) most of the stems are concentrated in the lower height stratum up to 13 meters. The relative majority of stems reach heights between five to nine meters. In conformity with typical rainforest stand structure the stem density decreases sharply with incremental height. This is especially true for data set 1 when all trees dbh≥1cm are considered in analysis. Except a weak concentration of trees between 21m to 29m height, the stem density per diameter class declines straight down with increasing height. Stems taller than 43m only occasionally occur.

The histogram given in Figure 15 illustrates the proportional distribution of forest stand characteristics and estimates per hectare across 2-meter height classes in data set 1 (dbh≥1cm). The distribution shows three “belts” (the last one is interrupted around its maximal turning point) of increasing size indicating the growing importance of tall trees for stand basal area, standing volume, above ground biomass and forest carbon stock. Even though more than ¾ of the individuals accumulate in the height sector below 10 meters, their contribution to the forest characteristics remains small.

Table 10: Vertical distribution of forest stand characteristics across 2m height classes for data set 1 (dbh≥1cm) and data set 2 (dbh ≥ 10cm)

	Data set 1						Data set 2				
Height (m)	**Stem /ha**	**BA (m^2/ha)**	**SV (m^3/ha)**	**AGB (kg/ha)**	**AGC (kg/ha)**	**Height (m)**	**Stem/ha**	**BA (m^2/ha)**	**SV (m^3/ha)**	**AGB (kg/ha)**	**AGC (kg/ha)**
H<3	318	0,14	0,19	119,50	58,57	**H<3**	0	0,00	0,00	0,00	0,00
3≤H<5	1203	1,16	2,79	1723,76	836,51	**3≤H<5**	3	0,13	0,34	180,31	85,88
5≤H<7	881	1,49	5,29	3249,92	1575,45	**5≤H<7**	19	0,22	0,80	459,07	222,60
7≤H<9	475	1,64	7,86	4986,26	2411,81	**7≤H<9**	32	0,50	2,44	1536,06	742,01
9≤H<11	323	2,80	17,14	10616,12	5148,04	**9≤H<11**	97	2,07	12,82	7957,57	3864,60
11≤H<13	175	2,51	17,81	10838,30	5262,64	**11≤H<13**	91	2,19	15,57	9442,07	4585,09
13≤H<15	79	2,00	16,73	10267,71	4996,36	**13≤H<15**	59	1,91	16,01	9770,79	4751,47
15≤H<17	36	1,07	10,13	5762,78	2812,43	**15≤H<17**	30	1,04	9,84	5595,79	2732,59
17≤H<19	21	1,14	12,21	8158,40	3931,59	**17≤H<19**	21	1,14	12,21	8158,40	3931,59
19≤H<21	21	1,05	12,45	7358,51	3575,35	**19≤H<21**	20	1,05	12,41	7328,79	3561,09
21≤H<23	29	2,87	37,22	23218,52	11318,02	**21≤H<23**	27	2,86	37,11	23153,65	11285,81
23≤H<25	19	2,57	36,62	22211,58	10868,02	**23≤H<25**	19	2,57	36,62	22211,58	10868,02
25≤H<27	15	3,45	53,30	30248,46	14766,50	**25≤H<27**	15	3,45	53,30	30248,46	14766,50
27≤H<29	20	3,10	51,42	28706,17	14000,35	**27≤H<29**	19	3,09	51,33	28662,84	13978,78
29≤H<31	6	0,67	11,84	6471,05	3184,74	**29≤H<31**	6	0,67	11,84	6471,05	3184,74
31≤H<33	10	2,69	52,03	30693,81	15275,48	**31≤H<33**	10	2,69	52,03	30693,81	15275,48
33≤H<35	3	0,62	12,75	5821,69	2904,60	**33≤H<35**	3	0,62	12,75	5821,69	2904,60
35≤H<37	4	0,99	21,07	11812,85	5701,88	**35≤H<37**	4	0,99	21,07	11812,85	5701,88
37≤H<39	2	0,67	14,96	11030,74	5518,45	**37≤H<39**	2	0,67	14,96	11030,74	5518,45
39≤H<41	2	0,52	12,35	5769,24	2872,13	**39≤H<41**	2	0,52	12,35	5769,24	2872,13
41≤H<43	1	0,46	11,52	7441,59	3690,14	**41≤H<43**	1	0,46	11,52	7441,59	3690,14
43≤H<45	0	0,00	0,00	0,00	0,00	**43≤H<45**	0	0,00	0,00	0,00	0,00
45≤H<47	3	1,61	45,08	35204,44	17055,27	**45≤H<47**	3	1,61	45,08	35204,44	17055,27
47≤H<49	0	0,00	0,00	0,00	0,00	**47≤H<49**	0	0,00	0,00	0,00	0,00
49≤H<51	1	1,20	35,65	16648,44	8288,16	**49≤H<51**	1	1,20	35,65	16648,44	8288,16
51≤H<53	0	0,00	0,00	0,00	0,00	**51≤H<53**	0	0,00	0,00	0,00	0,00
53≤H<55	1	0,55	17,96	8385,14	4174,41	**53≤H<55**	1	0,55	17,96	8385,14	4174,41
55≤H<57	0	0,00	0,00	0,00	0,00	**55≤H<57**	0	0,00	0,00	0,00	0,00
57≤H<59	1	3,27	111,98	49718,79	24873,29	**57≤H<59**	1	3,27	111,98	49718,79	24873,29
Sum	3649	40,23	628,35	356463,76	175100,2	**Sum**	486	35,49	607,98	343703,15	168914,58

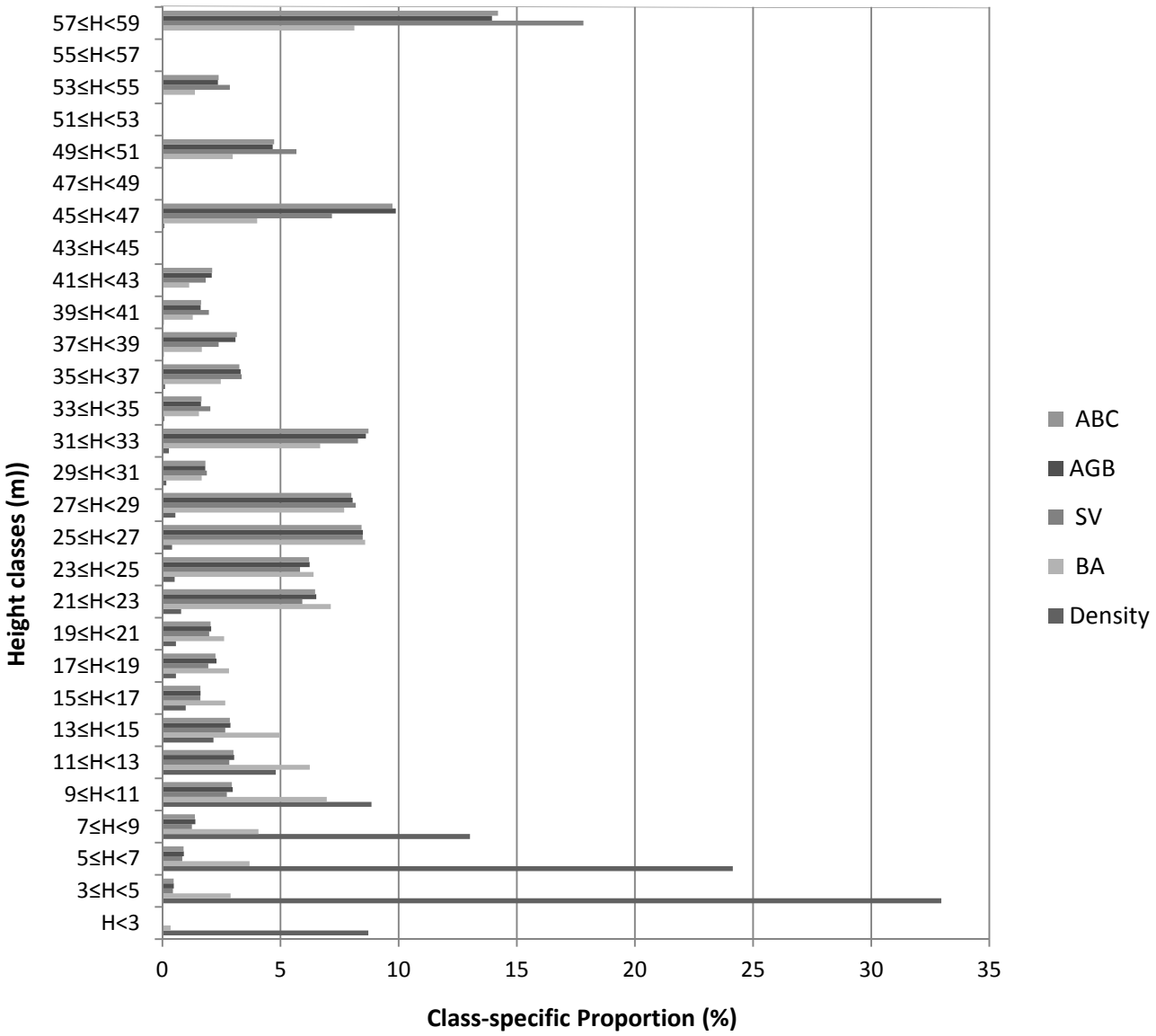

Figure 15: Distribution of key forest variables across height classes (m) for all trees dbh ≥ 1cm dbh. The class-specific proportion of the total stem density (Density), basal area (BA), standing volume (SV), above ground biomass (AGB) and carbon stock (AGC) is given as percental ratio.

Figure 16 displays the distribution of the forest characteristics and estimates under examination for data set 2 (dbh≥10cm). The relative majority of stems reach heights between 9 and 15 meters. The contribution of trees recorded in height classes smaller than 9m to the stand basal area, total volume as well as living biomass density and carbon stock per hectare remains marginal. Although these classes entail the percental majority of stems their class-specific share in the total is limited to less than 4% (expept for BA/ha).

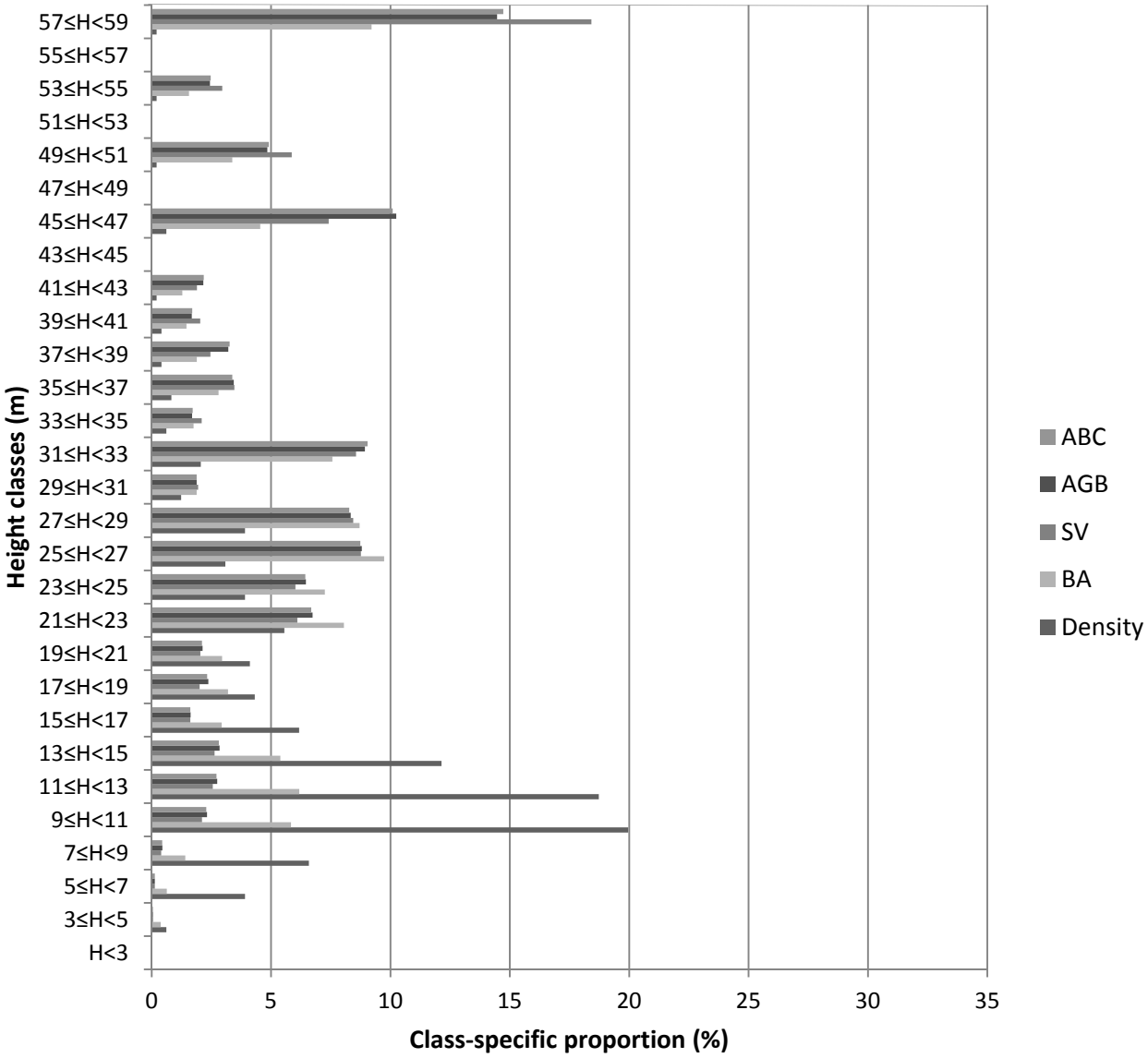

Figure 16: Distribution key forest variables in the vertical stratification system (2m height classes) of data set 2. The class-specific proportion of the total stem density (Density), basal area (BA), standing volume (SV), above ground biomass (AGB) and carbon stock (AGC) is given as percental ratio.

The analysis of prevalent distribution indicates the stratification of the forest in three vertical forest stand layers: understory, medium layer, and overstory.The understory layer consists of a mixture of juveniles of canopy trees, small understory trees and ligneous shrubs. It includes all woody vegetation smaller than 15m in height. Trees between 15 and 31 meters in height are assigned to the medium layer. All trees taller than 31 meter compose the overstory (canopy and emergent trees).

Table 11 summarizes density and species distribution across the understory, medium layer and overstory in data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm).

In data set 1 (dbh≥1cm) the understory contains 3454 individuals, i.e. roughly 95% of all stems. The 3454 individuals represent 142 (approximately 94%) of all species found in data set 1. The quadratic mean height in the understory is influenced by numerous small trees and juveniles. It remains relative low at 6.6 meters. In data set 2 (dbh≥10cm) the number of trees staying in the understory layer declines to 301 stems per hectare, i.e. 62% of all individuals in data set 2 can be found in the understory. In the understory 65 species were counted, which corresponds to nearly 75% of the 85 species found in data set 2.

Table 11: Vertical stand stratification of data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm). Species number per layer was determined counting each species represented by at least one tree in the respective height layer.

Layer	Height (m)	Mean Quadratic Height (m)	Density (stems/ha)	Prop. Density (%)	Species (ha)	Prop. Species (%)
Data set 1						
Understory	< 15	6.6	3454	95	142	94
Medium	< 31	21.7	167	5	48	32
Canopy	≥ 31	38.6	28	6	14	9
Data set 2						
Understory	< 15	11.1	301	62	64	75
Medium	< 31	21.9	157	32	49	57
Canopy	≥ 31	38.6	28	6	14	16

In data set 1 the medium layer is composed of 167 individuals (9%). The medium layer contains 10 fewer individuals in data set 2 and respectively, represents 32% of all trees. The number of species that occurs in the medium layer is quasi identical in data set 1 and data set 2 (48 and 49) Both, the number of stems and species found in the canopy layer is identical for data set 1 and data set 2.

The majority of canopy trees measure between 31m to 41m. Consequently, the estimated quadratic mean height equals 37.9 meters. Only a very few isolated “emergents” overtop the general canopy and reach heights up to 57m.

The detailed investigation of species´ occurrence and composition in the vertical classification scheme is given in Annex C, Table 28. The number of species found in each of the three height layers (understory, medium layer, canopy incl. emergent layer) was determined counting each species represented by at least one tree in the respective layer. To show species-specific distribution patterns in the vertical stratification system each species was assigned once to the layer where its tallest individual occurs. That is, with a maximum tree height of 14.6m Ozouga is counted as species in the understory. Aiele is

represented in both understory and medium layer. Since its tallest tree grows in the medium layer the species is assigned to the medium layer.
In sum 98 species, equal to 64.9% of all species, are exclusively represented in the understory layer and were not recorded with top heights greater than 15 meters. The medium layer contains another 39 species (25.8%) that do not grow beyond 31m top height. As already summarized in Table 10, 14 species with top heights of 31m and higher were assigned to the canopy and emergent layer.
The most frequent species represented in all height layers is Okoumé, a typical emergent tree. It is also the most abundant species in the canopy layer. Other characteristic species of the canopy like Faro, Douka, Tsêle, Ilomba and Tali were found and represented in all three forest stand layers. The abundant and frequent species of the under-, and medium layer Colatier and Commisaire was recorded with one tree in the canopy. Three of the species recorded in the canopy were not found in the understory or medium layer but solely occur as singletons in the overstory (Moka, Gaga, Tsama). Another mentionable species in regard to its vertical zonation is Lekaia. In the understory one individual was recorded, but the species is frequently found in the medium layer and provides two trees in the canopy and one in the emergent layer

To receive an appraisal of the vertical stand structure of the forests on the study side, the present results were compared to literature as well as to findings made 18 years ago in the Mondah forests and to a field assessment carried out in the Waka National Park, Gabon. Typically the forests of the Guineo-Congolian region measure at least 30m in height, whereas maximal heights between 45-55 meters occasionally occur and even taller trees are possible in rare cases (White 1983; Pietsch 2000). Regarding the vertical stand stratification around half of the trees (dbh>10cm) are predicted to stay in the understory layer, while 10% to 15% reach the canopy layer (Pietsch 2000).
The Waka National Park was selectively logged 50 years ago. Like in the surrounding of the Mondah forests signs of old settlements and human activities are still evident (Balinga 2006). Mean and plot-specific species abundance and composition, stand density and total basal area show similarities to the forest stand in Mondah (see Table 3 and Balinga 2006). However, in terms of the vertical stand structure differences can be observed between the two forests. While the stand structure of the Waka National Park fits the vertical categorization indicated by Pietsch (2000), the distribution in the Mondah forests differs (see Figure 17).

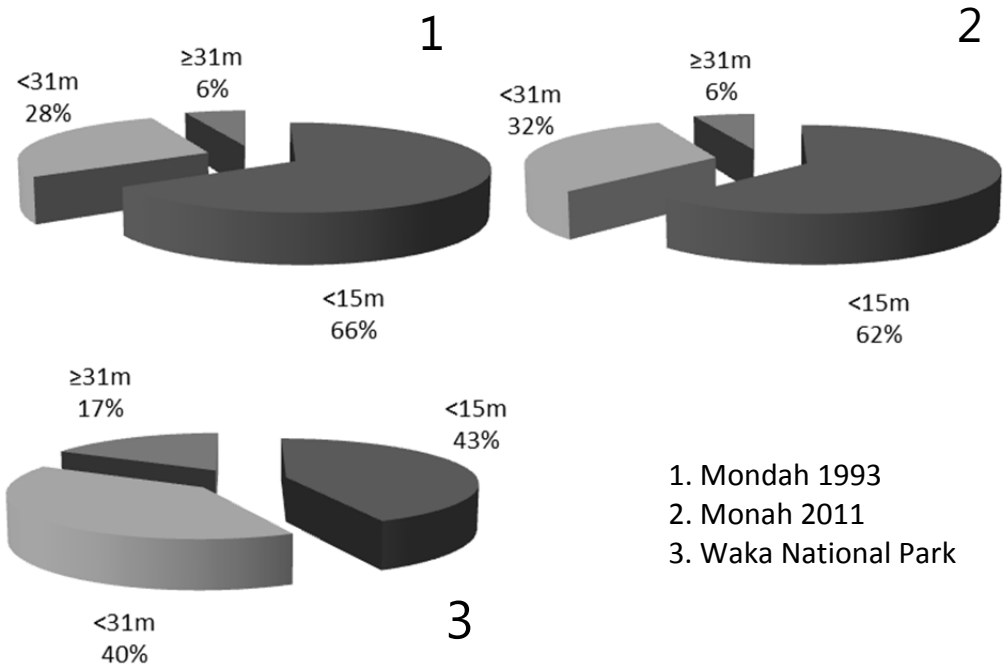

Figure 17: Vertical stand stratification in Mondah 1993 (1), Mondah 2011 (2) and the Waka National Park (3). Proportions are given in percent. Source: (Balinga 2006; Pietsch 2000)

The largest variations between the tree assessments can be detected between the understory layers of the different assessments. While in the Waka National Park 43% of the trees measure less than 15 meters in height, this number amounts to 62% at the present study site in the Mondah forest. Hence, the number of trees staying in the medium and canopy layer is 33% lower compared to the number assessed in the Waka National Park. Especially the canopy and emergent layer exhibits a lower portion of trees. The percental amount of stems in the canopy layer of the Waka National Park fits the regional specification given above. In contrast, only 6% of all trees could be ascribed to the canopy in the Mondah forests, which is approximately 50% less than predicted for the forest of the region.

In addition, the forest stand of the National Park in Makokou, Gabon is used to evaluate the maximum and mean height assessed in the study site. In 2006 Sasses and Wan (see Sassen and Wan 2006) surveyed several forest units placed in secondary and primary forest stands in Makokou. They conclude that the primary forest exhibits a mean height of 16.74m and reaches a maximum height of 45m. The trees situated in secondary forest stands exhibit a mean height of 13.2m and measures maximal 40m in height.

The quadratic mean height of the forest stand under investigation was calculated at 17.79m (see Table 11). The tallest tree found at the study site in Mondah measures 57.7m in height. Thereby, both mean and maximal tree height in the Mondah forests surmount the findings made in the forests of the Waka and Makokou National Parks.

3.1.3. Tree-Species Diversity

This chapter of the study focuses on the investigation of species richness, species composition and species distribution across the forest stand and its variability among the different point sample units in the study site. Diversity analysis was based on all species collected and identified in local languages.

3.1.3.1. Species Richness

The species richness of the present assessment equals the number of species recorded on one hectare, i.e the sum of the number of species found in the seven point sample units. The species richness in data set 1 (dbh≥1cm) amounts to 151 species/ha and to 85 species/ha in data set 2 (dbh≥10cm).

In order to evaluate and rank the species richness determined in data set 2 (dbh≥10cm), it was compared to the findings of other field assessments carried out in the region. This study found that although the number of species represented by stems with dbh≥10cm in the Mondah forest increased during the last two decades, it still ranks below those of other species rich forests in the region (see Table 12). On the other hand it is concluded that with 150 recorded species (dbh≥1cm) on one hectare the study site exhibits a high number of species in regard to small stem sizes.

Table 12: Indication of the number of species and families found in different forest stands in the western Congo Basin. Minimum dbh≥10cm. [1]only botanically identified species could be assigned to families. This number will rise when botanical species identification would be extended to all species. [2]min diameter requirement dbh≥5cm. [3]30 Sample plots of 40m length, divided into four rectangular sections of 10m length and a variable width (max. 40m) Sources: (Sunderland et al. 2004; Pietsch 2000; Balinga 2006; Sassen and Wan 2006; Campell et al.; Senterre and Nguema 2002)

Study Site	Reference Unit (ha)	Number of Species
Mondah Forest (1993)	1	78
	1,6	102
Mondah Forest (2011)	1	85
Waka National Park	1	93
	5	211
Mbé National Park	1	97
	5	152
Gamba Complex	7,5[2]	353
Mokokou Primary Forest	Unknown[3]	160
Norsk (Equatorial Guinea)	1.28	149

The area-species curve drawn for the study site was set in relation to nine other forest assessments carried out in Central Africa. The areal-species curve drawn for species that are represented by stems dbh≥10cm in the study site (Figure 18, named with Mondah) ranks

in the lower midrange compared to other Central-African rainforests. But similar to other study sites the course of the curve shows the potential to further rise with increasing sample size.

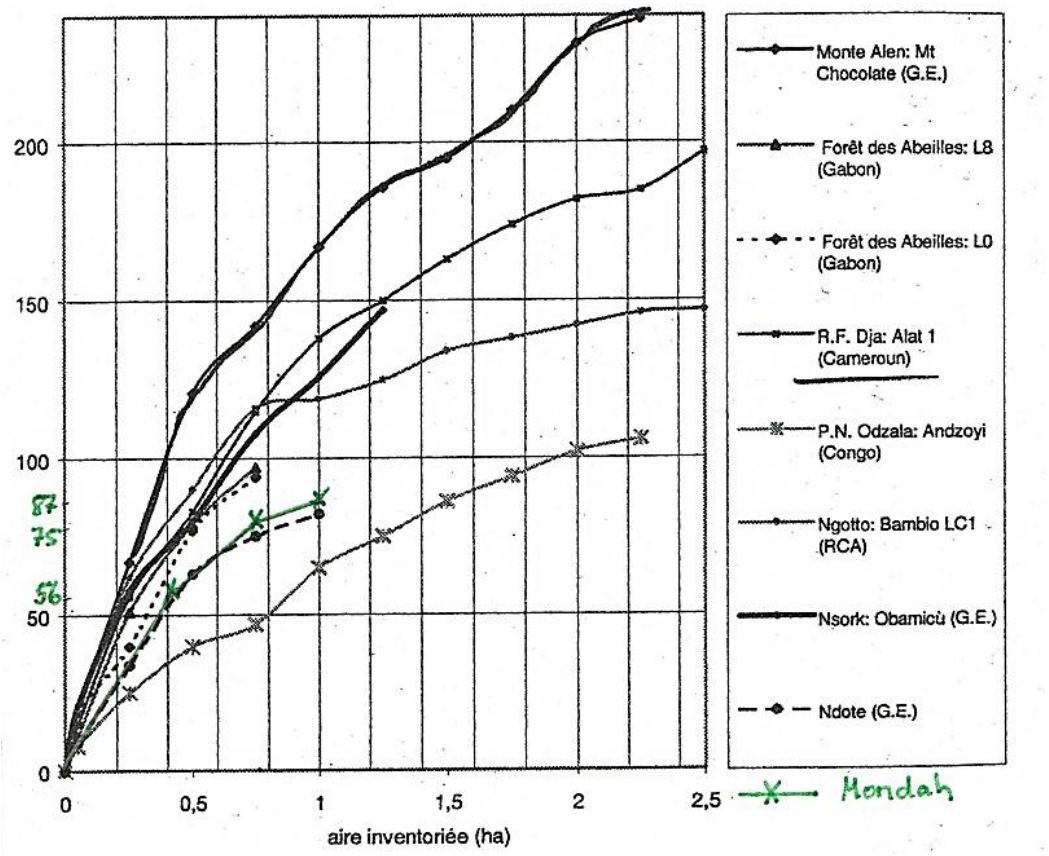

Figure 18: Area-Species-Curves, drawn for nine forest assessments conducted in Central Africa, including the study site in the Mondah forest. Minimum dbh ≥ 10cm. Source: (Senterre and Nguema 2002, p844) -modified.

When a minimum dbh≥30cm is assumed for surveying the study site exhibits relative species poverty, i.e. the number of species represented by stems dbh≥30cm found in the present study comes up to 42. Compared to the other Central-African sites shown in Figure 19 the area-species-curve estimated for the present study site runs below all other displayed areal-species curves.

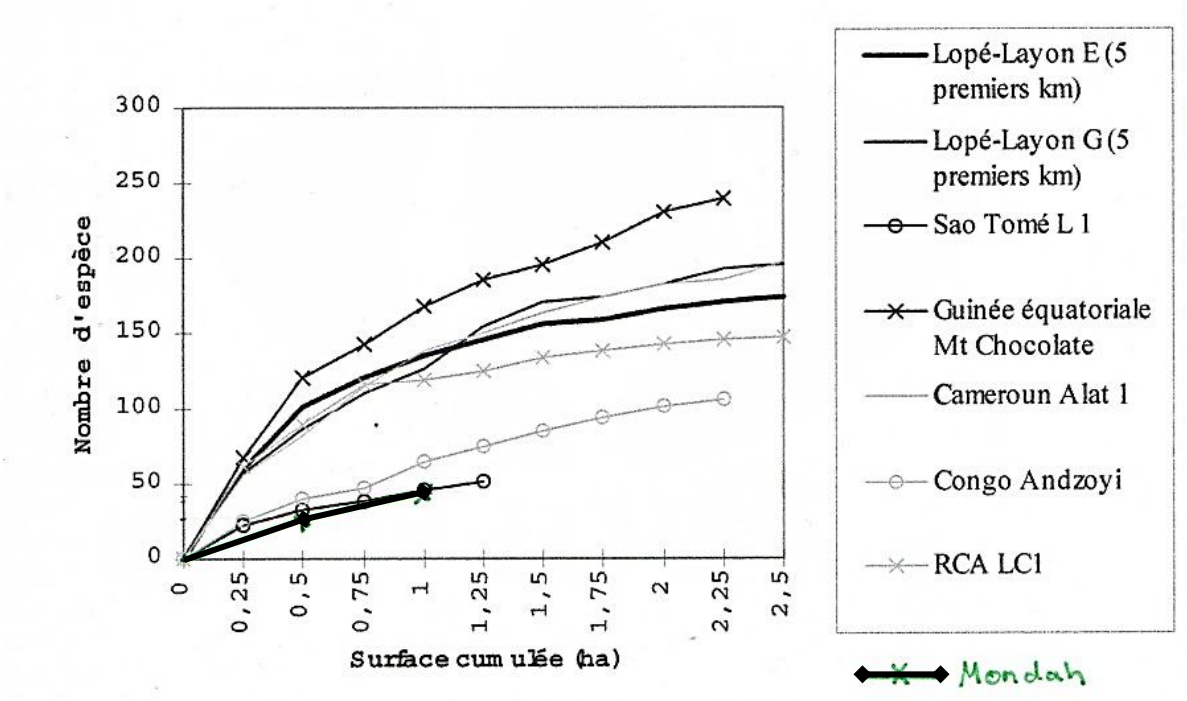

Figure 19: Area-Species-Curves, drawn for seven forest inventories realized on ECOFAC study sites and one site located in the Mondah forest. Minimum dbh ≥ 30cm. Source: (Doucet and Brugiere), Figure 2; after Lejoly 1996) -modified.

Even though the number of species in the study represented by stems dbh≥10cm or dbh≥30cm by far does not reach the levels found on the most species rich sites in the Congo Basin assessed up to now, it can be assumed that today´s numerous small-sized stems will increase that number in future.

3.1.3.2. Inventory Diversity

According to the definition in chapter 1.5 the term inventory diversity refers to “within habitat diversity”. It is reported as sample species richness for data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm).

Although single counting of species richness per hectare may lead to a useful outcome (Magurran 2004), it only delivers limited meaningful information in regard to the stands´ heterogeneity. Thus, more sophisticated indices that measure the proportional distribution of the individuals among these species serve as complement (Gray 2000).

In this context the concept of rare species is used as pragmatic measure for inventory diversity. In principle it is assumed that the higher the proportion of rare species, the more diverse an assemblage is. The analysis of the number of individuals per species reveals that 1/3 of all species are represented by 1 stem, and thus are classified as singletons. As illustrated in Table 13 this result is valid for both data set 1 and data set 2. Another 11% of species in data set 1 (dbh≥1cm) and 16% in data set 2 (dbh≥10cm), are represented by 2 stems and thus, counted as doubletons. Based on the findings illustrated in Table 13, the number of rare species within the study site is rated as high in both data sets. In addition, the

majority of species is represented by less than 10 stems. These results point to a highly heterogenous forest stand.

Table 13: Individuals per species (ha) in data set 1 (dbh≥1cm) and in data set 2 (dbh≥10cm)

	Data set 1		Data set 2	
Individual per Species	**Absl. N° Species**	**Rel N° Species (%)**	**Absl N° Species**	**Rel N° Species (%)**
1	49	32,67	29	33,72
2	17	11,33	14	16,28
3	10	6,67	12	13,95
4	7	4,67	6	6,98
≥ 5	16	10.60	13	15.12
≥ 10	17	11,33	6	6,98
≥ 20	16	10,67	6	6,98
≥ 50	8	5,33	1	1,16
≥ 100	9	6,00	0	0,00
≥ 200	2	1,33	0	0,00

The results of the complete inventory diversity assessment, including species richness of the sample site, are summarized in Table 14. Fisher's Alpha (α) is used as parameter that is assumed to indicate the number of extremely rare species in the sample and thus, giving an appraisal of the species heterogeneity in place.

Table 14: Measures applied to the assessment of inventory diversity for data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm). All formulas are given and explained in chapter 2.8.2.

Diversity Measure	**Appreviation**	**Equation**	**Data set 1**	**Data set 2**
Individuals	N	count	3649	486
Species	S	count	151	85
Singletons	Sing	count	50	30
Singletons (%)		(26)	33,11	35,29
Doubletons	Doub	count	16	14
Doubletons (%)		(27)	10,66	16,47
Indices				
Fisher´s Alpha	α	(18) (19)	31,23	26,47
Shannon	H´	(20)	3,70	3,75
Berger-Parker	d'	(21)	0,16	0,13
Simpsons	D	(23)	0,05	0,04
1-Simpson	1-D		0,95	0,96
Shannon-Evenness	J`	(24)(25)	0,74	0,84

The Shannon Index (H') stresses the richness component of inventory diversity taking into account species abundance and dominance. The index produces values from 0 for assemblage occupied by a single taxon to higher values for samples with a plurality of species, each with few individuals. According to Magurran (2004) in most cases the index value ranges between 1.5 and 3.5. It is suggested to rarely exceed 4.0 and only huge numbers of species in one sample could produce values > 5.0 (Magurran 2004).
For both data sets under consideration the index produces values greater than 3.5 (see Table 14). The index value produced by the Shannon measure for data set 2 was set in relation to another vegetation assessment carried out in the Waka National Park. The Shannon measure of heterogeneity was applied to investigate species diversity of one hectare sample plots for all trees with dbh≥10cm (Balinga 2006). The resulting values vary from 3.34 to 4.41. The value obtained for the study site in the Mondah forest ranks at the lower end of this range (see Figure 20).

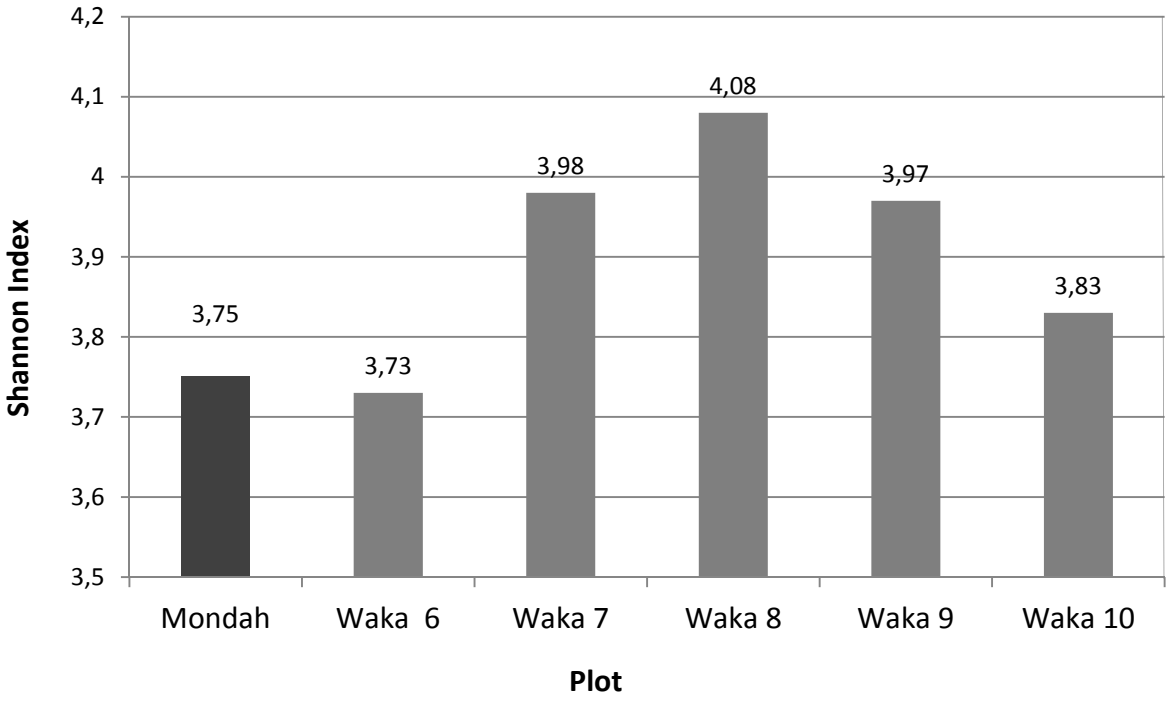

Figure 20: Comparison of species diversity of all trees≥10cm dbh across 1 hectare sample sites in the Waka National Park and the 1 hectare sample site in the Mondah forest using the Shannon diversity index. Source: (Balinga 2006) - modified.

The Berger-Parker (d') index is a dominance measure that describes the relative dominance of the most abundant species found in the sample. It simply gives the proportional number of stems provided by the most abundant species compared to the total. The index value varies between zero and one and equals one if the forest stand is completely dominated by one species. A decrease in the index value signifies a decrease of dominance and respectively,

an increase in the species diversity. As illustrated in Table 14 the Berger-Parker measure computes low index values for data set 1 and data set 2 and consequently rates the dominance of the most abundant species with the forest stand as low.
The Simpson measure (D) emphasizes the evenness component of diversity. Due to the fact that the Simpson index takes all species recorded into consideration it provides a more refined analysis of species dominance. The index value ranges between zero and one. An increase in D signifies a decrease in diversity thus, the maximal possible value 1 indicates that the sample is totally dominated by one species. Consequently, an increase in D signifies a decrease in diversity. Sometimes it is recommended to express the index value as the complement (i.e. 1-D). By doing so the index is turned into a kind of heterogeneity measure since the index value follows the intuitive logic and rises as the sample becomes more even and thus more diverse (Magurran 2004).The Simpson index produces very low values for both data set 1 and data set 2. Expressed as its reciprocal (1-D) the index produces values near one for both data sets under investigation indicating a very heterogeneous (non-dominated and evenly distributed) forest stand and thus, rates the species dominance in both data sets as very low.
The Shannon measure of evenness (J`) is normalized to the maximum diversity that could possibly occur within an assemblage ($H_{max}$). The values obtained by the Shannon measure of evenness (J`) varies from zero to one, whereas an increase in the values goes along with an increase in the evenness. Perfect evenness (J´= 1) is accomplished if all species are represented by the same number of individuals, i.e. all stems are equally distributed and no species dominates the forest stand. The ratio between observed diversity and maximum diversity can be used to express evenness (Magurran 2004). The values obtained for the two data sets under investigation indicate an augmented evenness regarding the stem distribution among the species ($H'_1 = 0.74$; $H'_2 = 0.84$) and hence point to a heterogeneous and diverse forest stand.

3.1.3.3. Turnover Diversity

According to the definition made in chapter 1.5 the term turnover diversity refers to “between habitat diversity”. The turnover diversity is given as pattern diversity, i.e. the change in species occurrence and composition between sample quadrates.
The single exaption in this context is Whittaker’s measure of beta-diversity (β_W) since β_W (see equation 28) was applied to assess the overall species differentiation (species turnover) across the sample area as a whole (for further detail see chapter 2.8.3.1).
In this case, the highest possible index value (maximum species turnover) equals the number of sample sites, no species replacement between the sample points would result in an index value of one (completely identical species composition across the entire sample

area). Since data set 1 and data set 2 entail four equally-sized sample sites (see explanation below), β_W =4 would indicate maximal species turnover, i.e. the different sample points share no species in common.
The overall turnover diversity in data set 1 (dbh≥1cm) was estimated at β_W = 1.95, indicating a species replacement at around 30%. The overall species turnover in data set 2 (dbh ≥10cm) equals β_W = 2.77 and hence, points to a species differentiation across the sample site at around 50%.

Pattern diversity between sample quadrates was assessed using pairwise comparison. The pairwise assessment of species turnover between spatial areas is only feasible for even-sized sample plots. The present data set is composed of different-sized plots. Thus, turnover diversity measures were applied two times. Spatial variation in species composition and occurrence was estimated between the four 0.25 hectare plots using Plot 1 (P1), Plot 2 (P2) and Plot 3 (P3). Additionally, a fourth 0.25 ha plot was created combining the data of Plot 4 (P4), Plot 5 (P5), Plot 6 (P6), and Plot 7 (P7), each 0.625 ha in size, and handle them as one 0.25ha plot. This plot was termed (P4-7). Additionally, the turnover diversity between the four 0.0625ha plots (P4, P5, P6, and P7) was calculated. In a second step, the differentiation of species turnover between data set 1 and data set 2 was assessed.
As introduced in chapter 2.8.3, four different indices stressing different components of species turnover were employed: the Marczewski-Steinhaus index of complementarity (C_{MS}), the Sørensen (C_S) index of similarity, Lennons β_{sim}, and the Brain-Curtis (C_N) quantitative similarity index.
The more complementary two sites are, the higher their species turnover is. Similarity indices (e.g. Sørensen) can be used to determine complementarity between sites. But similarity indices produce high values for similar and respectively, less diverse sample pairs. The result for two sites with completely identical species composition would equal one. The lower the index´ value, the higher is the differentiation between a pair of sample sites. In order to avoid confusion, the results of all similarity indices used for the present analysis are given as its complement (1 -index value). The subtraction of the index´ value from 1 modifies the indices into an intuitively meaningful diversity measure. Complete complementarity would then result in an index value equal to one, complete similarity would be expressed by an index value of zero.
The analysis of species turnover in data set 1 (dbh≥1cm) is summarized in Table 15. In regard to the 0.25ha plots the four applied measures produce similar rankings of the species differentiation between the sample quadrates. Consistently, all indices identify plots P1 and P4-7 as the most similar ones in reference to their species composition. In fact, these plots share 50 species while 19 species exclusively occur in P1 and 17 species solely in P4-7.

Table 15: Pairwise comparison of sample plots using the Marczewski-Steinhaus index of complementarity (C_{MS}; equation 30), the Sørensen (C_S; equation 31) index of similarity, Lennons β_{sim} (equation 33), and the Brain-Curtis quantitative similarity index (C_N; equation 32) as measures for pattern diversity between single sample units of data set 1 (dbh≥1cm). The highest and lowest index values are marked in grey. The index formulas used are given and explained in chapter 2.8.3.

Data set 1							
0.25ha Plots				**0.0625ha Plots**			
C_{MS}	**P2**	**P3**	**P4-7**	**C_{MS}**	**P5**	**P6**	**P7**
P1	0,53	0,63	0,42	**P4**	0,56	0,55	0,60
P2		0,63	0,55	**P5**		0,55	0,61
P3			0,65	**P6**			0,54
Mean = 0.56				**Mean = 0.56**			
1-C_S	**P2**	**P3**	**P4-7**	**1-C_S**	**P5**	**P6**	**P7**
P1	0,36	0,46	0,26	**P4**	0,39	0,35	0,40
P2		0,47	0,38	**P5**		0,38	0,44
P3			0,48	**P6**			0,37
Mean = 0.40				**Mean = 0.39**			
β_{sim}	**P2**	**P3**	**P4-7**	**β_{sim}**	**P5**	**P6**	**P7**
P1	0,30	0,38	0,25	**P4**	0,29	0,37	0,36
P2		0,44	0,31	**P5**		0,26	0,42
P3			0,39	**P6**			0,27
Mean = 0.35				**Mean = 0.33**			
1-C_N	**P2**	**P3**	**P4-7**	**1-C_N**	**P5**	**P6**	**P7**
P1	0,39	0,50	0,31	**P4**	0,44	0,43	0,58
P2		0,44	0,36	**P5**		0,62	0,59
P3			0,53	**P6**			0,51
Mean = 0.42				**Mean = 0.53**			

With one exception, the plot combination P3 and P4-7 is assessed as the most diverse in terms of species turnover by the measures employed. These quadrates have 41 species in common, 49 species could only be found in P1 and respectively, 26 in P4-7. The plot combinations P1/P3 and P2/P3 closely follow in reference to their differences in species composition.

Only index β_{sim} rates the species turnover between P2 and P3 (shared species = 46, only P2 = 36, only P3 = 44) higher than between P3/ P4-7 and P1/P3.

Although the four indices rank the plot consistently in regard to their complementarity in species, the estimated degree of species turnover varies in dependence of the employed measure. The species replacement is assessed as lowest by β_{sim} (between 0.25 and 0.44 on the scale between zero and one) and as highest by C_{MS} (between 0.42 and 0.65 on the scale between zero and one).

The assessment results produced for the smaller sample plots (0.0625ha) differ depending on the index used. Except for C_N, all measures rank P5 and P7 as the most complementary sites. Plot combination P4/P6 is assumed to be the most similar one by C_S and its quantitative counterpart C_N, while β_{sim} evaluates plots P5 and P6 as the most similar ones. It is worth noting that in contrast to β_{sim}, C_N appraises P5 and P6 as the plots with the highest species differentiation. Analoguos to the analysis of the large sample plots the index values vary depending on the applied measure in the range of 0.54 to 0.61 (C_{MS}), 0.35 to 0.44 (1-C_S), 0.26 to 0.42 (β_{sim}), and 0.43 to 0.63 (1-C_N).

The assessment of species turnover in data set 2 (dbh≥10cm) is summarized in Table 16.

Table 16: Pairwise comparison of sample plots using the Marczewski-Steinhaus index of complementarity (C_{MS}; equation 30), the Sørensen (C_S; equation 31) index of similarity, Lennons β_{sim} (equation 33), and the Brain-Curtis quantitative similarity index (C_N; equation 32) as measures for pattern diversity between single sample units of data set 2 (dbh≥10cm). The highest and lowest index values are marked in grey. The index formulas used are given and explained in chapter 2.8.3.

Data set 2							
0.25ha Plots				**0.0625ha Plots**			
C_{MS}	**P2**	**P3**	**P4-7**	**C_{MS}**	**P5**	**P6**	**P7**
P1	0.60	0.72	0.53	**P4**	0.77	0.74	0.83
P2		0.71	0.61	**P5**		0.84	0.96
P3			0.73	**P6**			0.87
Mean = 0.65				**Mean = 0.83**			
1-C_S	**P2**	**P3**	**P4-7**	**1-C_S**	**P5**	**P6**	**P7**
P1	0.44	0.56	0.36	**P4**	0,63	0.59	0.71
P2		0.55	0.44	**P5**		0.73	0.93
P3			0.58	**P6**			0.76
Mean = 0.49				**Mean = 0.73**			
β_{sim}	**P2**	**P3**	**P4-7**	**β_{sim}**	**P5**	**P6**	**P7**
P1	0.42	0.55	0.33	**P4**	0,50	0.57	0.67
P2		0.53	0.39	**P5**		0.64	0.92
P3			0.56	**P6**			0.73
Mean = 0.46				**Mean = 0.67**			
1-C_N	**P2**	**P3**	**P4-7**	**1-C_N**	**P5**	**P6**	**P7**
P1	0.49	0.53	0.49	**P4**	0,64	0.68	0.75
P2		0.67	0.54	**P5**		0.76	0.94
P3			0.67	**P6**			0.76
Mean = 0.57				**Mean = 0.75**			

In conformity with the results gained for the 0.25ha plots of data set 1 (dbh≥1cm) all four measures rank the quadrates P1 and P4-7 as the most similar (shared species = 27, only P1 = 13, only P4-7 = 17) and P3 and P4-7 as the most complementary sample points

(shared species = 18, only P3 = 23, only P4-7 = 26). Moreover, species turnover is high between P1 and P2, followed by P2 and P3. The quantitative C_N index assesses the latter together with P3/P4-7 as the most diverging ones. Like plots P3 and P4-7, the combination P2/P3 has 18 species in common, 20 species solely occur in P2 and respectively, 24 in P3. While C_{MS} produces values between 0.53 and 0.73 for the 0.25ha plots, C_S and β_{sim} come up to values from 0.33 to 0.58, and C_N varies in the range from 0.49 to 0.67.
In regard to the small sample quadrates (0.0625ha), the sample points P5 and P7 are rated as the most differentiating sample points by all measures, followed by P6/P7. Quadrates P4 and P6 are now perceived as the most similar combination by C_{MS} and C_S. In terms of species differentiation formerly middle-rated plots P4 and P5 are assessed as the most similar by β_{sim} and C_N.
The degree of species differentiation among pairs of sample quadrates oscillates in dependence of the respective plot combination. While the species turnover between P5 and P6 is ranked as very high by all indices (in fact, these two plots only have 4 tree species in common and are characterized by index values above 0.9) it drops down to values between 0.5 and 0.6 for other plot combinations.

The twofold analysis carried out for different sized sample quadrates can be used to investigate if the assessed species turnover is notably higher between small sample quadrates (0.0625ha) compared to the species differentiation between large sample plots (0.25ha) and thus, better mirror varying pattern diversity.
Table 17 summarizes the differences in pattern diversity between the two different sized sample quadrates. To quantify the difference in species turnover between small and large sample quadrates the mean index value obtained for all pairs of sample points was calculated.
In data set 1 (dbh≥1cm) it is not possible to detect a systematically augmented species turnover between smaller plots compard to the species turnover between larger sample plots. On the contrary, the average pattern diversity between the larger plots is rated as higher in two cases ($1\text{-}C_S$ =2.56% and β_{Sim} =8.94%). Only the mean value produced by the index of Bray-Curits (C_N) indicates an increased species differentiation between the smaller sample quadrates (21%).
This is not true regarding the findings accomplished for data set 2. In fact, the species differentiation is constantly higher between the 0.0625ha sample units than between the 0.25ha plots. As highlighted in Table 17, the increase in species turnover varies between 22% and 33%. The highest differences were found between the two indices that either emphasize the proportion of species shared by both sample plots ($1\text{-}C_S$) or reflect the gain and loss of species between a pair of sample points (β_{Sim}). That is, the amount of species

shared by a pair of 0.0625ha sample plots can be perceived as notably lower than between two 0.25ha plots at the same time as the average species replacement is rated as more elevated between the smaller sample quadrates.

Table 17: : Comparison of the mean values derived from four indices measuring species turnover to quantify differences in the analysis of pattern diversity for two different sized pairs of sample quadrates in data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm). The difference between the two different sized sample quadrates is given in percent and calculated according to the formula: Difference=(1-data set 1/data set 2)*100

Data Set 1		**Plot Size**	**Difference**
Measure	**0.25ha**	**0.0625ha**	**(%)**
$\mathbf{C_{MS}}$	0,57	0,57	0,00
$\mathbf{1\text{-}C_S}$	0,4	0,39	-2,56
$\mathbf{\beta_{Sim}}$	0,35	0,32	-8,94
$\mathbf{1\text{-}C_N}$	0,42	0,53	20,75
Data set 2		**Plot Size (ha)**	**Difference**
Measure	**0.25ha**	**0.0625ha**	**(%)**
$\mathbf{C_{MS}}$	0,65	0,83	21,67
$\mathbf{1\text{-}C_S}$	0,49	0,73	32,88
$\mathbf{\beta_{Sim}}$	0,46	0,67	31,34
$\mathbf{1\text{-}C_N}$	0,57	0,75	24.00

3.2. Forest Regeneration

According to literature the different successions in forest regeneration can be described as follows: In its first stage of regeneration pioneer Guineo-Congolian rainforests are dominated by a mixture of bushes, small trees, soft woody shrubs and climbers that vary in height from 4 to 12 meters. Later, the young forests are marked by the dominance of the parasol tree (Musanga cecropioides). This typical pioneer tree reaches its optimum after 8-10 years, afterwards it dies quickly. The old secondary forest is composed of semi-heliophilous species that reach heights up to 35 meters. Ultimately, very old secondary forest is often difficult or impossible to distinguish from old-growth forests (White 1983; Corlett and Primack 2011; Makana and Thomas 2006). This classification explains well the different stages of forest regeneration observed by the author in the surroundings of the study site within the Mondah forests.

According to the Gabonese government department of forestry, characteristic tree species of domestic mature tropical forests in the coastal basin of Gabon are inter alia: Tali (Erythrophleum suaveolens), Ozouga (Sacoglottis gabonensis), Pau Rosa (Swartzia fistuloides), Erismadelphus exsul, Alep (Desbordesia glaucescens), Ozigo (Dacryodes buttneri), and Okoumé (Nasi 2001; Ministere des Eaux et Forets, Gabon 1999). During the present forest assessment it was possible to record these species in different states of regeneration on the study site, including Ozouga and Pau Rosa which are considered endangered commercial timber species (Nasi 2001). For sure, Okoumé is the best known and most valuable tree species of Gabon. Although this species is assumed to provide a bad regeneration ability (Campell et al.) it could be recorded abundantly in all diameter classes on the study site during the present assessment. However, its occurrence on the study site is limited to light areas, hillsides and plateaus and decreases with increasing proximity to the sea as well as on valley plains. Both species, Ozouga and Ozigo were represented by approximately 40 stems per hectare on the study site. While Ozigo is well distributed across all diameter classes up to 60cm dbh (see Annex B, Table 27), almost all stems of Ozouga are smaller than 10cm dbh and the largest stem measures 13.7cm dbh (see Annex B, Table 27). This study proposes that this effect may result from previous overexploitation and/or slow regeneration ability of the latter species. Pau Rosa and Alep were both found with three stems on the terrain of the study site. While Pau Rosa only was recorded with three stems dbh<10cm, Alep was also represented by one giant individual. Although Erismadelphus exsul was not recorded as a botanically identified species in the present assessment, it is known that this species is represented in the Mondah forest. It was recorded during a field assessment carried out near the present study site in 1993 (Pietsch 2000).

The pioneer parasol tree described above was not surveyed within the sample quadrates situated in the dense forest. It only occurs abundantly along forest roads and formerly cleared areas. This study proposes that this fact points to a proceeding maturation of the dense forest stand.

The comparison of the present field data with the results of a field assessment carried out in 1993 in the Mondah forests by a German-Gabonese research team (Pietsch 2000) indicates progress in the recovery and restoration of the forest structure.
The tree family structure assessed during the present analysis complies with the findings made during the forest assessment 1993 (Pietsch 2000) and thus, backs the results of the present assessment. Similar to the present study Caesalpinaceae, Annonaceae, Burseraceae, Euphorbiaceae, and Olacaeae were identified as the most specious families (Pietsch 2000). The number of species per hectare represented by stems with a dbh≥10cm increased by eight species compared to 1993 (see Table 12).
As highlighted in Table 3, the arithmetic mean diameter estimated for the present study site in the Mondah forest today is 1.4 cm higher than the arithmetic mean diameter assessed 18 years ago (Pietsch 2000). This effect becomes even more apparent when the quadratic mean diameters assessed in the two inventories are compared (difference +2.59 cm).
The basal area/ha occupied by all trees dbh≥10cm has increased by 5.78m^2 compared to the basal area determined in 1993. While the total basal area provided by all stems smaller than 10cm dbh was estimated as 3.86m^2/ha in 1993 it equates 4.74m^2/ha in 2011.
The absolute number of stems dbh<10cm today is lower than 18 years ago, while the absolute number of stems dbh≥10cm remains constant (486 stems in 2011 vs. 485 stems in 1993). The stand basal area/ha occupied by stems dbh≥10cm has increased by 19%. The annual increment in basal area equates 1.1%. This is true for both data sets.
Correspondingly, today the forest possesses a higher standing volume. The analysis carried out on the basis of the data from 1993 by Pietsch (2000) calculated the standing volume at 346m^3/ha (using equation 8, form factor f = 0.5). When applying this form factor to the data of the present study the standing volume today is estimated at 507m^3/ha. This difference equates to a total increase of 47% volume per ha during the last 18 years and an annual increment of 2.5%.
In order to compare the above ground biomass density of 1993 with the present findings the standing volume per hectare given by Pietsch (2000) was multiplied by the overall mean wood density calculated for the present analysis. According to this estimation the above ground biomass density in 1993 came up to 213482kg/ha. Consequently, the total increment in above ground biomass over the last 18 years is calculated at 130221kg/ha. This equals a yearly increase in above ground biomass of 6854kg/ha. The IPCC defines an annual above

ground biomass growth for African natural tropical rainforest older than 20 years of 3 100kg/ha (IPCC 2006). The yearly above ground biomass increment of the study site doubles this default value.

Changes in the horizontal forest structure are graphically illustrated in Figure 21 and Figure 22. With 3163 surveyed individuals the total number of stems per hectare dbh<10cm clearly ranks below the documented stem density of 6563 stems/ha in 1993 (Pietsch 2000). Even though granting that numerous small trees (1cm≤dbh≤2cm) were cut during sample plot preparation for the present forest assessment this count indicates decreasing stem densities in the smallest diameter class during the last 18 years. This process is well described in Figure 10 below. While in 1993 the number of the smallest stems exceeded the one of 2011, the number of stems with dbh equal to or greater than 3cm is up to 80 % higher in 2011 compared to 1993.

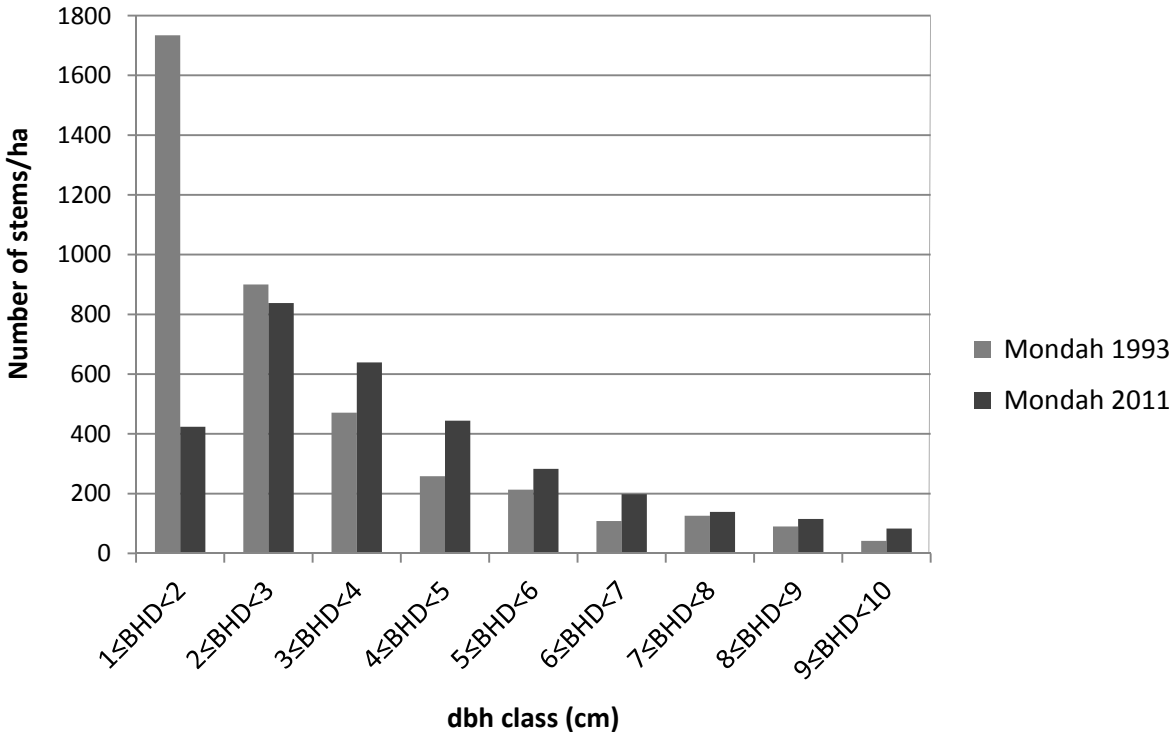

Figure 21: The number of stems smaller than 10cm dbh categorized in 1cm diameter classes recorded on one hectare within the Mondah forest in 1993 and 2011

Such a clear trend cannot be observed regarding the timber fraction 10cm≤dbh≤100cm. The findings of the two inventories are highly consistent in terms of total stem density and the overall tree diameter distribution. As in 1993 the inverted J-shaped diameter distribution described in Figure 9 and Figure 22 indicates a high natural regeneration potential of the forest (Nzogang 2009). During the present field assessment some fewer individuals could be assigned to smaller diameter classes and some more to the larger ones (except 60≤dbh<70).

However, it is suggested that this effect may arise by chance and therefore, does not necessarily point to a proceeding regeneration process of the large tree fraction.

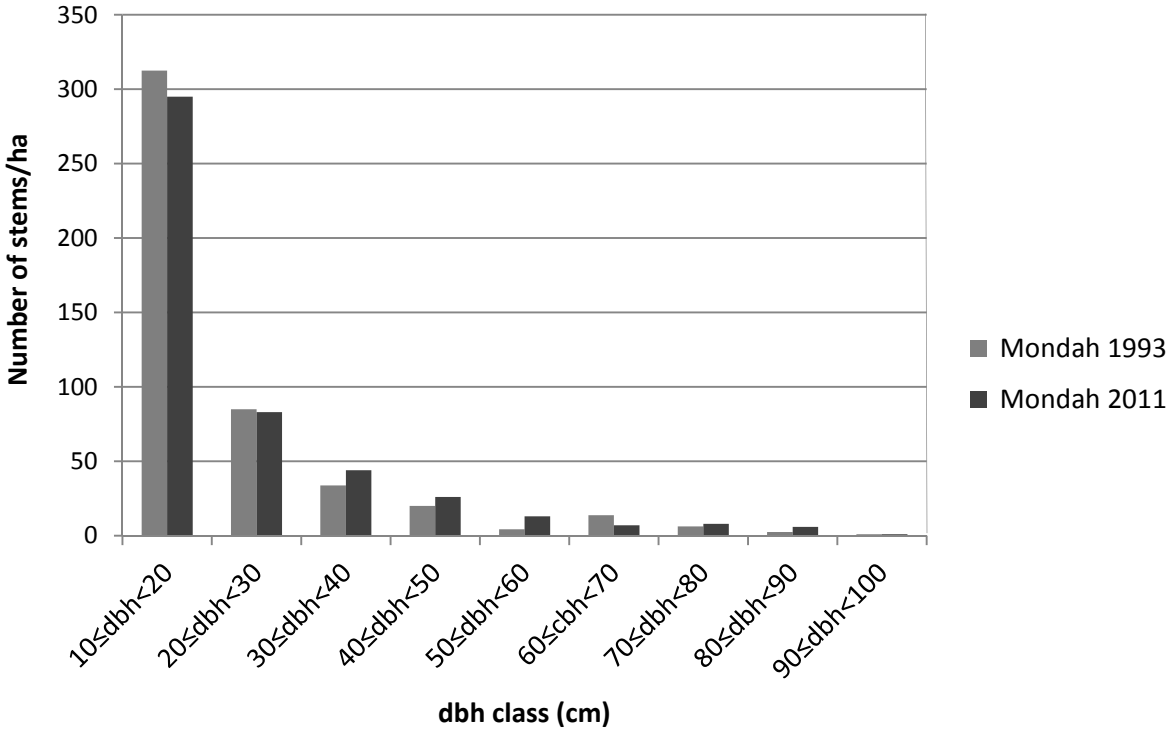

Figure 22: The number of stems equal to or greater than 10cm dbh categorized in 1cm diameter classes recorded on one hectare within the Mondah forest in 1993 and 2011

The previous findings are also true regarding the vertical stand stratification of the forest stand. In general the results of the present vertical stand structure analysis comply with the assessment of Pietsch (2000). The stem distribution across height classes is similarly shaped and characterized by decreasing stem counts with increasing height. Slight differences exist in regard to the total number of stems assigned to the understory and medium layer. During the present field assessment 4% fewer individuals were assigned to the understory at the same time as 4% more trees could be ascribed to the medium layer (see Figure 17). Figure 23 highlights that especially the height classes between 21m and 37m comprise more trees than in 1993. Despite this fact, the total number of stems in the canopy remains the same.

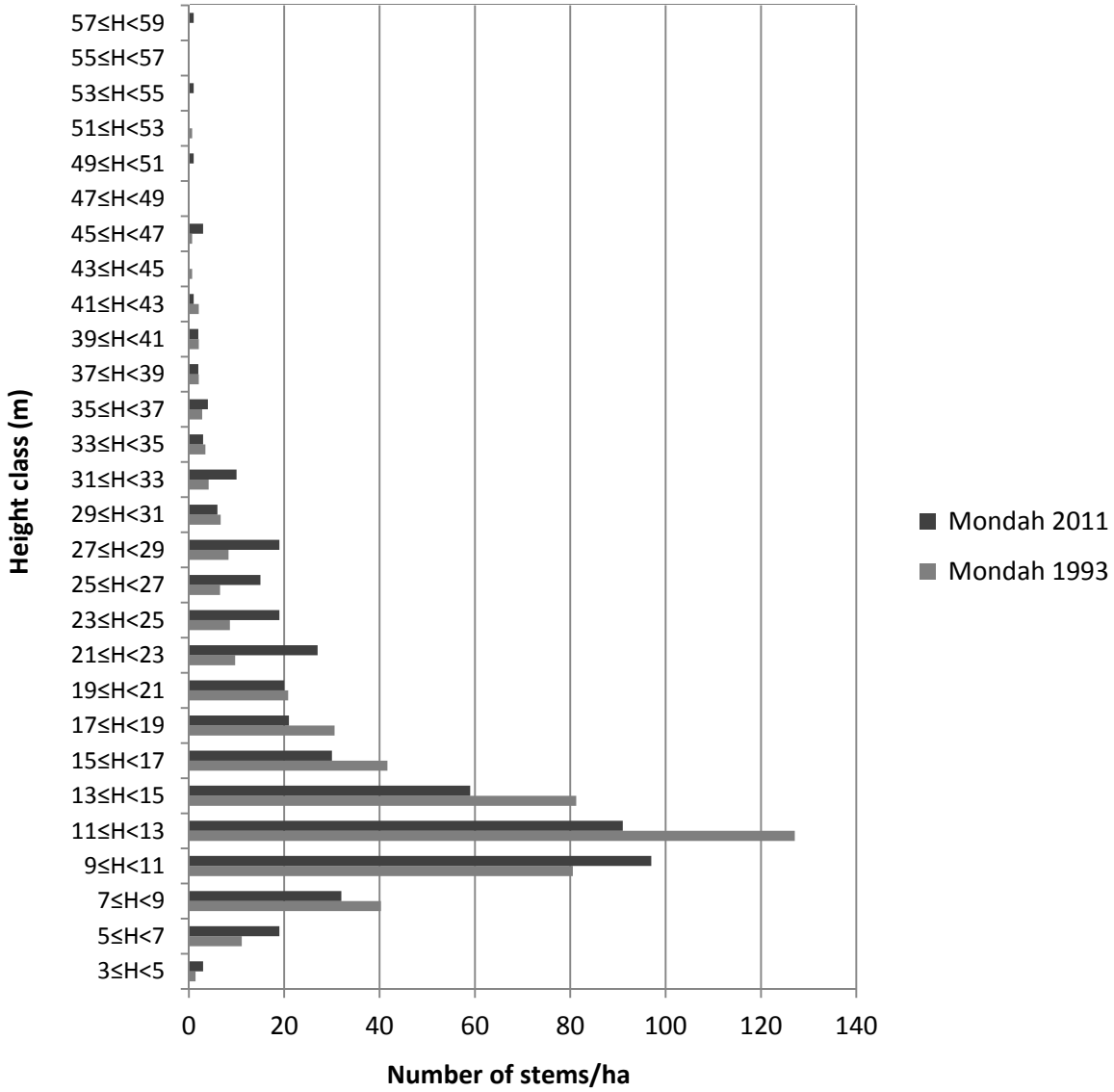

Figure 23: The number of stems equal to or greater than 10cm dbh recorded on one hectare within the Mondah forest in 1993 and 2011 categorized in 2m height classes.

3.3. Anthropogenic Impacts on the State of the Forest and Forest Recovery

The direct anthropogenic impact in the region around the study site is evident. Large parts of the Mondah forest ecosystems are heavily disturbed or destroyed, while intact forest areas are progressively diminishing. The local fauna is assumed to be heavily disturbed. Habitat destruction combined with high hunting pressure lead to the local expulsion of domestic mammals (e.g. elephants, big cats, antelopes, boars) and big reptiles (crocodiles, monitors). The clearance of forested areas for agricultural or construction purposes reaches right to the edge of the study site.

The state and regeneration of the forest stand under investigation is both directly affected by the intensive exploitation of valuable timber tree species in the past and indirectly impacted by consequences arising from human activities in the forest surroundings today.

The previous considerations (see chapter 3.1 and 3.2) reveal that the forest characteristics and stand structure of the study site already today tend to be more similar to those of mature forest structures. Given the precondition that the area is further protected from subsequent logging it can be assumed that structure and characteristics of the forest stand will reach a level comparable to mature forests in the region.

This is not true for the forest plant species diversity in place. In principle, due to its spatial proximity and similar climate and precipitation pattern the forests of Mondah can be assumed to exhibit comparably high levels of diversity as found in the Cristal Mountains, one of the most diverse areas of Gabon (Cabinet du Président de la République Gabon, s.a.; Sunderland et al. 2004). The lower level of species richness assessed on the present study site can be ascribed to human caused disturbances on the site itself and in the immediate spatial environment. Although numerous characteristic tree species of the coastal rainforest could be recorded during the present inventory, certain typical tree species of primary forest are lost (Sunderland et al. 2004) or only occur in minor abundances. The valuable timber tree species Moabi found in primary forest stands in Gabon can be used to representatively demonstrate the loss of plant species diversity due to anthropogenic disturbances in the region. That species once grew on the terrain of the study site and huge stumps of logged Moabi trees could be recorded during the present field assessment. Today this species still grows in the forests near the Cristal Mountains (Sunderland et al. 2004). Its natural regeneration on the terrain in and around the study site is prohibited. Beside the fact, that presumably all large reproduction trees of the species were removed from the forest, Moabi depends on forest elephants for seed dispersal. Since these large mammals were expelled decades ago, the regeneration of Moabi under present environmental conditions is impeded and the species locally extinct.

In contrast, there are other formerly heavily logged tree species whose regeneration does not seem to be impacted by human activities and which were found in a good stage of regeneration. One of these species is Douka. Numerous different-sized stumps at different stages of alteration of Douka were found on the terrain of the study site. Only one living individual with increased girth (44cm dbh) was recorded on the sample area. Both findings point to an intensive exploitation of the species. At the same time many small individuals with a dbh<10cm were collected across the study site indicating that the regeneration potential of this species is high despite ongoing human induced disturbances.

3.4. Impact of a Diameter Requirement dbh≥10cm on the Study Results

This study suggests that surveying trees to a minimum size limit of equal to dbh≥10 cm does not adequately represent the forest characteristics, structure and diversity in place. In particular, this assumption may be valid in reference to regenerating forests stands that are characterized by a high proportion of small diameter stems. Especially in this case juveniles and small trees potentially contribute more than the critical threshold of 5% percent to the stand basal area, standing volume, above ground biomass density and forest above ground carbon stock per hectare. Additionally, their exclusion possibly leads to misleading results regarding forest structure as well as plant species richness and diversity in place.
The low diameter requirement for a complete census defined for the purpose of the present study was set in order to capture the maximum of information in reference to the forest characteristics and ligneous stand diversity in place. Based on this information varying results caused by the definition of two different minimum diameters (data set 1, min dbh≥1cm; data set 2, min dbh≥10cm) could be analyzed in the following sub-chapters.

3.4.1. Impact on the Assessment of Forest Characteristics and Estimates

Table 18 briefly summarizes the absolute and relative differences caused by the definition of two different minimum diameters for the assessment of forest characteristics and variables. All values are standardized to one hectare. Row five indicates the proportional difference between data set 1 and data set 2. These values can be interpreted as the resulting “loss” if the ligneous vegetation smaller than 10cm dbh would be excluded from the assessment.

The stem densities between both data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm) differ. The neglect of stems smaller than 10cm dbh from forest mensuration leads to a decrease in assessed forest stand density of 86.7%. Consequently, the vast majority of stems are not missed in the analysis of data set 2. The exclusion of trees<10cm dbh in data set 2 implies a reduction of the diameter sum equal to 12233.7cm. Compared to data set 1 this signifies a relative decrease of 51.5%. The low arithmetic mean diameter in data set 1 (6.5cm) is strongly influenced by the large number of small trees included in the calculation. The quadratic mean diameter remains small too and is estimated at 11.85cm. The exclusion of small trees in data set 2 results in an increase of both the arithmetic mean diameter (+17.2cm) and quadratic mean diameter (+18.64cm).

Table 18: Key forest characteristics and estimates of data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm) with difference indicating the proportional reduction when stems (dbh<10cm) are excluded from the forest assessment; Difference = 100-((data set 2/data set 1)*100)

	Measuring Unit	Data set 1	Data set 2	Diff. absl.	Diff. (%)
Surveyed characteristics					
Density (abundance)	stems/ha	3649	486	3163	86.86
Species	nr/ha	151	85	66	43.70
Diameter sum	cm/ha	23772.9	11539.2	51.46	51.46
Mean diameter	cm	6.5	23.7	17.2	
Mean quadratic diameter	cm	11.85	30.49	18.64	
Mean height	m	6.9	15.8	8.9	
Mean quadratic height	m	8.64	17.79	9.15	
Lorey´s height	m	26	28.5	2.5	
Estimated variables					
Total basal area	m^2/ha	40.23	35.49	4.75	11.78
Total standing volume	m^3/ha	628.35	607.98	20.36	3.24
Above ground biomass	kg/ha	356463.76	343703.15	12760,61	3.58
Above ground carbon stock	t/ha	170.27	164.25	6.18	3.53

The difference in stand basal area between the two data sets accounts for 4.74m^2. Respectively, the neglect of small trees in data set 2 results in a loss of basal area equal to 11.8%. This value exceeds the critical threshold (5%) more than twice.
The total standing volume of data set 2 is 20.37m^3 lower than in data set 1, thus the difference between the two data sets counts for 3.2%. The difference in above ground biomass density between data set 1 and data set 2 equates a decrease of above ground living biomass density in data set 2 equal to 3.58%. Data set 2 holds 6014.95kg less carbon per hectare than in data set 1. This signifies a decrease of 3.5% in relation to the above ground carbon stock of data set 1. The previous results reveal that the contribution of trees smaller than 10cm dbh to total standing volume, above ground biomass density and carbon stock per hectare remains below the critical threshold of 5%.

3.4.2. Impact on the Assessment of the Stand Structure

3.4.2.1. Horizontal Structure

Both data sets resemble each other in regard to the horizontal stand structure. The smallest diameter class of both data sets (data set 1: 1≤dbh10<cm; data set 2: 10≤dbh<20cm) contains the largest share of stems and species. In both data sets the stems of the smallest diameter class occupy the proportionally largest portion of the stand basal area. However, the discrepancy between the first and the second diameter class in data set 1 is more pronounced than in data set 2. Thus, compared to data set 1 the relative decline of trees per diameter class with increasing diameter is lower in data set 2 (see Figure 9).

The relative species distributions in the diameter classes in data set 1 and data set 2 are similar. However, compared to data set 1 the first diameter class holds 10% less of all species recorded in the data set 2 (see Figure 13 and Figure 14). Except for the first diameter class of data set 1, the class-specific contribution to standing volume, above ground biomass density and carbon stock is similar for both data sets (see Figure 11 and Figure 12) and maximal one percentage point higher per class in data set 2.

3.4.2.2. Vertical Structure

The choice of the minimum diameter causes differences in the assessed vertical stand structure. The value of both mean height and quadratic mean height are strongly dependent on the number of smaller trees included in the estimation. Compared to data set 2, the arithmetic mean height calculated for data set 1 is 56% lower, the difference in the quadratic mean height counts for 51%. The mean height of Lorey remains limited and varies from 26m (data set 1) to 28.5m (data set 2) because it weights the contribution of trees to the stand height by their basal area (see equation 3).

The relative importance of the understory in regard to the contribution to forest characteristics and estimates under investigation is lower in data set 2. It can be seen that the exclusion of trees smaller than 10cm dbh in data set 2 results in a substantial drop regarding the total tree density (91%) and species abundance (55%) in the understory. While in data set 1 the understory provides 95% of all stems recorded, only 62% of the trees found in data set 2 can be ascribed to the understory layer. While in data set 1 most of the stems measure less than nine meters in height, the relative majority of stems in data set 2 reaches heights between 9 and 15 meters. The portion of stems represented in even smaller height classes decreases between 50% and 100% per class compared to data set 1. The quadratic mean height in the understory mirrors the exclusion of the smallest trees and rises from 6.6m in data set 1 to 11.1 meter in data set 2 (see Table 11).

The impact of the exclusion in reference to total class-specific basal area, standing volume, above ground biomass and carbon stock decreases with increasing height and is observable up to 15 meters height (see Table 10). However, the proportional importance of higher height classes remains higher in data set 2 than in data set 1.

The number of species that occur in the medium layer is quasi identical in data set 1 and data set 2 (48 and 49) but the proportional share of species the layer holds varies from 32% (data set 1) to 57% (data set 2). The quadratic mean height in the medium layer of data set 1 and data set 2 only slightly differs between 21.7 and 21.9 meters. This difference is caused by 10 slim (dbh<10cm) but tall trees recorded in data set 1 that reach the medium layer.

The tree and species composition of the canopy layer is completely identical for data set 1 and data set 2. Just the percental portions clearly differ between the two data sets.

3.4.2.3. Species Structure

The families found among the most specious ones are similar in data set 1 and data set 2, even though they change their rank and order in data set 2. However, since the family analysis is based on a subset of the data (i.e. only botanically identified species are considered) the results serve to deliver a first appreciation of the situation and are assumed to change and substantiate when all species are included in the analysis. The previous findings are also true regarding the most abundant families. The families which are the most important in terms of the number of stems by which they are represented, remain mostly the same in data set 1 and data set 2. For sure, this valuation will change when all species are considered in the analysis.

At this juncture the definition of a certain minimum diameter does not profoundly influence the assessed importance of families represented in the data sets. However, the exclusion of small-sized stems underlines the dominant role of Burseraceae (due to Okoumé) and diminishes the importance of Stericulaceae (most abundant family in data set 1 due to Cola).

In regard to the species abundance, dominance and frequency the two data sets differ. Compared to data set 1 the composition of the most abundant species differs between the two data sets. Species that frequently occur in the understory in data set 1, i.e. Molongo, Ihela and Ngolo are replaced by Commissaire, Etehi, Ilomba, Mougoudou and Niové in data set 2.

The exclusion of stems with a girth diameter less than 10cm in data set 2 further underlines the dominant role of Okoumé. It is remarkable that despite the exclusion of small stems, the second most abundant species in data set 2 is still Colatier. Again, it also holds the second largest portion of species-specific basal area among the most abundant species. Similar to the distribution in data set 1, the contribution of the other most abundant species to the forest variables per hectare remains moderate to low in data set 2 and does not exceed 5% (basal area) and 4% (volume, biomass, carbon stock).

The species composition of the 25 most dominant species is similar in data set 1 and data set 2. The most dominant species in both data sets is the abundantly occurring species Okoumé Aucoumea klaineana. The second most dominant and at the same time scarce species in both data sets is Lekaia. Only the widely abundant and thus dominant species Mololongo (Alchonea floribunda) and Assogo (Anthostema Aubryanum) in data set 1 are replaced in data set 2 by two rare but large species, Azobé (Lophira alata) and Baya (Hallea spp.). Regarding their contribution to the forest variables under investigation per hectare, the importance of the less dominant species in data set 2 declines compared to data set 1.That is, the most dominant species found in data set 2 also provide the major share in the forest characteristics and estimates.

Compared to data set 1, the number of frequently occurring species is lower in data set 2. While in data set 1 the percentage of species that are represented in at least 50% of the sample points make up 30%, this number drops down to 20% in data set 2. In contrast to data set 1, the most abundant species of data set 2 do not constantly possess the highest relative frequency values. Figure 14 shows that the run of the relative frequency curve is more volatile compared to data set 1 (see Figure 13) and only in its very beginning the relative abundance curve clearly exceeds the relative frequency. In the continuing course it declines and runs below the relative frequency curve. Like in data set 1, the following section is characterized by fluctuating relative frequencies indicating less abundant but spatially well distributed species. In both data sets the relative frequency is strongly influenced by the species-specific tree abundances if a species is represented by comparatively few individuals.

3.4.3. Impact on the Assessment of Species Diversity

3.4.3.1. Ligneous Plant Species Richness

As highlighted in Table 14, the total species richness between the two data sets varies from 151 species recorded in data set 1 to 85 species in data set 2. That is, 66 out of 151 species collected at the sample site were solely found with stem sizes below 10cm dbh and consequently, do not occur in the species composition of data set 2. Consequently, the exclusion of trees smaller than 10cm dbh from the assessment leads to a decrease (information loss) equal to 44% regarding the total species richness of the sample site. Well-known and important species that are affected by the exclusion, and respectively would not have been recorded at the study site, are among others Tampon, Sucari, Alep, Edjiki, Bembe, Bois Sacre, Bomba, Café, Mouvengi, Mboga blanche, and Kambala.The complete list of species that can only be found in data set 1 is given in Annex B, Table 26.
Certain woody species rarely grow beyond the widely used minimum diameter of 10cm dbh. Typical species of the understory like Bomba, Sucari and Café belong to this category. Other species only represented by small stems in the sample site (e.g.Tampon, Alep) could reach mammoth diameter.
These results implicate, that the loss of information regarding the actual forest stand diversity in place is immense if small-sized stems are excluded in the forest assessment.

3.4.3.2. Inventory Diversity

Contrary to the absolute species richness, the inventory diversity assessed by different diversity measures is concluded to slightly differ between data set 1 and data set 2 (see Table 14).

Analogous to the higher number of species recorded in data set 1, the absolute number of singletons and doubletons recorded in data set 1 is greater than in data set 2. However, compared to the total number of species found in each of the two data sets, the relative proportion of species represented by one or two stems in data set 2 exceeds those of data set 1. That is, the proportional share of singletons and doubletons is higher in data set 2, i.e. half of all surveyed species in the sample area are represented by only one or two stems. According to the Fisher's diversity measure, data set 1 is concluded to be more heterogeneous than data set 2 (Table 14). This result is presumably influenced by the absolute higher number of singletons found when small sized stems are included in the analysis. In contrast to Fisher´s Alpha the Shannon measure assesses data set 2 as more diverse than data set 1. Both data sets under investigation exhibit low dominance values. Those indices that emphasize the dominance aspect of diversity (Berger-Parker and Simpson) conclude data set 2 to be more heterogeneous than data set 1. This effect points to a decreasing importance of the most abundant species when abundantly occurring species represented by numerous but small-sized stems are excluded from analysis. The evenness of the stem-species distribution is assessed as noticeably higher in data set 2 by the Shannon Evenness measure.
Thus, although the differences between the two data sets remain small, it can be concluded that data set 2 is characterized by increasing inventory diversity values. In particular, this is true when dominance and evenness aspects are included into analysis.

3.4.3.3. Differentiation in Species Turnover

Whittaker´s measure of beta diversity (β_w) concludes that the exclusion of small-sized stems in data set 2 leads to an increase in species differentiation across the sample site equal to 20% (see chapter 3.1.3.3). While in data set 1 the overall species differentiation was estimated as 30%, it counts for 50% if only larger trees are considered in the analysis.
The neglect of smaller stem diameter in the pairwise comparison of sample units increases the dissimilarity between the sample sites. Table 19 displays the mean values produced by each of the employed indices used for the pairwise comparisons carried out in data set 1 and data set 2. Row four gives the relative difference in mean values between data set 1 and data set 2. Although the order of more similar or dissimilar rated pairs of sample quadrates often remains the same as in data set 1, data set 2 is characterized by increased species turnover. This is especially true for the 0.0625ha plots. Hence, the species turnover in data set 2 is concluded to be 14% to 109% higher compared to data set 1.

Table 19: Comparison of mean values derived from the four measures of turnover diversity employed for the analysis of pattern diversity between pair of sample quadrates in data set 1 (dbh≥1cm) and data set 2 (dbh≥10cm). The difference between the two data sets is given in percent and calculated according to the formula: Difference=(1-data set 1/data set 2)*100

0.25ha Plots			
	Data set 1	**Data set 2**	**Difference**
Measure	**Mean Value**	**Mean Value**	**(%)**
C_{MS}	0.57	0.65	14
$1\text{-}C_S$	0.40	0.49	22
β_{Sim}	0.35	0.46	31
$1\text{-}C_N$	0.42	0.57	36
0.0625ha Plots			
C_{MS}	0.57	0.83	46
$1\text{-}C_S$	0.39	0.73	87
β_{Sim}	0.32	0.67	109
$1\text{-}C_N$	0.53	0.75	42

The assessed differences in species composition between the pairs of sample points vary on the scale between zero (no species replacement) and one (complete complementarity in species composition). It is rated as lowest in data set 1 by β_{sim} between the plots P1 and P4-7 (β_{sim} = 0.25) and as highest in data set 2 by C_{MS} for the combination P5/P7 (C_{MS} = 0.96).
In general, the species turnover remains moderate in data set 1. On the possible scale between zero and one the values obtained range between 0.25 and 0.65. Consistently, the different indices produce noticeably higher species turnover between the sample plots in data set 2. While the minimum value equates 0.33 the maximum value comes up to 0.94 (nearly complete species turnover).
However, analogous to data set 1 the assessed complementarity between sites in data set 2 is reduced if shared species between sample quadrates are emphasized by the index (C_S and β_{sim}) and increases if rare species are considered by the index (C_N).
This finding points to augmented complementarity in species represented by larger trees between the sample plots. The exclusion of abundantly occurring species represented by small-sized stems which are well distributed throughout the study site in data set 2 contributes to this effect.

4. Discussion

4.1. State of a tropical Exploitation Forest after 40 Years of Regeneration

Based on the findings of the previous chapter, the state of the forest situated on the study site is discussed using reference values from literature and other forest assessments carried out in the region. The plausibility of the assessment results is approved by the findings made during a field assessment 18 years ago in immediate proximity to the present study area.

The state of the forests situated on the study site is comparable to other mature forests in the Congo Basin region. However, signs indicating previous intensive timber harvesting are still evident. Although the forest stand under examination exhibits one of the highest stem densities/ha (dbh≥10cm) among the forest assessments under comparison, the stem density is one-third lower than the theoretical maximum per hectare indicated for the region by literature. The stand basal area/ha ranks below other mature forest stands in Gabon. The forest carbon stock is lower than its local potential. The predominant and economically most valuable species Okoumé provides a lower species-specific standing volume/ha in the study site than the average standing volume assumed for Okoumé per hectare in Gabon ($7m^3$/ha in Mondah vs. $10m^3$/ha on average in Gabon) (Blaser et al. 2011).
The prior intensive logging still marks the horizontal, vertical as well as species structure of the forest. The horizontal stem-diameter-distribution indicates an uneven-aged forest stand. The mortality in the juvenile age is very high, i.e. only 83 out of 3136 stems (2.6%) in the smallest diameter class (1≤dbh<10cm) reach girth diameters between 9cm and 10cm and possible grow beyond the widely assumed minimum diameter for surveying equal to 10cm. The number of stems in the large timber fraction (dbh≥70cm) ranks below the potential given for Gabon (Blaser et al. 2011). The maximum and mean tree heights surmount the ones of other mature forests in Gabon but the distribution of stems in the vertical stand stratification differs from the reference values under comparison. The canopy layer entails 60% fewer trees than predicted for Gabon. At the same time the number of trees that stunt in the understory is disproportionately high. Based on the comparison with the vertical stand structure of the Waka National Park, Gabon, it can be presumed that the understory and medium layer provide numerous tree species of the overstory layer which are still in regeneration and thus, growing.
Despite previous exploitations, the number of tree families represented in the Mondah forest does not seem to be considerably lower than in other species rich forests in the country. During the present assessment the botanically identified species represented by stems

dbh≥10cm was assigned to 26 families. Since in 1993, 36 families could be identified in the Mondah forests it can be assumed that the number of families recorded on the present sample site would rise with both increasing sample size and a complete botanical identification of all surveyed trees.

The potential tree-species diversity of the African tropical rainforests is discussed controversially. Often, African rainforests are supposed to be relatively species-poor compared to tropical forests in South-America and South-East Asia. At the same time several studies carried out in the Congo Basin region suggest that Central African rainforest can be assumed to be as species rich as tropical rainforests elsewhere, i.e. to potentially host more than 250 tree species per hectare (Corlett and Primack 2011). Although the number of species represented by stems with dbh≥10cm in the Mondah forest increased during the last two decades, it still ranks below those of other species rich forests in the region (see Table 12). At the same time the study site exhibits high levels of absolute tree species diversity for small stem sizes (dbh≥1cm).

The different diversity measures applied to the inventory diversity assessment of the study site indicate a heterogeneous forest stand which is not dominated by one or few species and characterized by an even species distribution in terms of the number of stems per species. Compared to other forests in Gabon the overall level of tree-species diversity in the study site is assumed to be moderate. This can partly be ascribed to previous exploitations. But even though the number of species in the study area represented by trees dbh≥10cm does not reach the levels found on the most species rich sites in the Congo Basin assessed up to now, it can be assumed that today´s numerous small-sized stems will increase that number in future. This supposition needs further investigation to produce robust results.

The preliminary forest walks carried out as basis for plot demarcation reveal that the topographic landscape as well as the forest vegetation change within a few meters. Within the given scope of the present study it was not possible to capture the complete variability in plant species diversity. To assess the turnover diversity of the study site, four different indices stressing different aspects of species differentiation were applied. All measures used are restricted to species identities. They implicitly make the assumption that the sites that are being compared have been completely censused (Magurran 2004). This assumption is rarely met in practice. The complete census of the ligneous vegetation situated within the sample plots carried out for the purpose of this study proves to be a major advantage in this context since there is no need to make any approximative estimations regarding the actual diversity in place.

The measures of Jaccard (C_J; here given as its complement, the Marczewski-Steinhaus index C_{MS}) and Sørensen (C_S) are still regarded as one of the most popular similarity and overlap measures of our time (Jost 2007). While these similarity indices are easy to compute

and interpret they do not capture relative species abundances, i.e. dominant species are equally weighted as species solely represented by a singleton. The quantitative version of the Sørensen index, the Bray Curitis index (C_N), addresses the major shortcomings of the mere presence/absence measures. The performance of this quantitative transformation is also considered a particularly suitable and satisfactory measure (Magurran 2004). The newer turnover diversity measure $ß_{sim}$ more precisely takes into account differences in species composition between sites (Magurran 2004). Koleff et al. (2003) found that on balance of measures under their investigation (including among others Jaccard (1942), Sørensen (1948), Whittaker (1960) and Lennon et al. (2001) that β_{sim} perhaps performs best overall (Koleff et al. 2003). The mere presence/absence measure C_{MS} appraises the differentiation between the pairs of sample points as highest. The evaluated complementarity is reduced when shared species between sample quadrates are emphasized by the index (C_S). The measure including gain and loss of species between sample points (β_{sim}) gives the lowest turnover values of all indices used. The quantitative C_N index differentiates between dominant and rare species putting more weight on the latter. In most cases it produces higher turnover values than C_S and β_{sim} but generates lower values than C_{MS}.
The assessed species turnover between the pairs of sample points strongly varies on the scale between 0.25 (lower species replacement equal to one quarter) and 0.96 (nearly complete complementarity in species composition). However, in most cases, the different measures produce moderate to high values of species turnover (see Table 15 and Table 16) pointing to a complementary forest stand in terms of species composition. It can be presumed that the level of turnover diversity will further rise when all forest formations situated on the study site would be included in the analysis.

4.2. Forest Regeneration

In can be assumed that it is possible to restore most of the forest characteristics, stand structure and plant species diversity to levels similar to those of primary forests (Makana and Thomas 2006). In principle, Gabonese forests are suggested to regenerate well (Blaser et al. 2011). However, the return of a regeneration forest to a state comparable to mature forests usually takes more than one century and presupposes that the disturbed forest stand is protected from repeated exploitation activities and subsequent clearing (Makana and Thomas 2006). Especially when forests are subject to repeated selective timber harvesting, fundamental functions of complex forest ecosystem may profoundly be disturbed and the timber tree regeneration ability reduced. The removal of single large reproduction trees implicates limited seed availability and dispersal. The rapid invasion of logging gaps by brush vegetation and lianas which suppress the growth of other ligneous species and the slow

growth of successor species further hinders their regeneration (Makana and Thomas 2006). Due to disturbances or the destruction of habitats, tree species may disappear together with the animals they depend on for seed dispersal. In the worst case, high selective timber exploitation leads to the local extinction of tree species (Makana and Thomas 2006).
The proceeding recovery process of the forest stand situated on the study site demonstrates well that the forest regeneration is possible if the disturbed area is protected from repeated logging and subsequent clearing. The ongoing maturation of the forest is approved by increasing forest estimates compared to former levels. This is especially true in regard to the higher basal area and higher standing volume per hectare. During the present field study more species per hectare were recorded than in 1993. In contrast to the assessment carried out 18 years ago, the Parasol tree, indicator for a young secondary forest stand, could not be recorded inside the dense forest but exclusively occurs along forest roads and on formerly cleared fallows. Further, the proceeding maturation becomes manifest in the general heightening of the forest stand and changes in the horizontal stand structure. To gain robust information on the long-term development of the forest and its regeneration process repeated field surveys are considered as a basic requirement in future.

4.3. Anthropogenic Impacts on the State of the Forest and Forest Recovery

Due to its valuable timber stock in combination with its immediate proximity to the coast and the major city of Gabon the Mondah forests repeatedly were the object of selective timber extraction in the past. Today forest clearing and fragmentation as well as the overexploitation of plant and animal species are identified as major threats to mature or regeneration forests. The increasing anthropogenic pressure is the main driver behind the ongoing deforestation (AGP 2011), including spontaneous human colonization and land occupations for private building activities and the creation of commercial plantations. In addition, intense and often illegal exploitation of its resources through the urban population of Libreville including the illegal logging of timber for charcoal production, sand mining, and limestone quarrying (AGP 2011) contribute to forest degradation. Thanks to its effective protection, the direct anthropogenical disturbances of the forests situated in the study site terminated with the end of the exploitations approximately 40 years ago. However, up to now the present state of the forest and its regeneration ability is affected indirectly by humans. Above all, this is mirrored by the reduced tree-species diversity in place. Certainly, the limited availability of large reproduction trees due to overharvesting is partly responsible for minor species abundances and richness. Another reason is that numerous tree species depend on distinct animals for seed dispersal. Since the local fauna is assumed to be heavily disturbed by humans, the reproduction of certain tree species is reduced of even impeded. On the basis of the

considerations above it is reasonable to conclude that under the present conditions the forest system under investigation cannot return to its original equilibrium. Even though the forests on the study site are protected against repeated exploitation activities and subsequent clearing the (indirect) anthropogenically impact on the forest system impeded its natural regeneration. The regrowing forest may develop a forest structure and exhibit forest characteristics comparable to other primary forest stands, but it will differ in species composition. Thus, the state of the forest is marked by anthropogenical impacts.

4.4. Impact of a Diameter Requirement dbh≥10cm on the Study Results

The study at hand analyses the consequences of a minimum requirement equal to10cm dbh on the survey's outcome. It was investigated if the systematic survey of small-sized stems has to be included in the forest assessment because its neglect leads to an alteration of the study results in excess of the 5% significance threshold.

This study comes to the result that the neglect of stems smaller than 10cm dbh implicates an underestimation of the stem density and stand basal per hectare in excess of the 5% threshold. Further, it influences the evaluation of the stand structure in place. Thereby, the modification can result in both an over-, and underestimation of forest characteristics and variables in excess of 5%. The contribution of trees smaller than 10cm dbh to standing volume, above ground biomass density and forest carbon stock per hectare remains proportionally small and remains below the threshold level of 5%. From this point of view the record of the vegetation smaller than 10cm dbh is negligible.

This is not true at all in regard to the forest species richness. The exclusion of small-sized stems results in a loss of information equal to 44% regarding the woody plant-species richness of the sample. Well-known and characteristic species of the Atlantic coastal rainforest would not have been recorded at the study site, i.e. the species richness at the present state of the forest would have been underestimated and consequently the disturbance of the flora overestimated. This is partly due to the fact that certain woody species rarely grow beyond 10cm dbh. Other species that could reach mammoth diameter perhaps only were found with small stems due to their reduced abundance and still ongoing recovery after logging. Contrary to the absolute species richness, the differences in the inventory diversity caused by different minimum diameter requirements remain small. However, most of the diversity measures used for analysis rate the level of inventory diversity of data set 2 (dbh≥10cm) higher as the ones of data set 1. In particular, this is true when dominance and evenness aspects are included into consideration by the index. Regarding the species turnover between the sample points, the exclusion of small-sized

stems leads to an increase in species differentiation across the sample site and between the sample points. This is especially true for the species turnover between smaller sample units. Thus, the neglect of small trees results in an overestimation of both the inventory and differentiation diversity.

5. Conclusion

Tropical forest ecosystems provide essential benefits for humanity. Forest degradation leads to the loss of biological diversity that alters complex forest ecosystems. Consequently, the provision of ecosystem functions and services essential for humanity can profoundly be disturbed. Against this backdrop, the study at hand aims to investigate the state and regeneration process of a tropical rainforest system after heavy degradation. The present study was carried out on a densely forested terrain in the coastal rainforests of Mondah, Gabon. In the past these forests were repeatedly object of selective timber harvesting. After the termination of exploitations 40 years ago the study site was effectively protected against subsequent logging. Based on a forest assessment the present state of the forest, the forests' regeneration process and the role of human caused impacts on the forest ecosystems were examined and discussed.

This study concludes that forest preservation plays a crucial role in forest recovery and the stabilization of forest ecosystems after heavy exploitations. Under protection a forest stand can restore most of its characteristics and structure similar to levels of a primary forest. This assumption is backed by the noticeable progress in the recovery process documented during the present assessment. On the other hand, signs of previous selective timber extraction are still evident within the forest site. Further, sprawl urban development and increasing population pressure threaten the forest ecosystems of Mondah. Anthropogenic impacts on the state of the forest and forest recovery are ubiquitous. This is especially true in regard to the plant-species diversity in place. Although numerous typical tree species of the equatorial Atlantic rainforests was recorded in the study site, other formerly represented species are lost together with the animals they depend on for seed dispersal. The regeneration potential of some species seems to be reduced as a result of timber overexploitation. Based on the previous findings, this thesis comes to the conclusion that, despite effective protection, the forest stand under consideration cannot return to its original state but change to a new equilibrium. This is mainly due to ongoing (indirect) human impacts on the forest ecosystem situated on the study site.

Special purpose of the present thesis was to quantify the impact of certain minimum diameter requirement for forest surveying. Usually, tropical forest assessments report to a minimum dbh≥10cm or even larger. It was suggested that surveying trees to a minimum diameter equal to 10cm dbh leads to an alteration of the assessments' outcome in excess of the 5% critical threshold. The analysis concludes with the following findings: For most of the forest parameters under investigation hold that the exclusion of small-sized stems leads to a modification of the study's result above the critical value of 5% threshold. The alteration can results in both an over-, and underestimation of forest characteristics and variables. This is

especially true for the evaluation of the stand density, basal area and tree species richness per hectare. The exclusion of small stems biases the assessment of the actual forest structure. Only in regard to forest estimates of economic interest (standing volume, living biomass and carbon stock per hectare) the inclusion of stems smaller than 10cm dbh into surveying is negligible because their contribution ranks below the 5% threshold. Consequently, this study concludes that especially when young forests are the subject of the investigation a low diameter requirement should be defined in in order to avoid misleading results, capture the maximum of information and to adequately represent the forest characteristics, structure and ligneous species diversity in place.

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Annex

Annex A – Site-Specific Data

Table 20: Metering points along the East-West transect. The table gives the horizontal distance (HD) and slope to the next metering point as well as number, geographical position and the ground level above sea (a.s.l.) for each point.

Point N°	HD (m)	Slope (°)	Nord	East	a.s.l. (m)	Notes
125			0°32'59,444	9°18'43,918	44,8	Western border of P3
126	23,4	-8,7	0°32'59,548	9°18'42,999	40,9	
127	24,6	9,9	0°32'59,432	9°18'42,563	40	corner stake between 126/127
128	23,2	6,1	0°32'59,302	9°18'41,903	39	
129	16,2	-6,3	0°32'59,321	9°18'41,586	45	
130	17,3	-17,3	0°32'59,314	9°18'40,647	41	corner stake between 130/131
131	17	-7,4	0°32'59,446	9°18'40,378	39	corner stake between 131/132
132	21,6	13,1	0°32'59,403	9°18'39,805	43,7	
133	13,7	24,4	0°32'59,362	9°18'39,177	50	
134	34,7	10,1	0°32'59,161	9°18'38,037	49,4	
135	20	-3,5	0°32'59,120	9°18'37,378	55	corner stake at 135
136	25	-10	0°32'59,129	9°18'36,593	46,7	corner stake at 136
137	26,1	-10,2	0°32'59,294	9°18'35,711	53,5	
138	16,8	-24,2	0°32'59,085	9°18'35,065	41,8	
139	22	13,7	0°32'59,241	9°18'34,365	42,9	
140	18,4	17,2	0°32'59,279	9°18'33,599	54,8	corner stake between 140/141
141	29,2	-1,8	0°32'59,244	9°18'32,853	37,9	corner stake 141
142	17,7	-13,1	0°32'59,386	9°18'32,573	38,5	
143	20	-18,5	0°32'59,365	9°18'31,615	38,2	
End of transect borders a stagnant water body surrounded by marshy ground; Mangroves and coastal vegetation dominante. Horizontal distance to the sea ca 40m. Length of transect = 386.9 meters.						

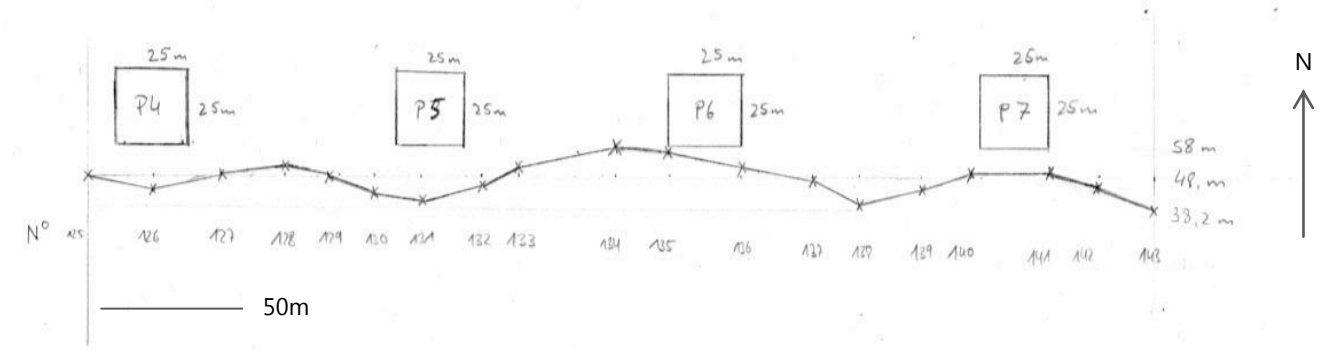

Figure 24: Terrain cross section of the East-West-Transect with the location of P4 to P7 along the transect.

Annex B – Vegetation-Specific Data

Table 21: Species-specific wood density and carbon content. Sources: (Gautam and Pietsch 2012; Chave *et al.* 2009; Zanne *et al.* (2009); Brown 1997; CIRAD 2009; Garzuglia and Saket 2003)

No. Species	Titre de travaille	Binominal	Famille	$WD_{0\%}$	C(%)
1	Aiele	Canarium schweinfurthii	Burseraceae	541	46,67
2	Alep	Desbordesia glaucescens	Irvingiaceae	915	
3	Amvut	Trichoscyphata acuminata	Anacardiaceae	729	47,85
4	Assogo	Anthostema Aubryanum	Euphorbiaceae	330	
5	Azobé	Lophira alata	Ochnaceae	897	
6	Baya	Hallea spp.	Rubinaceae	479	
7	Bembe	Ganophyllum giganteum	Sapindaceae	707	49,67
16	Chocolatier	Irvingia gabonensis	Irvingiaceae	775	
17	Colatier L.F.	Cola acuminata	Sterculiaceae	507	
20	Dabema	Piptadeniastrum africanum	Mimosaceae	605	
21	Djaghesa	Sorindeia oxyandra B&B	Anacardiaceae	653	47,46
23	Douka	Tieghemella africana	Sapotaceae	652	
25	Ebap	Santiria Trimera	Burseraceae	546	
26	Ébène	Diospyros spp.	Ebenaceae	805	45,14
27	Edjiki	Strephonema spp.	Combretaceae	633	
31	Enzisie	Tetrapleura tetraptera	Mimosaceae	530	
33	Etehi	Scyphocephallum mannii	Myristicaceae	507	
34	Evesse	Klainedoxa Gabonensis	Irvingiaceae	926	
35	Eyombo	Dialium pachyphyllum Wild.	Caesalpiniaceae	922	47,27
36	Faro	Daniellia spp.	Caesalpiniaceae	491	
40	Hombe	Ricinodendron heudeloti	Euphorbiaceae	211	
54	Ikoma	Swartzia fistuioides	Caesalpiniaceae	790	
57	Ilogui	Chrysophyllum africanum	Sapotaceae	610	

54	Ikoma	Swartzia fistuioides	Caesalpiniaceae	790	
57	Ilogui	Chrysophyllum africanum	Sapotaceae	610	
58	Ilogui rouge	Chrysophyllum Lacourtiana	Sapotaceae	630	
59	Ilomba	Pycnanthus angolensis	Myristicaceae	499	45,93
70	Kalala	Plagiostyles africana	Euphoriaceae	726	45,99
71	Kambala	Chlorophora Exelsa Benth. & Hook	Moraceae	572	
77	Lebambi	Homalium spp. (letestui)	Salicaceae	730	
78	Lebobo	Diaspyros Canaliculata	Ebenaceae	805	45,14
80	Lekaia	Khaya Ivorensis	Meliaceae	444	
81	Letanda	Rhizophora Racemosa	Rhizophoraceae	959	
85	Mbaza	Parkia bicolor	Mimosaceae	963	47,97
88	Mboga blanche	Chlorophora excelsa	Moraceae	603	47,82
89	Mboudi	Garcinia kola Heckel	Clusiaceae	800	47,28
92	Moambe jaune	Enanthia chlorantha	Annonaceae	420	48,97
93	Moambe noir	Polyalthia suaveolens	Annonaceae	695	49,2
151	Moka	Ochthocosmus spp.	Ixonanthaceae	803	
98	Mokeke	Ongokea Gore	Olacaceae	855	47,29
104	Mololongo	Alchonea floribunda	Euphorbiaceae	713	48,5
108	Moubamba	Aneulophus africanus B.	Annonaceae	691	47,78
113	Mougoudou	Eriocoelum spp.	Sapinadaceae	500	
122	Mouvengui	Distemonanthus benthamianus	Caesalpiniaceae	605	
124	Mutombo	Sorindeia Thouars	Anacardiaceae	737	48,28
128	Niové	Staudtia stipitata	Myristicaceae	787	
129	Noisetier	Coula edulis	Olacaceae	895	
130	Okala	Xylopia aethiopica Dunal A. Rich	Annonaceae	715	48,93
132	Okoumé	Aucumea kleineana	Burseraceae	467	48,41

135	Ozigo	Dacryodes buettneri	Burseraceae	789	47,95
136	Ozouga	Sacoglottis gabonensis	Humiriaceae	796	
140	Talis	Erythrophleum ivorense	Caesalpiniaceae	814	
141	Tampon	Zanthoxylum Heitzii	Rutaceae	557	48,2
142	Tsaga	Anthocleista Nobilis	Gentianaceae	499	
145	Tselê	Albizia Durazz.	Mimosaceae	646	48,22
146	Tsoulobatseki			975	47,4

Tabel 22: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 1

N° Species	Species	Abundance		Frequency		Basal Area/Dominance		Standing Volume		Above Ground Biomass		Above Ground C	
		absl.	prop. (%)	absl (%)	prop.(%)	absl. (m^2/ha)	prop (%)	absl. (m^3/ha)	prop (%)	absl. (kg)	prop (%)	absl. (kg/ha)	prop (%)
1	Aiele	14	0,3837	28,57	0,5076	0,2191	0,5446	2,4225	0,3855	1434,13	0,4023	688,30	0,3931
2	Alep	2	0,0548	28,57	0,5076	0,0006	0,0015	0,0014	0,0002	1,32	0,0004	0,63	0,0004
3	Amvut	4	0,1096	28,57	0,5076	0,0308	0,0767	0,2150	0,0342	156,71	0,0440	77,11	0,0440
4	Assogo	146	4,0011	57,14	1,0152	0,5641	1,4021	3,3826	0,5383	1118,53	0,3138	553,50	0,3161
5	Azobé	6	0,1644	71,43	1,2690	0,3792	0,9425	5,9232	0,9427	2920,76	0,8194	1419,96	0,8109
6	Baya	1	0,0274	14,29	0,2538	0,3959	0,9840	6,2001	0,9867	2969,85	0,8331	1424,83	0,8137
7	Bembe	16	0,4385	28,57	0,5076	0,0167	0,0416	0,0488	0,0078	34,47	0,0097	17,61	0,0101
8	Bogoudou	1	0,0274	14,29	0,2538	0,0031	0,0077	0,0148	0,0024	9,31	0,0026	4,46	0,0025
9	Bois Sacre	1	0,0274	14,29	0,2538	0,0020	0,0049	0,0073	0,0012	4,62	0,0013	2,24	0,0013
10	Bomba	11	0,3015	28,57	0,5076	0,0087	0,0216	0,0269	0,0043	16,18	0,0045	8,07	0,0046
11	Bongawê	7	0,1918	28,57	0,5076	0,0559	0,1390	0,3543	0,0564	252,30	0,0708	121,04	0,0691
12	Bono	95	2,6035	100,00	1,7766	0,1764	0,4384	1,0174	0,1619	629,99	0,1767	303,61	0,1734
13	Bougaou	1	0,0274	14,29	0,2538	0,0040	0,0098	0,0147	0,0023	8,95	0,0025	4,30	0,0025
14	Café	36	0,9866	57,14	1,0152	0,0359	0,0892	0,1285	0,0204	80,69	0,0226	38,96	0,0223
15	Cagoué	1	0,0274	14,29	0,2538	0,0047	0,0116	0,0123	0,0020	7,28	0,0020	3,66	0,0021
16	Chocolatier	13	0,3563	71,43	1,2690	0,2772	0,6889	2,4288	0,3865	1882,29	0,5280	908,47	0,5188
17	Colatier	578	15,8400	100,00	1,7766	2,5245	6,2745	19,7062	3,1362	9991,03	2,8028	4853,06	2,7716
18	Commissaire	67	1,8361	100,00	1,7766	0,9177	2,2809	12,5415	1,9960	7572,06	2,1242	3761,34	2,1481
19	Curdent	151	4,1381	100,00	1,7766	1,1307	2,8102	10,7792	1,7155	6647,75	1,8649	3194,08	1,8241
20	Dabema	7	0,1918	57,14	1,0152	0,1409	0,3501	1,7971	0,2860	1087,25	0,3050	545,29	0,3114
21	Djaghesa	1	0,0274	14,29	0,2538	0,0001	0,0003	0,0002	0,0000	0,16	0,0000	0,08	0,0000
22	Djangala	177	4,8506	100,00	1,7766	1,3806	3,4314	15,0468	2,3947	10593,52	2,9718	5101,29	2,9134

Continuation Table 22: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 1

23	Douka	30	0,8221	71,43	1,2690	0,2521	0,6266	5,2374	0,8335	3414,81	0,9580	1650,17	0,9424
24	Dseho	3	0,0822	14,29	0,2538	0,0020	0,0050	0,0048	0,0008	2,87	0,0008	1,44	0,0008
25	Ebap	4	0,1096	14,29	0,2538	0,2187	0,5437	2,6209	0,4171	1431,03	0,4015	719,46	0,4109
26	Ébène	196	5,3713	100,00	1,7766	0,7320	1,8192	4,8945	0,7789	3940,04	1,1053	1828,99	1,0445
27	Edjiki	1	0,0274	14,29	0,2538	0,0005	0,0012	0,0010	0,0002	0,65	0,0002	0,33	0,0002
28	Ehaka	1	0,0274	14,29	0,2538	0,0007	0,0016	0,0017	0,0003	1,10	0,0003	0,54	0,0003
29	Ehele	2	0,0548	14,29	0,2538	0,0062	0,0153	0,0321	0,0051	19,00	0,0053	9,55	0,0055
30	Elimbi	1	0,0274	14,29	0,2538	0,0127	0,0315	0,1208	0,0192	71,54	0,0201	35,97	0,0205
31	Enzisie	1	0,0274	14,29	0,2538	0,0008	0,0020	0,0012	0,0002	0,64	0,0002	0,32	0,0002
32	Epopoko	1	0,0274	14,29	0,2538	0,1633	0,4059	2,5575	0,4070	1749,31	0,4907	851,40	0,4862
33	Etehi	35	0,9592	71,43	1,2690	1,7848	4,4359	23,0040	3,6610	11663,03	3,2719	5631,73	3,2163
34	Evesse	4	0,1096	14,29	0,2538	0,0364	0,0903	0,3273	0,0521	303,04	0,0850	145,44	0,0831
35	Eyombo	3	0,0822	28,57	0,5076	0,0096	0,0238	0,0455	0,0072	41,95	0,0118	20,39	0,0116
36	Faro	12	0,3289	57,14	1,0152	0,5120	1,2726	10,1129	1,6095	4965,46	1,3930	2409,13	1,3759
37	Gaga	1	0,0274	14,29	0,2538	0,0419	0,1042	0,9555	0,1521	611,55	0,1716	305,94	0,1747
38	Grate Corp	88	2,4116	71,43	1,2690	0,1672	0,4155	0,7248	0,1153	455,62	0,1278	220,33	0,1258
39	Guove	3	0,0822	14,29	0,2538	0,0260	0,0646	0,2838	0,0452	179,63	0,0504	87,14	0,0498
40	Hombe	1	0,0274	14,29	0,2538	0,0003	0,0007	0,0005	0,0001	0,11	0,0000	0,06	0,0000
41	Ibana	1	0,0274	14,29	0,2538	0,0011	0,0028	0,0048	0,0008	2,82	0,0008	1,42	0,0008
42	Ibasa	16	0,4385	28,57	0,5076	0,0138	0,0342	0,0611	0,0097	36,31	0,0102	18,22	0,0104
43	Ibodo	92	2,5212	100,00	1,7766	0,2818	0,7003	1,6848	0,2681	1058,47	0,2969	518,33	0,2960
44	Iboko	2	0,0548	14,29	0,2538	0,0011	0,0028	0,0040	0,0006	2,40	0,0007	1,15	0,0007
45	Igaba	1	0,0274	14,29	0,2538	0,0059	0,0148	0,0350	0,0056	21,25	0,0060	10,20	0,0058
46	Igaou	1	0,0274	14,29	0,2538	0,0006	0,0015	0,0017	0,0003	1,06	0,0003	0,53	0,0003
47	Igogné	1	0,0274	14,29	0,2538	0,0013	0,0031	0,0034	0,0005	2,01	0,0006	1,01	0,0006
48	Igogou	6	0,1644	28,57	0,5076	0,0284	0,0706	0,1715	0,0273	101,53	0,0285	51,04	0,0291

Continuation Table 22: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 1

49	Igoko	72	1,9731	85,71	1,5228	0,1752	0,4353	1,0043	0,1598	624,68	0,1752	309,91	0,1770
50	Igome	2	0,0548	28,57	0,5076	0,0019	0,0048	0,0063	0,0010	3,89	0,0011	1,92	0,0011
51	Igondi	4	0,1096	14,29	0,2538	0,1548	0,3848	1,5788	0,2513	999,37	0,2804	484,77	0,2769
52	Ihela	119	3,2612	100,00	1,7766	0,2945	0,7320	1,7248	0,2745	1045,93	0,2934	509,53	0,2910
53	Ikogozigo	2	0,0548	28,57	0,5076	0,0956	0,2376	0,9079	0,1445	620,51	0,1741	302,06	0,1725
54	Ikoma	3	0,0822	14,29	0,2538	0,0109	0,0270	0,0418	0,0067	33,06	0,0093	16,62	0,0095
55	Ilobo	1	0,0274	14,29	0,2538	0,0127	0,0315	0,0783	0,0125	47,60	0,0134	22,84	0,0130
56	Ilogo	7	0,1918	14,29	0,2538	0,0367	0,0911	0,2626	0,0418	166,23	0,0466	80,64	0,0461
57	Ilogui	24	0,6577	57,14	1,0152	0,5292	1,3154	6,1580	0,9800	3756,36	1,0538	1802,93	1,0297
58	Ilogui Rouge	5	0,1370	28,57	0,5076	0,1510	0,3754	1,8428	0,2933	1160,98	0,3257	562,92	0,3215
59	Ilomba	77	2,1102	100,00	1,7766	1,3435	3,3392	16,3023	2,5945	8134,82	2,2821	3842,32	2,1944
60	Imana	5	0,1370	28,57	0,5076	0,1027	0,2553	1,6807	0,2675	1021,82	0,2867	490,48	0,2801
61	Imanamoudou	1	0,0274	14,29	0,2538	0,0002	0,0004	0,0003	0,0000	0,19	0,0001	0,09	0,0001
62	Imbonga	1	0,0274	14,29	0,2538	0,0003	0,0008	0,0007	0,0001	0,42	0,0001	0,21	0,0001
63	Itaba	1	0,0274	14,29	0,2538	0,0003	0,0008	0,0013	0,0002	0,77	0,0002	0,37	0,0002
64	Itogou	2	0,0548	14,29	0,2538	0,0124	0,0307	0,0735	0,0117	43,53	0,0122	21,88	0,0125
65	Itoubou	1	0,0274	14,29	0,2538	0,0006	0,0014	0,0021	0,0003	1,22	0,0003	0,61	0,0004
66	Itsotsotso	1	0,0274	14,29	0,2538	0,0010	0,0025	0,0026	0,0004	1,62	0,0005	0,79	0,0004
67	Ivaçi	8	0,2192	42,86	0,7614	0,5343	1,3279	6,8407	1,0887	4205,80	1,1799	2029,59	1,1591
68	Iwaga	11	0,3015	57,14	1,0152	0,0739	0,1837	0,4267	0,0679	267,58	0,0751	128,35	0,0733
69	Iwele	1	0,0274	14,29	0,2538	0,0008	0,0020	0,0027	0,0004	1,57	0,0004	0,79	0,0005
70	Kalala	10	0,2740	42,86	0,7614	0,1105	0,2747	0,8361	0,1331	607,00	0,1703	287,08	0,1640
71	Kambala	1	0,0274	14,29	0,2538	0,0002	0,0006	0,0008	0,0001	0,48	0,0001	0,24	0,0001
72	Kaza	4	0,1096	42,86	0,7614	0,0137	0,0342	0,0709	0,0113	42,07	0,0118	21,12	0,0121
73	Kobato	1	0,0274	14,29	0,2538	0,0001	0,0002	0,0001	0,0000	0,07	0,0000	0,03	0,0000
74	Kodouloulou	1	0,0274	14,29	0,2538	0,0003	0,0006	0,0007	0,0001	0,42	0,0001	0,21	0,0001

Continuation Table 22: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 1

75	Koga	1	0,0274	14,29	0,2538	0,0003	0,0009	0,0008	0,0001	0,49	0,0001	0,24	0,0001
76	Koho	1	0,0274	14,29	0,2538	0,0003	0,0008	0,0005	0,0001	0,33	0,0001	0,16	0,0001
77	Lebambi	8	0,2192	57,14	1,0152	0,0338	0,0839	0,2133	0,0339	155,71	0,0437	74,99	0,0428
78	Lebobo	126	3,4530	85,71	1,5228	0,3840	0,9545	2,3006	0,3661	1852,01	0,5196	859,72	0,4910
79	Leicodo	1	0,0274	14,29	0,2538	0,0049	0,0122	0,0347	0,0055	20,54	0,0058	10,33	0,0059
80	Lekaia	6	0,1644	42,86	0,7614	3,9764	9,8830	124,2523	19,7745	55168,01	15,4765	27553,09	15,7356
81	Letanda	2	0,0548	14,29	0,2538	0,0092	0,0228	0,0348	0,0055	33,35	0,0094	16,18	0,0092
82	Lissesse	17	0,4659	57,14	1,0152	0,0575	0,1429	0,3865	0,0615	230,71	0,0647	114,76	0,0655
83	Londo	1	0,0274	14,29	0,2538	0,1787	0,4441	2,6162	0,4164	1656,04	0,4646	803,31	0,4588
84	Marumbo Diano	115	3,1515	100,00	1,7766	0,8517	2,1167	6,0318	0,9599	4154,93	1,1656	2001,96	1,1433
85	Mbaza	14	0,3837	42,86	0,7614	0,1216	0,3023	1,3985	0,2226	1346,77	0,3778	664,38	0,3794
86	Mbegou	4	0,1096	14,29	0,2538	0,0078	0,0194	0,0346	0,0055	21,93	0,0062	10,64	0,0061
87	Mbehe	2	0,0548	14,29	0,2538	0,0006	0,0015	0,0010	0,0002	0,58	0,0002	0,29	0,0002
88	Mboga blanche	11	0,3015	42,86	0,7614	0,0167	0,0415	0,0569	0,0091	34,31	0,0096	16,87	0,0096
89	Mboudi	3	0,0822	14,29	0,2538	0,0015	0,0038	0,0053	0,0008	3,11	0,0009	1,51	0,0009
90	Mboudou	46	1,2606	57,14	1,0152	0,0659	0,1637	0,1876	0,0298	119,03	0,0334	57,66	0,0329
91	Moadi	2	0,0548	14,29	0,2538	0,0008	0,0019	0,0016	0,0003	0,94	0,0003	0,47	0,0003
92	Moambe Jaune	5	0,1370	28,57	0,5076	0,0219	0,0544	0,1367	0,0218	57,41	0,0161	28,91	0,0165
93	Moambe Noir	16	0,4385	71,43	1,2690	0,1151	0,2861	1,2398	0,1973	861,65	0,2417	435,96	0,2490
94	Mogawou	2	0,0548	14,29	0,2538	0,0030	0,0076	0,0065	0,0010	4,18	0,0012	2,09	0,0012
95	Mogomouna	1	0,0274	14,29	0,2538	0,0027	0,0068	0,0130	0,0021	9,25	0,0026	4,44	0,0025
96	Mogougou rouge	1	0,0274	14,29	0,2538	0,0003	0,0009	0,0008	0,0001	0,53	0,0001	0,26	0,0001
97	Mohoma	3	0,0822	28,57	0,5076	0,0007	0,0016	0,0012	0,0002	0,76	0,0002	0,37	0,0002
151	Moka	1	0,0274	14,29	0,2538	1,4187	3,5260	39,6667	6,3129	31852,32	8,9356	15450,82	8,8240
98	Mokeke	3	0,0822	28,57	0,5076	0,0121	0,0302	0,0811	0,0129	69,30	0,0194	33,70	0,0192
99	Mokoko	10	0,2740	14,29	0,2538	0,0044	0,0110	0,0078	0,0012	4,63	0,0013	2,33	0,0013

Continuation Table 22: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 1

100	Mokokosou	29	0,7947	57,14	1,0152	0,0699	0,1737	0,3692	0,0588	230,49	0,0647	111,17	0,0635
101	Mokourdougou	1	0,0274	14,29	0,2538	0,0003	0,0009	0,0010	0,0002	0,61	0,0002	0,29	0,0002
102	Mokoute	1	0,0274	28,57	0,5076	0,0129	0,0320	0,0896	0,0143	53,02	0,0149	26,66	0,0152
103	Molologuma	18	0,4933	71,43	1,2690	0,1200	0,2982	0,6881	0,1095	426,06	0,1195	209,07	0,1194
104	Mololongo	201	5,5084	100,00	1,7766	0,4331	1,0765	2,8280	0,4501	1955,20	0,5485	979,47	0,5594
105	Mombassa	2	0,0548	14,29	0,2538	0,0041	0,0101	0,0133	0,0021	8,40	0,0024	4,08	0,0023
106	Mopepeda	25	0,6851	85,71	1,5228	0,0356	0,0886	0,2398	0,0382	143,49	0,0403	71,23	0,0407
107	Mossuga	5	0,1370	42,86	0,7614	1,2585	3,1279	22,0004	3,5013	13862,49	3,8889	6850,98	3,9126
108	Moubamba	69	1,8909	71,43	1,2690	0,6618	1,6449	6,7213	1,0697	4644,41	1,3029	2282,05	1,3033
109	Moubulongo	1	0,0274	14,29	0,2538	0,0008	0,0020	0,0021	0,0003	1,26	0,0004	0,63	0,0004
110	Mougaou	24	0,6577	71,43	1,2690	0,0638	0,1585	0,3201	0,0509	210,38	0,0590	101,69	0,0581
111	Mougawe	12	0,3289	42,86	0,7614	0,0577	0,1435	0,3616	0,0575	255,49	0,0717	122,63	0,0700
112	Mougele	1	0,0274	14,29	0,2538	0,0000	0,0000	0,0000	0,0000	0,00	0,0000	0,00	0,0000
113	Mougnegnegue	2	0,0548	14,29	0,2538	0,0004	0,0009	0,0006	0,0001	0,35	0,0001	0,17	0,0001
114	Mougoudou	31	0,8495	85,71	1,5228	0,6097	1,5153	6,2829	0,9999	3141,46	0,8813	1515,88	0,8657
115	Moukata	1	0,0274	14,29	0,2538	0,0464	0,1152	0,7594	0,1209	485,89	0,1363	243,03	0,1388
116	Moukoudjou	3	0,0822	14,29	0,2538	0,0199	0,0493	0,1394	0,0222	89,21	0,0250	44,63	0,0255
117	Moukoukouto	2	0,0548	14,29	0,2538	0,0271	0,0672	0,1995	0,0318	118,12	0,0331	59,39	0,0339
118	Moukoutoutou	2	0,0548	28,57	0,5076	0,0072	0,0179	0,0361	0,0057	25,65	0,0072	12,31	0,0070
119	Moumboumbou	1	0,0274	14,29	0,2538	0,0005	0,0012	0,0008	0,0001	0,45	0,0001	0,23	0,0001
120	Mousesse	1	0,0274	14,29	0,2538	0,0023	0,0057	0,0062	0,0010	3,76	0,0011	1,80	0,0010
121	Moussassa	1	0,0274	14,29	0,2538	0,0007	0,0018	0,0018	0,0003	1,15	0,0003	0,56	0,0003
122	Moussoube	1	0,0274	14,29	0,2538	0,0080	0,0199	0,0538	0,0086	31,87	0,0089	16,02	0,0092
123	Mouvengui	22	0,6029	71,43	1,2690	0,0284	0,0706	0,1107	0,0176	66,95	0,0188	32,19	0,0184
124	Mouwouwou	1	0,0274	14,29	0,2538	0,0001	0,0003	0,0003	0,0000	0,16	0,0000	0,08	0,0000
125	Mutombo	8	0,2192	42,86	0,7614	0,0377	0,0937	0,2620	0,0417	193,09	0,0542	95,87	0,0548

Continuation Table 22: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 1

126	Nbeyi	2	0,0548	14,29	0,2538	0,0022	0,0054	0,0048	0,0008	2,82	0,0008	1,42	0,0008
127	Ngolo	103	2,8227	100,00	1,7766	0,1536	0,3817	0,6523	0,1038	399,73	0,1121	195,23	0,1115
128	Niga	4	0,1096	14,29	0,2538	0,1945	0,4834	2,6815	0,4268	1587,44	0,4453	798,09	0,4558
129	Niové	49	1,3428	85,71	1,5228	1,1996	2,9814	15,1747	2,4150	11942,47	3,3503	5807,94	3,3169
130	Noisetier	19	0,5207	57,14	1,0152	0,1900	0,4723	2,3090	0,3675	2066,60	0,5797	1038,38	0,5930
131	Okala	9	0,2466	28,57	0,5076	0,1947	0,4839	2,4468	0,3894	1749,45	0,4908	880,29	0,5027
132	Okoma	1	0,0274	14,29	0,2538	0,0006	0,0015	0,0020	0,0003	1,29	0,0004	0,62	0,0004
133	Okoumé	102	2,7953	71,43	1,2690	7,4196	18,4407	146,0882	23,2496	68223,17	19,1389	33963,81	19,3968
134	Olala	12	0,3289	14,29	0,2538	0,0261	0,0648	0,1419	0,0226	84,01	0,0236	42,24	0,0241
135	Osongue	1	0,0274	14,29	0,2538	0,0059	0,0148	0,0449	0,0072	28,45	0,0080	13,80	0,0079
136	Ozigo	40	1,0962	57,14	1,0152	0,6429	1,5979	9,0865	1,4461	7169,23	2,0112	3535,17	2,0189
137	Ozouga	43	1,1784	85,71	1,5228	0,1381	0,3433	0,7896	0,1257	628,48	0,1763	310,04	0,1771
138	Sero	1	0,0274	14,29	0,2538	0,0468	0,1162	0,4124	0,0656	244,15	0,0685	122,75	0,0701
139	Somoukoé	65	1,7813	85,71	1,5228	0,1443	0,3585	0,5832	0,0928	362,35	0,1017	175,11	0,1000
140	Sucari	72	1,9731	100,00	1,7766	0,0558	0,1386	0,1662	0,0265	106,66	0,0299	51,72	0,0295
141	Talis	5	0,1370	57,14	1,0152	1,2449	3,0940	25,1711	4,0059	18727,26	5,2536	9368,85	5,3506
142	Tampon	1	0,0274	14,29	0,2538	0,0010	0,0025	0,0029	0,0005	1,28	0,0004	0,64	0,0004
143	Tsaga	3	0,0822	28,57	0,5076	0,0096	0,0238	0,0534	0,0085	26,64	0,0075	12,91	0,0074
144	Tsama	1	0,0274	14,29	0,2538	0,4128	1,0260	8,7932	1,3994	5539,70	1,5541	2655,31	1,5164
145	Tsarassa	6	0,1644	57,14	1,0152	0,0641	0,1593	0,5181	0,0825	316,30	0,0887	152,02	0,0868
146	Tselê	5	0,1370	42,86	0,7614	0,5283	1,3131	11,9897	1,9081	7745,32	2,1728	3840,75	2,1935
147	Tsoulobatseki	24	0,6577	57,14	1,0152	0,4229	1,0512	4,9963	0,7951	4871,36	1,3666	2374,53	1,3561
148	Vecol	1	0,0274	14,29	0,2538	0,0177	0,0439	0,1506	0,0240	89,13	0,0250	44,81	0,0256
149	Zassi	3	0,0822	28,57	0,5076	0,0925	0,2299	1,0753	0,1711	654,77	0,1837	314,24	0,1795
150	Zouga	2	0,0548	14,29	0,2538	0,0017	0,0043	0,0048	0,0008	3,06	0,0009	1,48	0,0008

Tabel 23: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 2

N° Species	Species	Abundance		Frequency		Basal Area/Dominance		Standing Volume		Above Ground Biomass		Above Ground C	
		absl.	prop. (%)	absl (%)	prop.(%)	absl. (m^2/ha)	prop (%)	absl. (m^3/ha)	prop (%)	absl. (kg)	prop (%)	absl. (kg/ha)	prop (%)
1	Aiele	5	1,0288	14,29	0,5348	0,2091	0,5891	2,3817	0,3917	1409,98	0,4102	676,71	0,4006
3	Amvut	2	0,4115	14,29	0,5348	0,0268	0,0756	0,1988	0,0327	144,96	0,0422	71,33	0,0422
4	Assogo	24	4,9383	42,86	1,6043	0,3518	0,9913	2,4550	0,4038	810,14	0,2357	401,74	0,2378
5	Azobé	2	0,4115	14,29	0,5348	0,3623	1,0209	5,8269	0,9584	2834,32	0,8246	1376,50	0,8149
6	Baya	1	0,2058	14,29	0,5348	0,3959	1,1156	6,2001	1,0198	2969,85	0,8641	1424,83	0,8435
11	Bongawê	3	0,6173	14,29	0,5348	0,0534	0,1503	0,3453	0,0568	246,52	0,0717	118,27	0,0700
12	Bono	5	1,0288	42,86	1,6043	0,0955	0,2691	0,7233	0,1190	445,62	0,1297	214,20	0,1268
16	Chocolatier	5	1,0288	57,14	2,1390	0,2697	0,7599	2,4029	0,3952	1862,23	0,5418	898,43	0,5319
17	Colatier	43	8,8477	100,00	3,7433	1,8001	5,0724	16,8495	2,7714	8542,70	2,4855	4144,59	2,4537
18	Commissaire	12	2,4691	100,00	3,7433	0,8313	2,3425	12,1744	2,0024	7345,41	2,1371	3651,29	2,1616
19	Curdent	20	4,1152	57,14	2,1390	0,9226	2,5999	9,8429	1,6189	6059,17	1,7629	2909,40	1,7224
20	Dabema	3	0,6173	42,86	1,6043	0,1292	0,3642	1,7390	0,2860	1052,07	0,3061	528,37	0,3128
22	Djangala	20	4,1152	57,14	2,1390	1,2009	3,3840	14,3361	2,3580	10122,62	2,9452	4872,74	2,8847
23	Douka	2	0,4115	28,57	1,0695	0,2072	0,5839	5,0855	0,8365	3315,76	0,9647	1602,43	0,9487
25	Ebap	4	0,8230	14,29	0,5348	0,2187	0,6164	2,6209	0,4311	1431,03	0,4164	719,46	0,4259
26	Ébène	12	2,4691	42,86	1,6043	0,4124	1,1620	3,5690	0,5870	2873,07	0,8359	1333,70	0,7896
30	Elimbi	1	0,2058	14,29	0,5348	0,0127	0,0357	0,1208	0,0199	71,54	0,0208	35,97	0,0213
32	Epopoko	1	0,2058	14,29	0,5348	0,1633	0,4602	2,5575	0,4206	1749,31	0,5090	851,40	0,5040
33	Etehi	17	3,4979	57,14	2,1390	1,7502	4,9320	22,8350	3,7559	11577,34	3,3684	5589,03	3,3088
34	Evesse	2	0,4115	14,29	0,5348	0,0326	0,0917	0,3097	0,0509	286,79	0,0834	137,65	0,0815
36	Faro	2	0,4115	28,57	1,0695	0,4927	1,3883	10,0365	1,6508	4927,92	1,4338	2390,56	1,4152

Continuation Table 23: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 2

37	Gaga	1	0,2058	14,29	0,5348	0,0419	0,1181	0,9555	0,1572	611,55	0,1779	305,94	0,1811
38	Grate corp	3	0,6173	28,57	1,0695	0,0348	0,0980	0,1790	0,0294	116,76	0,0340	56,71	0,0336
39	Guove	1	0,2058	14,29	0,5348	0,0177	0,0498	0,2333	0,0384	147,66	0,0430	71,62	0,0424
43	Ibodo	6	1,2346	71,43	2,6738	0,1142	0,3217	0,7833	0,1288	501,43	0,1459	246,56	0,1460
48	Igogou	1	0,2058	14,29	0,5348	0,0206	0,0581	0,1261	0,0207	74,68	0,0217	37,54	0,0222
49	Igoko	4	0,8230	57,14	2,1390	0,0801	0,2256	0,6022	0,0990	381,25	0,1109	188,90	0,1118
51	Igondi	3	0,6173	14,29	0,5348	0,1506	0,4245	1,5539	0,2556	983,64	0,2862	477,14	0,2825
52	Ihela	4	0,8230	28,57	1,0695	0,1550	0,4368	1,1995	0,1973	721,35	0,2099	352,90	0,2089
53	Ikogozigo	1	0,2058	14,29	0,5348	0,0940	0,2649	0,9026	0,1485	617,40	0,1796	300,49	0,1779
55	Ilobo	1	0,2058	14,29	0,5348	0,0127	0,0357	0,0783	0,0129	47,60	0,0138	22,84	0,0135
56	Ilogo	1	0,2058	14,29	0,5348	0,0299	0,0842	0,2473	0,0407	156,53	0,0455	75,93	0,0450
57	Ilogui	8	1,6461	42,86	1,6043	0,4992	1,4067	6,0037	0,9875	3662,23	1,0655	1757,66	1,0406
58	Ilogui Rouge	2	0,4115	28,57	1,0695	0,1466	0,4130	1,8196	0,2993	1146,33	0,3335	555,82	0,3291
59	Ilomba	18	3,7037	85,71	3,2086	1,2347	3,4791	15,7639	2,5928	7866,18	2,2887	3715,44	2,1996
60	Imana	1	0,2058	14,29	0,5348	0,1012	0,2852	1,6763	0,2757	1019,16	0,2965	489,15	0,2896
64	Itogou	1	0,2058	14,29	0,5348	0,0115	0,0324	0,0711	0,0117	42,07	0,0122	21,15	0,0125
67	Ivaçi	5	1,0288	42,86	1,6043	0,5262	1,4829	6,7958	1,1178	4178,31	1,2157	2016,32	1,1937
68	Iwaga	1	0,2058	14,29	0,5348	0,0519	0,1462	0,3393	0,0558	213,73	0,0622	102,45	0,0607
70	Kalala	3	0,6173	28,57	1,0695	0,0929	0,2617	0,7424	0,1221	538,99	0,1568	254,91	0,1509
72	Kaza	1	0,2058	14,29	0,5348	0,0117	0,0329	0,0645	0,0106	38,20	0,0111	19,21	0,0114
77	Lebambi	3	0,6173	28,57	1,0695	0,0274	0,0771	0,1806	0,0297	131,83	0,0384	63,54	0,0376
78	Lebobo	13	2,6749	57,14	2,1390	0,1794	0,5054	1,3235	0,2177	1065,43	0,3100	494,58	0,2928
80	Lekaia	6	1,2346	42,86	1,6043	3,9764	11,2050	124,2523	20,4368	55168,01	16,0511	27553,09	16,3118
82	Lissesse	2	0,4115	14,29	0,5348	0,0367	0,1033	0,2982	0,0491	176,55	0,0514	88,76	0,0525
83	Londo	1	0,2058	14,29	0,5348	0,1787	0,5036	2,6162	0,4303	1656,04	0,4818	803,31	0,4756
84	Marumbo Diano	21	4,3210	71,43	2,6738	0,6821	1,9220	5,2884	0,8698	3678,73	1,0703	1770,50	1,0482

Continuation Table 23: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 2

85	Mbaza	2	0,4115	14,29	0,5348	0,0890	0,2507	1,2657	0,2082	1218,90	0,3546	601,30	0,3560
90	Mboudou	2	0,4115	14,29	0,5348	0,0199	0,0560	0,0564	0,0093	35,72	0,0104	17,33	0,0103
92	Moambe Jaune	1	0,2058	14,29	0,5348	0,0100	0,0283	0,0758	0,0125	31,84	0,0093	16,04	0,0095
93	Moambe Noir	6	1,2346	42,86	1,6043	0,1030	0,2901	1,1867	0,1952	824,79	0,2400	417,31	0,2471
151	Moka	1	0,2058	14,29	0,5348	1,4187	3,9977	39,6667	6,5243	31852,32	9,2674	15450,82	9,1471
100	Mokokosou	2	0,4115	14,29	0,5348	0,0215	0,0607	0,1620	0,0266	102,76	0,0299	49,58	0,0294
102	Mokoute	1	0,2058	14,29	0,5348	0,0129	0,0363	0,0896	0,0147	53,02	0,0154	26,66	0,0158
103	Molologuma	5	1,0288	42,86	1,6043	0,0767	0,2162	0,4668	0,0768	281,96	0,0820	139,22	0,0824
104	Mololongo	7	1,4403	71,43	2,6738	0,2792	0,7868	2,3537	0,3871	1622,04	0,4719	812,45	0,4810
106	Mopepeda	1	0,2058	14,29	0,5348	0,0177	0,0498	0,1707	0,0281	101,06	0,0294	50,81	0,0301
107	Mossuga	3	0,6173	28,57	1,0695	1,2571	3,5424	21,9957	3,6178	13859,51	4,0324	6849,53	4,0550
108	Moubamba	8	1,6461	71,43	2,6738	0,5509	1,5523	6,2183	1,0228	4296,88	1,2502	2111,29	1,2499
110	Mougaou	3	0,6173	42,86	1,6043	0,0299	0,0842	0,1771	0,0291	114,22	0,0332	55,02	0,0326
111	Mougawe	2	0,4115	14,29	0,5348	0,0386	0,1087	0,2883	0,0474	205,84	0,0599	98,76	0,0585
113	Mougoudou	11	2,2634	57,14	2,1390	0,5691	1,6038	6,0912	1,0019	3045,58	0,8861	1469,52	0,8700
115	Moukoudjou	2	0,4115	14,29	0,5348	0,0625	0,1761	0,8839	0,1454	565,67	0,1646	282,99	0,1675
116	Moukoukouto	1	0,2058	14,29	0,5348	0,0219	0,0617	0,1643	0,0270	97,25	0,0283	48,89	0,0289
121	Moussoube	1	0,2058	14,29	0,5348	0,0080	0,0226	0,0538	0,0089	31,87	0,0093	16,02	0,0095
124	Mutombo	1	0,2058	14,29	0,5348	0,0165	0,0465	0,1486	0,0244	109,53	0,0319	54,38	0,0322
126	Ngolo	3	0,6173	42,86	1,6043	0,0366	0,1031	0,2232	0,0367	138,16	0,0402	67,29	0,0398
127	Niga	4	0,8230	14,29	0,5348	0,1945	0,5481	2,6815	0,4410	1587,44	0,4619	798,09	0,4725
128	Niové	21	4,3210	85,71	3,2086	1,1191	3,1534	14,7578	2,4273	11614,42	3,3792	5649,30	3,3445
129	Noisetier	3	0,6173	14,29	0,5348	0,1698	0,4783	2,2402	0,3685	2004,95	0,5833	1008,00	0,5968
130	Okala	3	0,6173	14,29	0,5348	0,1821	0,5131	2,3652	0,3890	1691,14	0,4920	850,95	0,5038
132	Okoumé	62	12,757	71,43	2,6738	7,2696	20,4847	145,135	23,8717	67778,41	19,7200	33742,39	19,9760
133	Olala	1	0,2058	14,29	0,5348	0,0135	0,0380	0,0793	0,0130	46,92	0,0137	23,59	0,0140

Continuation Table 23: Species-specific absolute and relative Abundance, Frequency, Dominance, Volume, Above Ground Biomass and Carbon Content in data set 2

135	Ozigo	7	1,4403	42,86	1,6043	0,5739	1,6173	8,7582	1,4405	6910,21	2,0105	3407,45	2,0173
136	Ozouga	5	1,0288	42,86	1,6043	0,0692	0,1949	0,4705	0,0774	374,50	0,1090	185,17	0,1096
137	Sero	1	0,2058	14,29	0,5348	0,0468	0,1318	0,4124	0,0678	244,15	0,0710	122,75	0,0727
138	Somoukoé	2	0,4115	28,57	1,0695	0,0265	0,0748	0,1402	0,0231	87,61	0,0255	42,36	0,0251
140	Talis	4	0,8230	42,86	1,6043	1,2445	3,5068	25,1699	4,1399	18726,41	5,4484	9368,44	5,5463
142	Tsaga	1	0,2058	14,29	0,5348	0,0079	0,0221	0,0490	0,0081	24,46	0,0071	11,86	0,0070
143	Tsama	1	0,2058	14,29	0,5348	0,4128	1,1633	8,7932	1,4463	5539,70	1,6118	2655,31	1,5720
144	Tsarassa	1	0,2058	14,29	0,5348	0,0573	0,1613	0,4913	0,0808	298,68	0,0869	143,35	0,0849
145	Tselê	3	0,6173	28,57	1,0695	0,5258	1,4816	11,9813	1,9707	7739,94	2,2519	3838,08	2,2722
146	Tsoulobatseki	2	0,4115	28,57	1,0695	0,3861	1,0881	4,8295	0,7943	4708,76	1,3700	2295,27	1,3588
147	Vecol	1	0,2058	14,29	0,5348	0,0177	0,0498	0,1506	0,0248	89,13	0,0259	44,81	0,0265
148	Zassi	2	0,4115	14,29	0,5348	0,0851	0,2398	1,0319	0,1697	627,39	0,1825	301,12	0,1783
135	Ozigo	7	1,4403	42,86	1,6043	0,5739	1,6173	8,7582	1,4405	6910,21	2,0105	3407,45	2,0173
136	Ozouga	5	1,0288	42,86	1,6043	0,0692	0,1949	0,4705	0,0774	374,50	0,1090	185,17	0,1096
137	Sero	1	0,2058	14,29	0,5348	0,0468	0,1318	0,4124	0,0678	244,15	0,0710	122,75	0,0727
138	Somoukoé	2	0,4115	28,57	1,0695	0,0265	0,0748	0,1402	0,0231	87,61	0,0255	42,36	0,0251
140	Talis	4	0,8230	42,86	1,6043	1,2445	3,5068	25,1699	4,1399	18726,41	5,4484	9368,44	5,5463
142	Tsaga	1	0,2058	14,29	0,5348	0,0079	0,0221	0,0490	0,0081	24,46	0,0071	11,86	0,0070
143	Tsama	1	0,2058	14,29	0,5348	0,4128	1,1633	8,7932	1,4463	5539,70	1,6118	2655,31	1,5720
144	Tsarassa	1	0,2058	14,29	0,5348	0,0573	0,1613	0,4913	0,0808	298,68	0,0869	143,35	0,0849
145	Tselê	3	0,6173	28,57	1,0695	0,5258	1,4816	11,9813	1,9707	7739,94	2,2519	3838,08	2,2722
146	Tsoulobatseki	2	0,4115	28,57	1,0695	0,3861	1,0881	4,8295	0,7943	4708,76	1,3700	2295,27	1,3588
147	Vecol	1	0,2058	14,29	0,5348	0,0177	0,0498	0,1506	0,0248	89,13	0,0259	44,81	0,0265
148	Zassi	2	0,4115	14,29	0,5348	0,0851	0,2398	1,0319	0,1697	627,39	0,1825	301,12	0,1783

Table 24: Botanically identified species and species abundances (number of individuals) in data set 1. Identification based on (Prota 2012; Walker and Sillans 1961, 1961; Wilks and Issembé 2000; CIRAD 2009; Betti and Lejoly; Sassen and Wan 2006; Bouquet and Jacquot 1967; Noiraud *et al.* 2005; Gautam and Pietsch 2012; Pietsch 2000)

No. Species	Titre de travaille	Nom Pilote	Abund.	Binominal	Family
1	Aiele	Aiele	14	Canarium schweinfurthii	Burseraceae
2	Alep	Alep	2	Desbordesia glaucescens	Irvingiaceae
3	Amvut	Amvut	4	Trichoscyphata acuminata	Anacardiaceae
4	Assogo	Assogo	146	Anthostema Aubryanum	Euphorbiaceae
5	Azobé	Azobé	6	Lophira alata	Ochnaceae
6	Baya		1	Hallea spp.	Rubinaceae
7	Bembe	Bembe	16	Ganophyllum giganteum	Sapindaceae
12	Bono		95	Carpolobia spp.	Polygalaceae
16	Chocolatier	Chocolatier, Andok	13	Irvingia gabonensis	Irvingiaceae
17	Colatier	Colatier rouge, Cola,	578	Cola acuminata	Sterculiaceae
20	Dabema		8	Piptadeniastrum africanum	Mimosaceae
21	Djaghesa		1	Sorindeia oxyandra B&B	Anacardiaceae
22	Djangala		177	Dalbergia bakeri	Papilionaceae
23	Douka	Douka	30	Tieghemella africana	Sapotaceae
25	Ebap	Ebap	4	Santiria Trimera	Burseraceae
26	Ébène	Ébène	196	Diospyros spp.	Ebenaceae
27	Edjiki	Andong	1	Strephonema spp.	Combretaceae
31	Enzisie	Enzisie	1	Tetrapleura tetraptera	Mimosaceae
33	Etehi	Sorro	35	Scyphocephallum mannii	Myristicaceae
34	Evesse		4	Klainedoxa Gabonensis	Irvingiaceae
35	Eyombo	Eyoum	3	Dialium pachyphyllum Wild.	Caesalpiniaceae
36	Faro	Faro	12	Daniellia spp.	Caesalpiniaceae
40	Hombe	Ihombé	1	Ricinodendron heudeloti	Euphorbiaceae
42	Ibasa		16	Pseudospondias microcarpa	Anacardiaceae
54	Ikoma	Pao Rosa	3	Swartzia fistuioides	Caesalpiniaceae
57	Ilogui		24	Chrysophyllum africanum	Sapotaceae
58	Ilogui rouge	Ilonghi	5	Chrysophyllum Lacourtiana	Sapotaceae
59	Ilomba	Ilomba	77	Pycnanthus angolensis	Myristicaceae
70	Kalala		10	Plagiostyles africana	Euphoriaceae
71	Kambala		1	Chlorophora Exelsa Benth. & Hook	Moraceae
77	Lebambi		8	Homalium spp. (letestui)	Salicaceae
78	Lebobo		126	Diaspyros Canaliculata	Ebenaceae
80	Lekaia	Acajou	6	Khaya Ivorensis	Meliaceae

81	Letanda		2	Rhizophora Racemosa	Rhizophoraceae
85	Mbaza		14	Parkia bicolor	Mimosaceae
88	Mboga blanche		11	Chlorophora excelsa	Moraceae
89	Mboudi		3	Garcinia kola Heckel	Clusiaceae
92	Moambe Jaune	Moambe Jaunes	5	Enanthia chlorantha	Annonaceae
93	Moambe noir	Otunga, Moambe noir	16	Polyalthia suaveolens	Annonaceae
98	Mokeke		3	Ongokea Gore	Olacaceae
100	Mokokosou	Hibou	29	Aeolanthus Lamborayi	Lamiaceae
104	Mololongo		201	Alchonea floribunda	Euphorbiaceae
106	Mopepeda		25	Desmodium Salicifolium DC	Fabaceae
108	Moubamba		69	Aneulophus africanus B.	Annonaceae
109	Moubulongo		1	Solanum Angustispinosum	Solanaceae
110	Mougaou	Mugau	24	Phoenix Reclinata	Arecaceae
113	Mougoudou	Mugondi	31	Eriocoelum spp.	Sapinadaceae
122	Mouvengui		22	Distemonanthus benthamianus	Caesalpiniaceae
124	Mutombo		8	Sorindeia Thouars	Anacardiaceae
126	Ngolo		103	Terminalia superba	Combretaceae
128	Niové	Niové	49	Staudtia stipitata	Myristicaceae
129	Noisetier	Noisetier	19	Coula edulis	Olacaceae
130	Okala	Okala	9	Xylopia aethiopica	Annonaceae
132	Okoumé	Okoumé	102	Aucumea kleineana	Burseraceae
135	Ozigo	Ozigo	40	Dacryodes buettneri	Burseraceae
136	Ozouga	Ozouga	43	Sacoglottis gabonensis	Humiriaceae
140	Talis	Talis	5	Erythrophleum ivorense	Caesalpiniaceae
141	Tampon	Olon	1	Zanthoxylum Heitzii	Rutaceae
142	Tsaga		3	Anthocleista Nobilis	Gentianaceae
145	Tselê		5	Albizia Durazz.	Mimosaceae
151	Moka		1	Ochthocosmus spp.	Ixonanthaceae

Table 25: Botanically identified species and species abundances (number of individuals) in data set 2. Identification based on (Prota 2012; Walker and Sillans 1961, 1961; Wilks and Issembé 2000; CIRAD 2009; Betti and Lejoly; Sassen and Wan 2006; Bouquet and Jacquot 1967; Noiraud *et al.* 2005; Gautam and Pietsch 2012; Pietsch 2000).

No. Species	Titre de travaille	Nom Pilote	Abund.	Binominal	Famille
1	Aiele	Aiele	5	Canarium schweinfurthii	Burseraceae
3	Amvut	Amvut	2	Trichoscyphata acuminata	Anacardiaceae
4	Assogo	Assogo	24	Anthostema Aubryanum	Euphorbiaceae
5	Azobé	Azobé	2	Lophira alata	Ochnaceae
6	Baya		1	Hallea spp.	Rubinaceae
12	Bono		5	Carpolobia spp.	Polygalaceae
16	Chocolatier	Chocolatier, Andok	5	Irvingia gabonensis	Irvingiaceae
17	Colatier	Colatier rouge, Cola,	43	Cola acuminata	Sterculiaceae
20	Dabema	Dabema	3	Piptadeniastrum africanum	Mimosaceae
22	Djangala		20	Dalbergia bakeri	Papilionaceae
23	Douka	Douka	2	Tieghemella africana	Sapotaceae
25	Ebap	Ebap	4	Santiria Trimera	Burseraceae
26	Ébène	Ébène	12	Diospyros spp.	Ebenaceae
33	Etehi	Sorro	17	Scyphocephallum mannii	Myristicaceae
34	Evesse		2	Klainedoxa Gabonensis	Irvingiaceae
36	Faro	Faro	2	Daniellia spp.	Caesalpiniaceae
57	Ilogui	Ilonghi	8	Chrysophyllum africanum	Sapotaceae
58	Ilogui rouge		2	Chrysophyllum Lacourtiana	Sapotaceae
59	Ilomba	Ilomba	18	Pycnanthus angolensis	Myristicaceae
70	Kalala		3	Plagiostyles africana	Euphoriaceae
77	Lebambi		3	Homalium spp. (letestui)	Salicaceae
78	Lebobo		13	Diaspyros Canaliculata	Ebenaceae
80	Lekaia	Acajou	6	Khaya Ivorensis	Meliaceae
85	Mbaza		2	Parkia bicolor	Mimosaceae
92	Moambe jaune	Moambe jaunes	1	Enanthia chlorantha	Annonaceae
93	Moambe noir	Otunga, Moambe noir	6	Polyalthia suaveolens	Annonaceae
151	Moka	Moka	1	Ochthocosmus spp.	Ixonanthaceae
100	Mokokosou	Hibou	2	Aeolanthus Lamborayi	Lamiaceae
104	Mololongo		7	Alchonea floribunda	Euphorbiaceae
106	Mopepeda		1	Desmodium Salicifolium DC	Fabaceae
108	Moubamba		8	Aneulophus africanus B.	Annonaceae
110	Mougaou	Mugau	3	Phoenix Reclinata	Arecaceae
113	Mougoudou	Mugondi	11	Eriocoelum spp.	Sapinadaceae
124	Mutombo		1	Sorindeia Thouars	Anacardiaceae
126	Ngolo		3	Terminalia superba	Combretaceae

128	Niové	Niové	21	Staudtia stipitata	Myristicaceae
129	Noisetier	Noisetier	3	Coula edulis	Olacaceae
130	Okala	Okala	3	Xylopia aethiopica Dunal A. Rich	Annonaceae
132	Okoumé	Okoumé	62	Aucumea kleineana	Burseraceae
135	Ozigo	Ozigo	7	Dacryodes buettneri	Burseraceae
136	Ozouga	Ozouga	5	Sacoglottis gabonensis	Humiriaceae
140	Talis	Talis	4	Erythrophleum ivorense	Caesalpiniaceae
142	Tsaga		1	Anthocleista Nobilis	Gentianaceae
145	Tselê	Tselê	3	Albizia Durazz.	Mimosaceae

Table 26: Species and number of individuals per species (abundance) represented exclusively by stems smaller than 10cm dbh in data set 1

N°/Species	Species	Abund./ha	N°/Species	Species	Abundance/ha
					Continuation
2	Alep	2	86	Mbegou	4
7	Bembe	16	87	Mbehe	2
8	Bogoudou	1	88	Mboga blanche	11
9	Bois Sacre	1	89	Mboudi	3
10	Bomba	11	91	Moadi	2
13	Bougaou	1	94	Mogawou	2
14	Café	36	95	Mogomouna	1
15	Cagoué	1	96	Mogougou rouge	1
21	Djaghesa	1	97	Mohoma	3
24	Dseho	3	98	Mokeke	3
27	Edjiki	1	99	Mokoko	10
28	Ehaka	1	101	Mokourdougou	1
29	Ehele	2	105	Mombassa	2
31	Enzisie	1	109	Moubulongo	1
35	Eyombo	3	150	Mougele	1
40	Hombe	1	112	Mougnegnegue	2
41	Ibana	1	114	Moukata	1
42	Ibasa	16	117	Moukoutoutou	2
44	Iboko	2	118	Moumboumbou	1
45	Igaba	1	119	Mousesse	1
46	Igaou	1	120	Moussassa	1
47	Igogné	1	122	Mouvengui	22
50	Igome	2	123	Mouwouwou	1
54	Ikoma	3	125	Nbeyi	2
61	Imanamoudou	1	131	Okoma	1
62	Imbonga	1	134	Osongue	1
63	Itaba	1	139	Sucari	72
65	Itoubou	1	141	Tampon	1
66	Itsotsotso	1	149	Zouga	2
69	Iwele	1	Total		66
71	Kambala	1	(%)		43.7
73	Kobato	1			
74	Kodouloulou	1			
75	Koga	1			
76	Koho	1			
79	Leicodo	1			
81	Letanda	2			

Table 27: Species occurrence and distribution in the horizontal classification scheme (10cm diameter classes). Species in bold were found in data set 1 and data set, species in italic and bold only occur in data set 2. Species marked in blue were only found in at least one of the first smallest diameter classes (dbh<10cm, dbh<20cm, dbh<30cm). Species marked in yellow are represented by stems up to 60cm dbh. Species marked in orange reached the general minimum cutting diameter

Species	1≤dbh<10	10≤dbh<20	20≤dbh<30	30≤dbh<40	40≤dbh<50	50≤dbh<60	60≤dbh<70	70≤dbh<80	80≤dbh<90	90≤dbh	Density (Abun-dance/ha)	Frequency (max=7)
Aiele	9	2	2	1	0	0	0	0	0	0	14	2
Alep	2	0	0	0	0	0	0	0	0	0	2	2
Amvut	2	2	0	0	0	0	0	0	0	0	4	2
Assogo	122	24	0	0	0	0	0	0	0	0	146	4
Azobé	4	1	0	0	0	0	1	0	0	0	6	5
Baya	0	0	0	0	0	0	0	1	0	0	1	1
Bembe	16	0	0	0	0	0	0	0	0	0	16	2
Bogoudou	1	0	0	0	0	0	0	0	0	0	1	1
Bois Sacre	1	0	0	0	0	0	0	0	0	0	1	1
Bomba	11	0	0	0	0	0	0	0	0	0	11	2
Bongawê	4	3	0	0	0	0	0	0	0	0	7	2
Bono	90	4	1	0	0	0	0	0	0	0	95	7
Bougaou	1	0	0	0	0	0	0	0	0	0	1	1
Café	36	0	0	0	0	0	0	0	0	0	36	4
Cagoué	1	0	0	0	0	0	0	0	0	0	1	1
Chocolatier	8	1	3	1	0	0	0	0	0	0	13	5
Colatier	535	25	10	6	1	1	0	0	0	0	578	7
Commissaire	55	7	2	2	0	0	0	1	0	0	67	7
Curdent	131	10	6	2	2	0	0	0	0	0	151	7
Dabema	4	2	0	1	0	0	0	0	0	0	8	4
Djaghesa	1	0	0	0	0	0	0	0	0	0	1	1
Djangala	157	9	5	2	3	1	0	0	0	0	177	7
Douka	28	0	1	0	1	0	0	0	0	0	30	5
Dseho	3	0	0	0	0	0	0	0	0	0	3	1
Ebap	0	2	1	0	1	0	0	0	0	0	4	1
Ébène	184	10	0	1	0	1	0	0	0	0	196	7
Edjiki	1	0	0	0	0	0	0	0	0	0	1	1
Ehaka	1	0	0	0	0	0	0	0	0	0	1	1
Ehele	2	0	0	0	0	0	0	0	0	0	2	1
Elimbi	0	1	0	0	0	0	0	0	0	0	1	1
Enzisie	1	0	0	0	0	0	0	0	0	0	1	1
Epopoko	0	0	0	0	1	0	0	0	0	0	1	1
Etehi	18	8	3	3	0	1	1	0	1	0	35	5
Evesse	2	2	0	0	0	0	0	0	0	0	4	1
Eyombo	3	0	0	0	0	0	0	0	0	0	3	2
Faro	10	1	0	0	0	0	0	1	0	0	12	4
Gaga	0	0	1	0	0	0	0	0	0	0	1	1
Grate Corp	85	3	0	0	0	0	0	0	0	0	88	5
Guove	2	1	0	0	0	0	0	0	0	0	3	1
Hombe	1	0	0	0	0	0	0	0	0	0	1	1
Ibana	1	0	0	0	0	0	0	0	0	0	1	1
Ibasa	3	0	0	0	0	0	0	0	0	0	16	2
Ibodo	86	4	2	0	0	0	0	0	0	0	92	7
Iboko	2	0	0	0	0	0	0	0	0	0	2	1
Igaba	1	0	0	0	0	0	0	0	0	0	1	1
Igaou	1	0	0	0	0	0	0	0	0	0	1	1
Igogné	1	0	0	0	0	0	0	0	0	0	1	1
Igogou	5	1	0	0	0	0	0	0	0	0	6	2
Igoko	68	4	0	0	0	0	0	0	0	0	72	6
Igome	2	0	0	0	0	0	0	0	0	0	2	2
Igondi	1	2	0	1	0	0	0	0	0	0	4	1
Ihela	115	2	1	1	0	0	0	0	0	0	119	7
Ikogozigo	1	0	0	1	0	0	0	0	0	0	2	2
Ikoma	3	0	0	0	0	0	0	0	0	0	3	1
Ilobo	0	1	0	0	0	0	0	0	0	0	1	1
Ilogo	6	1	0	0	0	0	0	0	0	0	7	1
Ilogui	11	4	0	0	1	0	0	0	0	0	24	4
Ilogui Rouge	3	1	0	0	1	0	0	0	0	0	5	2
Ilomba	59	11	3	1	2	0	0	0	1	0	77	7
Imana	4	0	0	1	0	0	0	0	0	0	5	2
Imanamoudou	1	0	0	0	0	0	0	0	0	0	1	1
Imbonga	1	0	0	0	0	0	0	0	0	0	1	1
Itaba	1	0	0	0	0	0	0	0	0	0	1	1
Itogou	1	1	0	0	0	0	0	0	0	0	2	1
Itoubou	1	0	0	0	0	0	0	0	0	0	1	1
Itsotsotso	1	0	0	0	0	0	0	0	0	0	1	1
Ivaçi	3	2	1	1	0	0	1	0	0	0	8	3
Iwaga	10	0	1	0	0	0	0	0	0	0	11	4
Iwele	1	0	0	0	0	0	0	0	0	0	1	1

Contunuing Table 27

Species	1≤dbh<10	10≤dbh<20	20≤dbh<30	30≤dbh<40	40≤dbh<50	50≤dbh<60	60≤dbh<70	70≤dbh<80	80≤dbh<90	90≤dbh	Density (Abun-dance/ha)	Frequency (max=7)
Kalala	7	2	1	0	0	0	0	0	0	0	10	3
Kambala	1	0	0	0	0	0	0	0	0	0	1	1
Kaza	3	1	0	0	0	0	0	0	0	0	4	3
Kobato	1	0	0	0	0	0	0	0	0	0	1	1
Kodouloulou	1	0	0	0	0	0	0	0	0	0	1	1
Koga	1	0	0	0	0	0	0	0	0	0	1	1
Koho	1	0	0	0	0	0	0	0	0	0	1	1
Lebambi	5	3	0	0	0	0	0	0	0	0	8	4
Lebobo	113	13	0	0	0	0	0	0	0	0	126	6
Leicodo	1	0	0	0	0	0	0	0	0	0	1	1
Lekaia	0	1	1	1	0	1	1	0	0	1	6	3
Letanda	2	0	0	0	0	0	0	0	0	0	2	1
Lissesse	15	2	0	0	0	0	0	0	0	0	17	4
Londo	0	0	0	0	1	0	0	0	0	0	1	1
Marumbo Diano	94	12	6	3	0	0	0	0	0	0	115	7
Mbaza	12	1	0	1	0	0	0	0	0	0	14	3
Mbegou	4	0	0	0	0	0	0	0	0	0	4	1
Mbehe	2	0	0	0	0	0	0	0	0	0	2	1
Mboga blanche	11	0	0	0	0	0	0	0	0	0	11	3
Mboudi	3	0	0	0	0	0	0	0	0	0	3	1
Mboudou	44	2	0	0	0	0	0	0	0	0	46	4
Moadi	2	0	0	0	0	0	0	0	0	0	2	1
Moambe Jaune	4	1	0	0	0	0	0	0	0	0	5	2
Moambe Noir	10	6	0	0	0	0	0	0	0	0	16	5
Mogawou	2	0	0	0	0	0	0	0	0	0	2	1
Mogomouna	1	0	0	0	0	0	0	0	0	0	1	1
Mogougou rouge	1	0	0	0	0	0	0	0	0	0	1	1
Mohoma	3	0	0	0	0	0	0	0	0	0	3	2
Mokeke	3	0	0	0	0	0	0	0	0	0	3	2
Mokoko	10	0	0	0	0	0	0	0	0	0	10	1
Mokokosou	27	2	0	0	0	0	0	0	0	0	29	4
Mokourdougou	1	0	0	0	0	0	0	0	0	0	1	1
Mokoute	0	1	0	0	0	0	0	0	0	0	1	2
Molologumba	13	5	0	0	0	0	0	0	0	0	18	5
Mololongo	194	2	4	1	0	0	0	0	0	0	201	7
Mombassa	2	0	0	0	0	0	0	0	0	0	2	1
Mopepeda	24	1	0	0	0	0	0	0	0	0	25	6
Mossuga	2	0	1	0	0	0	0	1	0	1	5	3
Moubamba	61	3	2	1	2	0	0	0	0	0	69	5
Moubulongo	1	0	0	0	0	0	0	0	0	0	1	1
Mougaou	21	3	0	0	0	0	0	0	0	0	24	5
Mougawe	10	2	0	0	0	0	0	0	0	0	12	3
Mougele	1	0	0	0	0	0	0	0	0	0	1	1
Mougnegnegue	2	0	0	0	0	0	0	0	0	0	2	1
Mougoudou	20	6	2	2	0	1	0	0	0	0	31	6
Moukata	1	0	0	0	0	0	0	0	0	0	1	1
Moukoudjou	1	1	1	0	0	0	0	0	0	0	3	1
Moukoukouto	1	1	0	0	0	0	0	0	0	0	2	1
Moukoutoutou	2	0	0	0	0	0	0	0	0	0	2	2
Moumboumbou	1	0	0	0	0	0	0	0	0	0	1	1
Mousesse	1	0	0	0	0	0	0	0	0	0	1	1
Moussassa	1	0	0	0	0	0	0	0	0	0	1	1
Moussoube	0	1	0	0	0	0	0	0	0	0	1	1
Mouvengui	22	0	0	0	0	0	0	0	0	0	22	5
Mouwouwou	1	0	0	0	0	0	0	0	0	0	1	1
Mutombo	7	1	0	0	0	0	0	0	0	0	8	3
Nbeyi	2	0	0	0	0	0	0	0	0	0	2	1
Ngolo	80	3	0	0	0	0	0	0	0	0	103	7
Niga	0	0	4	0	0	0	0	0	0	0	4	1
Niové	28	13	5	1	1	0	1	0	0	0	49	6
Noisetier	16	2	0	0	1	0	0	0	0	0	19	4
Okala	6	0	2	1	0	0	0	0	0	0	9	2
Okoma	1	0	0	0	0	0	0	0	0	0	1	1
Okoumé	40	33	5	6	7	5	1	2	2	1	102	5
Olala	11	1	0	0	0	0	0	0	0	0	12	1
Osongue	1	0	0	0	0	0	0	0	0	0	1	1
Ozigo	33	3	2	0	1	1	0	0	0	0	40	4
Ozouga	38	5	0	0	0	0	0	0	0	0	43	6
Sero	0	0	1	0	0	0	0	0	0	0	1	1
Somoukoé	63	2	0	0	0	0	0	0	0	0	65	6
Sucari	65	0	0	0	0	0	0	0	0	0	72	7
Talis	1	1	0	1	0	0	0	0	2	0	5	4
Tampon	1	0	0	0	0	0	0	0	0	0	1	1
Tsaga	2	1	0	0	0	0	0	0	0	0	3	2
Tsama	0	0	0	0	0	0	0	1	0	0	1	1
Tsarassa	5	0	1	0	0	0	0	0	0	0	6	4
Tselê	2	0	2	0	0	0	0	1	0	0	5	3
Tsoulobatseki	4	0	0	0	0	0	1	0	0	0	24	4
Vecol	0	1	0	0	0	0	0	0	0	0	1	1
Zassi	0	1	0	1	0	0	0	0	0	0	3	2
Zouga	2	0	0	0	0	0	0	0	0	0	2	1
Moka	0	0	0	0	0	0	0	0	0	1	1	1

Table 28: Species composition and abundance in the vertical classification scheme: Stratification of the samples in three height layers (understory, medium layer, and canopy with emergent layer), represented in 2m height classes. Species in bold were found in sample 2 and sample 2

Height class	Understory							Medium Layer								Canopy and Emergent Layer														
Species	**Understory**	**3≤H<5**	**5≤H<7**	**7≤H<9**	**9≤H<11**	**11≤H<13**	**13≤H<15**	**15≤H<17**	**17≤H<19**	**19≤H<21**	**21≤H<23**	**23≤H<25**	**25≤H<27**	**27≤H<29**	**29≤H<31**	**31≤H<33**	**33≤H<35**	**35≤H<37**	**37≤H<39**	**39≤H<41**	**41≤H<43**	**43≤H<45**	**45≤H<47**	**47≤H<49**	**49≤H<51**	**51≤H<53**	**53≤H<55**	**55≤H<57**	**57≤H<59**
Aiele	0	2	5	2	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alep	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amvut	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assogo	11	44	38	15	23	6	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Azobé	0	1	1	1	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baya	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bembe	1	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bogoudou	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bois Sacre	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bomba	0	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bongawê	1	1	1	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bono	16	46	20	8	1	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bougaou	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Café	5	14	11	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cagoué	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chocolatier	1	4	2	0	3	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colatier	35	217	166	83	39	19	8	3	2	2	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commissaire	9	18	10	10	9	4	2	1	0	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Curdent	12	36	39	31	13	9	2	1	2	2	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dabema	0	1	1	2	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Djaghesa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Djangala	12	77	41	16	15	4	4	2	0	2	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douka	1	11	13	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dseho	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ebap	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ébène	10	64	59	32	21	7	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Edjiki	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ehaka	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ehele	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elimbi	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Enzisie	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epopoko	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Etehi	1	3	8	4	5	3	3	1	1	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evesse	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eyombo	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Faro	3	3	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gaga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Grate Corp	10	28	30	11	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guove	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hombe	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ibana	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ibasa	1	6	6	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ibodo	2	24	24	20	10	8	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iboko	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igaba	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igaou	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igogné	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igogou	1	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igoko	8	27	18	9	5	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igome	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igondi	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ihela	23	42	34	8	6	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ikogozigo	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ikoma	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilobo	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilogo	4	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilogui	0	6	2	6	4	3	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilogui Rouge	1	0	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilomba	3	16	19	13	9	6	3	3	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Imana	0	3	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imanamoudou	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imbonga	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Itaba	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Itogou	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Itoubou	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Itsotsotso	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ivaçi	0	0	0	1	1	4	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iwaga	1	3	2	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iwele	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalala	2	1	1	2	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kambala	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kaza	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kobato	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kodouloulou	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koga	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Height class	Understory							Medium Layer								Canopy and Emergent Layer														
Species	Understory	3≤H<5	5≤H<7	7≤H<9	9≤H<11	11≤H<13	13≤H<15	15≤H<17	17≤H<19	19≤H<21	21≤H<23	23≤H<25	25≤H<27	27≤H<29	29≤H<31	31≤H<33	33≤H<35	35≤H<37	37≤H<39	39≤H<41	41≤H<43	43≤H<45	45≤H<47	47≤H<49	49≤H<51	51≤H<53	53≤H<55	55≤H<57	57≤H<59
Lebambi	0	1	2	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lebobo	6	37	32	21	15	10	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leicodo	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lekaia	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Letanda	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lissesse	0	4	6	4	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Londo	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marumbo Diano	5	35	23	17	19	11	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mbaza	1	5	3	2	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mbegou	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mbehe	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mboga blanche	1	5	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mboudi	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mboudou	7	19	16	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moadi	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moambe Jaune	0	0	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moambe Noir	3	3	0	3	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mogawou	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mogomouna	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mogougou rouge	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mohoma	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokeke	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokoko	8	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokokosou	3	4	9	7	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokourdougou	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mokoute	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Molologumba	0	1	5	3	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mololongo	49	103	30	9	5	1	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mombassa	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mopepeda	4	10	7	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mossuga	0	0	2	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moubamba	7	23	15	6	12	2	1	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moubulongo	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougaou	0	5	9	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougawe	1	3	2	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougele	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougnegnegue	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougoudou	0	3	7	6	9	1	2	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moukata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moukoudjou	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moukoukouto	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moukoutoutou	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moumboumbou	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mousesse	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moussassa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moussoube	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mouvengui	1	6	8	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mouwouwou	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mutombo	0	1	1	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nbeyi	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ngolo	7	54	20	14	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niga	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niové	0	9	5	7	9	8	2	1	1	1	2	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noisetier	1	7	6	1	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Okala	1	1	1	2	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Okoma	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Okoumé	0	4	10	7	14	18	6	6	3	1	5	5	2	6	3	5	2	1	0	2	0	0	0	0	1	0	1	0	0	0
Olala	2	3	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Osongue	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ozigo	1	7	12	9	2	2	2	0	0	1	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ozouga	1	17	8	9	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sero	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Somoukoé	2	32	19	5	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sucari	23	32	10	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Talis	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Tampon	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tsaga	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tsama	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Tsarassa	0	2	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tselê	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tsoulobatseki	0	7	7	7	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vecol	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zassi	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zouga	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moka	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sum	318	1203	881	475	323	175	79	36	21	21	29	19	15	20	6	10	3	4	2	2	1	0	3	0	1	0	1	0	1	0

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