Human Impact on Flora and Vegetation of Kakamega Forest, Kenya

Structure, distribution and disturbance of plant communities in an East African rainforest

Dissertation

zur Erlangung des akademischen Grades eines
Doktors der Naturwissenschaft
Fachbereich 3: Mathematik/Naturwissenschaften
Universität Koblenz-Landau

vorgelegt

am 23. Mai 2005
von Arnhild Johanna Althof

geb. am 11. August 1975 in Bochum

Referent: Prof. Dr. Eberhard Fischer
Koreferent: Prof. Dr. Wilhelm Barthlott

In Memory of

Prof. Dr. Clas M. Naumann

‘*Vegetation is the best measure for environment*’

Greig-Smith 1979

Abstract

In the present study the flora and vegetation of Kakamega Forest, an East African rainforest in Western Kenya, was investigated. Kakamega Forest is highly degraded and fragmented and is an ideal model to study the anthropogenic influence on the forest inventory. The main focus was to analyse the influence of human impact on the vascular plant species composition.
During five field phases in the years 2001 to 2004 a total of 19 study sites scattered over the whole forest including all fragments were investigated regarding forest structure, species composition and plant communities. The different forest sites were analysed by three different methods, phytosociological relevés, line-transect and with the variable-area transect method.

The forest survey revealed about 400 taxa of vascular plant species, among them 112 trees, 62 shrubs, 58 climbers and 114 herbs. Several species are restricted to this forest in Kenya, but only one endemic species, the herb *Commelina albiflora*, could be discovered. About 15 species were recorded as new for Kenya and probably at least one species is new to science. Kakamega Forest is a unique mixture of Guineo-Congolian and Afromontane floral elements. About one half of the vascular plant species has its origin in the lowland forests of the Congo basin and one third originates from Afromontane habitats.

The present study represents the first description of plant communities of Kakamega Forest. An analysis of different forest sites and plantations resulted in 17 different vegetation units. For the mature forest sites eleven plant communities were described. The young succession stage consists of two plant communities. Since the disturbance history and the age of the different plant communities could be estimated, their chronology was also described. An exception are the study sites within the plantations and afforested sites. The four defined vegetation units were not described as plant communities, because they are highly affected by man and do not belong to the natural succession of Kakamega Forest. Nevertheless, the regeneration potential of such forests was investigated.

Due to the different succession stages the changing species composition along a disturbance gradient could be analysed. Most of Kakamega Forest consists of middle-aged secondary forest often surrounded by very young secondary forest. A true primary rainforest could not be found due the massive influence by over-exploitation. In all parts of the forest the anthropogenic influence could be observed. The forest develops towards a climax stage, but a comparison with former surveys shows that the regeneration is much slower than expected. Human impact has to be avoided to allow the forest to develop into a primary-like rainforest. But several climax tree species might be missing anyway, because after the broad logging activities in the past there are not enough seed trees remaining.

Species richness was highest in disturbed forest sites. A mixture of pioneer, climax and bushland species could be recorded there. Therefore, a high species richness is not a suitable indicator for forest quality. The proportion of climax species typical for Kakamega Forest would be a better measure. Compared to the main forest block the forest fragments do not lack in diversity as expected due to fragmentation processes. Instead, the only near primary forest could be recorded in Kisere, a northern fragment. The high amount of climax species and the more or less undisturbed forest structure is a result of the strict protection by the Kenya Wildlife Service and due to low logging activities. Differences in species composition between the studied forest sites are either a result of the different logging history or management regime rather than due to different edaphic or climatic conditions.

Zusammenfassung

In der vorliegenden Studie wurden die Flora und die Vegetation des Kakamega Forest, eines ost-afrikanischen Regenwaldes in West Kenia, untersucht. Der Kakamega Forest ist hochgradig degradiert und fragmentiert und daher ein ideales Modell, um den anthropogenen Einfluß auf den Waldbestand zu erforschen. Das Hauptziel war es, den menschlichen Einfluß auf die Pflanzenzusammensetzung zu analysieren.
Während fünf Feldaufenthalten in den Jahren 2001 bis 2004 wurden in insgesamt 19 über den gesamten Wald einschließlich seiner Fragmente verteilten Untersuchungsgebieten die Waldstruktur, die Artenzusammensetzung und die Pflanzengesellschaften untersucht. Mit Hilfe von drei verschiedenen Methoden, mit pflanzensoziologischen Relevés, mit Linientransekten und mit der Variable-Area-Transect-Methode wurden die Unterschiede zwischen den Waldstandorten untersucht.

Die Erfassung des Waldbestandes ergab, daß es ungefähr 400 verschiedene Taxa gibt, darunter 112 Bäume, 62 Sträucher, 58 Lianen und 114 krautartige Pflanzen. Viele dieser Arten kommen in Kenia nur in diesem Wald vor, aber nur eine einzige erfaßte Art, das Kraut *Commelina albiflora*, ist endemisch. Ungefähr 15 Arten wurden das erste Mal für Kenia beschrieben, aber nur eine Art scheint neu für die Wissenschaft zu sein. Der Kakamega Forest ist eine einmalige Mischung aus Guineo-Kongolischen und Afromontanen Florenelementen. Ungefähr die Hälfte aller erfaßten Pflanzenarten hat ihren Ursprung in den Tieflandwäldern des Kongobeckens und ein Drittel aller Arten entspringt den afromontanen Habitaten.

In dieser Studie wurden zum ersten Mal die Pflanzengesellschaften des Kakamega Forest beschrieben. Eine Analyse der verschiedenen Waldstandorte und Plantagen ergab 17 verschiedene Vegetationseinheiten. Für den hoch entwickelten Wald wurden elf Pflanzengesellschaften beschrieben. Die jungen Sekundärstadien sind zusammengesetzt aus zwei verschiedenen Pflanzengesellschaften. Da die Störungshistorie und das Alter der verschiedenen Pflanzengesellschaften abgeschätzt werden konnten, wurde deren Abfolge ebenfalls beschrieben. Eine Ausnahme bilden die Untersuchungsgebiete innerhalb der Plantagen und aufgeforsteten Waldstandorte. Die vier definierten Vegetationseinheiten wurden nicht als Pflanzengesellschaften beschrieben, da sie zu stark vom Menschen beeinflußt sind und nicht zu der natürlichen Sukzession des Kakamega Forest gehören. Nichtsdestotrotz wurde das Regenerationspotential solcher Wälder untersucht.

Aufgrund der verschiedenen Sukzessionsstadien konnte der Wechsel der Artenzusammensetzung entlang eines Störungsgradienten analysiert werden. Der Hauptteil des Kakamega Forest besteht aus mittelaltem Sekundärwald, oft umgeben von sehr jungen Sekundärwäldern. Ein echter Primärwald konnte aufgrund des massiven Einflußes durch Überausbeutung nicht mehr gefunden werden. In allen Teilen des Waldes konnte der menschliche Einfluß beobachtet werden. Der Wald entwickelt sich hin zu einem Klimaxstadium, aber Vergleiche mit ehemaligen Bestandsaufnahmen zeigen, daß die Regeneration weitaus langsamer vorangeht als erwartet. Die menschliche Beeinflussung muß ausgeschlossen werden können, um dem Wald die Möglichkeit zu verschaffen, sich wieder zu einem primären Regenwald zu entwickeln. Allerdings könnten viele Klimaxarten aufgrund der weitgehenden Holzschlagaktivitäten der Vergangenheit völlig verschwinden, da es nicht genug adulte Bäume gibt, die als Verbreitungseinheit für junge Bäume dienen könnten.

Die Artenvielfalt ist in gestörten Waldstandorten am höchsten. Dort gibt es eine Mischung aus Pionier-, Klimax- und Buschlandarten. Daher ist eine hohe Artenzahl kein guter Maßstab für die Waldqualität. Der Anteil von Klimaxarten, die typisch für den Kakamega Forest sind, wäre ein besserer Meßwert. Waldfragmente, die mit dem Hauptwald verglichen werden, weisen keine geringere Diversität auf, was aufgrund von Fragmentierungsprozessen eigentlich zu erwarten gewesen wäre. Stattdessen wurde der einzige nahezu primäre Wald in Kisere, einem nördlichen Fragment, erfaßt. Der hohe Anteil an Klimaxarten in Kisere und die mehr oder weniger beeinflußte Waldstruktur ist ein Ergebnis des strikten Schutzes durch den Kenianischen Wildlife Service und von geringen Holzeinschlägen. Unterschiede in der Artenzusammensetzung zwischen den untersuchten Waldstandorten sind eher auf Unterschiede in der Holzeinschlagshistorie oder dem Management Regime als auf edaphische oder klimatische Bedingungen zurückzuführen.

1. Introduction

General background

Tropical rainforests sustain more than half of the world’s species despite occupying only seven percent of Earth’s land area (Myers 1984). Nevertheless, no other land community sustains such a high species diversity and ecological complexity like tropical rainforests (Laurance & Bierregaard 1997). Deforestation driven by an increasing human population and a rush towards industrialisation in developing nations is suggested to result in a loss of much of the world’s tropical rainforests in our lifetimes (Laurance & Bierregaard 1997). By a rate of 1.2 % loss of the total extent of tropical rainforests per year one-third of the remaining tropical rainforests will be cleared or modified in the next thirty years (Whitmore 1997). It is commonly known that deforestation causes a massive extinction wave (Myers 1988). Conservation and the sustainable use of the tropical rainforest resources have received increasing attention. The rainforest ecosystem is vulnerable to over-utilisation and exploitation due to the sensivity of its complex and highly diverse ecosystem. Major consequences of large-scale forest loss are habitat fragmentation, degradation and conversion. The consequence of the rapid loss and destruction of tropical forests is that an unknown number of species become extinct without ever being recognised.

A decline in biodiversity can result in changes of ecosystem processes. The natural life-cycle of forest regeneration can be disrupted if certain plant species are missing due to fragmentation and exploitation events. Human activitiy accelerates the natural changes of environment. Thus, a once disturbed tropical rainforest cannot recover and regenerate towards a primary rainforest with its former species assemblage.

Tropical rainforests comprise a unique biodiversity and also have relevance as watercatchment systems. The actual influence of rainforest destruction on the world’s climate is not yet understood (Clark 2004, Ostendorf et al. 2001). The environment is affected on both regional and global scales (Laurance & Bierregaard 1997). Part of the rainfall of the forests is produced through the forest’s own transpiration. Precipitation changes with increasing fragmentation and forest loss. Climatic changes including elevated CO_2, rising temperature and decline in rainfall regional and global, are feedback processes of deforestation and habitat loss of tropical rainforests (Bazzaz 1998, Semazzi & Song 2001, Malhi & Wright 2004). Vice versa, changing climatic conditions can influence the biodiversity of tropical rainforests in terms of phenology, plant-animal interactions or eliminate species with narrow niches (Chapman et al. 2005).

Studies of fragmented ecosystems commenced after the ground-breaking publications of MacArthur's and Wilson's monography *The Theory of Island Biogeography* (1967). Nevertheless, the long-term consequences of fragmentation and human impact on the plant species diversity is yet not well known. Habitat loss has much more negative effects on biodiversity whereas habitat fragmentation might have positive and negative effects resulting in higher species richness of plants in fragments compared to main forest blocks (Fahrig 2003, Gillespie 2005). However, habitat loss and land conversion are the most serious threat to the Earth's biological diversity (Collinge 1996).

Public awareness of the research and conservation of biodiversity was first achieved by the Earth Summit conference of Rio de Janeiro in 1992. The following Conference of the German Parties led to the Convention of Biological Diversity which aims to develop biodiversity indicators based on changes in the status of threatened species and trends in the abundance and distribution (Lughadha et al. 2005). Centers of high plant diversity are called "hotspots", but these areas are as well the most threathened parts of the world (Küper et al. 2004).

Why Kakamega Forest?

East African rainforests suffer large over-exploitation by humans and belong to the most threatened and least explored ecosytems on Earth (Köhler 2004). Only about 0.1 % of the estimated 10 million km² of tropical rainforest in the world occur in Eastern Africa, which is about 10.000 km². Unlike the vast West and Central African forests, the forests of Eastern Africa are highly fragmented - discrete islands surrounded by comparatively arid woodland (Lovett & Waser 1993). Kakamega Forest is located in West Kenya in vicinity to Lake Victoria and is a forest ecosystem of fragments of different size, structure and distances to each other. In the last decades continuous human disturbances conversed and fragmented the forests in different intensities. Nowadays, parts of the forest are protected to a certain degree. The forest consists of secondary forests of different regrowth and changes of diversity of flora and vegetation along a regeneration gradient can be recognised. A decline of regeneration can lead to changes in the abundance and spatial distribution of plants. For future management decisions data on the far-reaching consequences for the diversity, dynamic and stability of the forest ecosystem are needed (Köhler 2004). Due to its special characteristic Kakamega Forest provides an ideal model for ecologists for the investigation of consequences of fragmentation and degradation on the biodiversity and ecosystem processes.

A review on the literature available for Kakamega Forest shows that only few studies deal with the vegetation of this forest. Among them are investigations of the vegetation status and the human impact on the forest (Kokwaro 1988, Tsingalia 1990, Waas 1995, Mutangah 1996, Fashing et al. 2004). Research of the regeneration processes of important, climax tree species like *Prunus africana* or *Olea capensis* or regeneration in general are rare (Kigomo 1987, Tsingalia 1988, Tsingalia 1989, Kiami & Kiyiapi 2000, Nzilani 2002, Fashing 2004). Also some studies on the vegetation structure and tree composition were conducted (Mutangah 1992, Fashing & Gathua 2004).

Objectives

A survey of the vascular plant species of Kakamega Forest is needed to answer the following questions. The main forest block as well as every surrounding fragment are investigated to provide a comprehensive floristic inventory. The first objective is to analyse the plant species composition and distribution of different forest sites. Therefore,

- a first description of the plant communities of Kakamega Forest should be provided by the present study.

- What abiotic factors (e.g. habitat structure, microclimate, soil properties) and biotic factors (e.g. pollination and dispersal) determine the spatial distribution of flora and vegetation?

It is known from the literature that Kakamega Forest contains sites of different succession stages. Therefore,

- an analysis of the different succession stages and the changes of the species composition from one stage to another should be provided.

The forest is a system of different fragments varying in size, shape and distances to each other with different levels of human impact in the last decades. Therefore, investigations of the influence of human disturbance and fragmentation on the flora and vegetation of Kakamega Forest could be done. Due to different types of near primary, secondary forests and forest fragments the species composition and forest structure could be analysed along a disturbance gradient:

· How does the diversity change between forests of different past and recent anthropogenic influences?

· What differences in the plant species composition of forest sites of different structure, fragmentation degree and distances to each other could be observed?

· Are small habitat-islands affected by fragmentation due to lower species richness of the isolated populations?

As a result of the analysis of the flora and vegetation of the forest indicator species for a rapid biodiversity assessment (RBA) are identified.

· What species are applicable indicators for the assessment and evaluation of the qualitiy of East African forests?

The present study was conducted in the framework of BIOTA-East Africa (Biodiversity Monitoring Transect Analysis) funded mainly by the BMBF (German Federal Ministry of Education and Research).

2. Study area

Geographic location

Kakamega Forest is located in the Western Province of Kenya, laying between latitudes 00°08’30.5’’ N (41 236 in UTM 36 N) and 00°22’12.5’’ N (15 984) and longitudes 34°46’08.0’’ E (696 777) and 34°57’26.5’’ E (717 761) at an altitude of about 1500 to 1700 m (fig. 1). From the 150 km remote Rift Valley it is separated by highlands like the Cheranganis in the north and the Mau Escarpment in the south (KIFCON 1994). The distance to Kisumu at Lake Victoria is about 43 km (fig. 2). Kakamega town on the western side of the forest is located about 7.5 km to the nearest point of the main forest block (fig. 3). Kakamega Forest is located about 66 km from the border to Uganda and about 94 km to Mt. Elgon (Gertrud Schaab & Tobias Lung pers. comm.).

Fig. 1: Map of Africa.

Fig. 2: Map of Kenya, shaded relief produced by the U.S. CIA, source: University of Texas at Austin libraries.

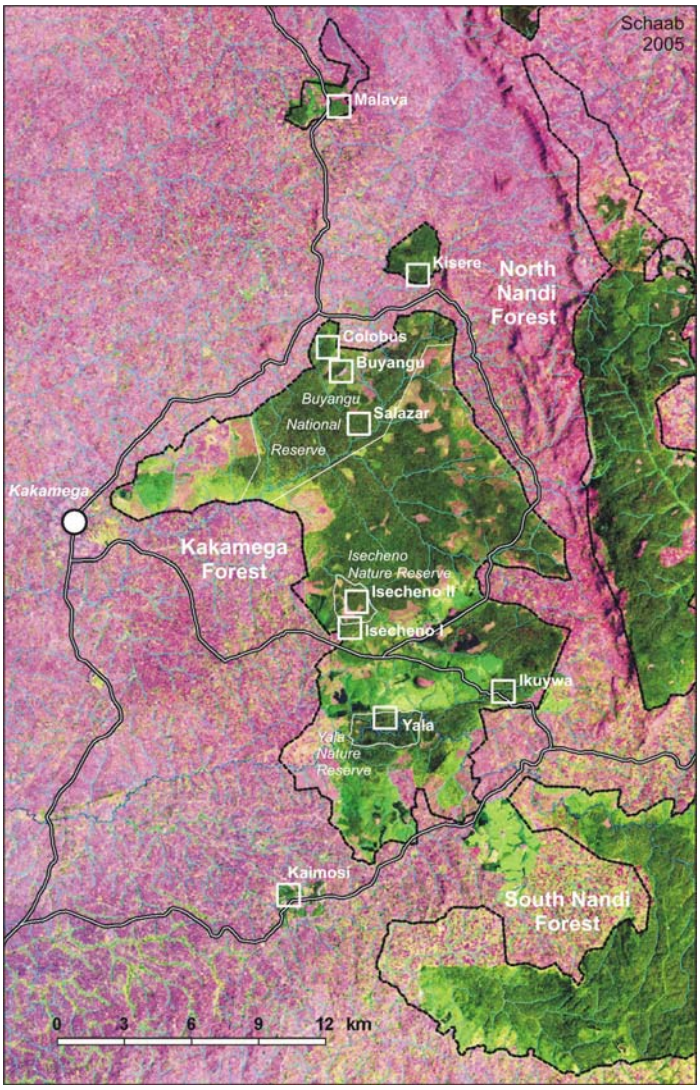


Fig. 3: Landsat ETM+ (7) satellite image (05 Feb 2001, spectral bands 5/4/3, contrast enhanced) of Kakamega Forest, its peripheral fragments and the Nandi Forests (source: BIOTA-E02, G. Schaab, FH Karlsruhe).

Adjacent forests are the Nandi Forests placed on an escarpment which stretchs north-south and borders Kakamega Forest to the east. The Nandi escarpment is located about 200 to 300 m higher (fig. 3). Further associated forests are Bunyalu Forest in the north which is not included in this study, because indigenous trees are now missing (Mitchell 2004), as well as Malava and Kisere Forest and in addition Kaimosi Forest in the south (see fig. 3). A lot of small rivers and streams cross Kakamega Forest with two main river systems, the Isiukhu river in the north and the Yala river in the south. Two major hills loom inside the forest. One in the northern part named after the area around it as Buyangu Hill and another one, Lirhanda Hill in the south. The BIOTA - campsite as well as the KWS-head office are located near Buyangu Hill. That hill is covered with forest except of the southern slope whereas Lirhanda hill is covered with a dense waist-high grasslayer. Lirhanda Hill's special feature is a tunnel cut into massive rock originated during the gold rush in and around Kakamega Forest. Figure 4 shows the converted area around the forest fragment Kisere north of the main forest block. Within the small-scaled agricultural land the forest and the main forest block lay.

Fig. 4: Aerial picture of Kisere Forest. Source: R. Steinbrecher, IMK-IFU, Garmisch-Partenkirchen.

Geology and soils

A wide variety of rock types is found in Kenya. The underlying rocks of the Lake Victoria Basin at an altitude of 1134 m belong to the Precambrian (Lovett & Waser 1993). Kakamega Forest is situated on that Lake Victoria Basin which was formed during the middle Pleistocene by earth movements. The same movements created the western arm of the Great Rift Valley system stretching from north to south throughout East Africa (White 1983).

Kakamega Forest grows on rocks of the Kavirondo and Nyanzian age. These underlying rocks include basalt, phenolites and ancient gneisses which are nerved with gold-bearing quartz veins (KIFCON 1994). The rocks from the Nyanzian System are made up of acid to basic volcanic lavas with minor tuff.

Fertile clay-loam soils develop out of rock systems which predominantly are of granit. These soils belong to the latosols, more precisely to the ferrisols (Schultka 1975). They are well drained, very deep, reddish brown to yellowish red with a humic top soil (Mutangah 1996). Soils of granitic origin are known as fairly fertile and thus support large numbers of forest plant species (Tsingalia 1988). Organic material of the forest cover falling to the ground is reincorparted into the soil so that the soil can maintain on itself. These natural nutrient recycling activity is disrupted when the forest is cleared. With removing of live or dead fuel wood and the felling of trees the soil fertility declines. About 56 % of the soils of Kakamega Forest are granitic in origin, the others are mainly from basic rock such as basalt and phenolites or gneiss rocks (Tsingalia 1988).

Climate

The climate is related to Lake Victoria which is an important source of precipitation. Annual rainfall is sufficiently high and well distributed throughout the year to support rainforest (White 1983). Beside the Intertropical Convergent Zone (ITCZ) with the movement of air masses between two temperature belts in the northern and southern hemisphere, Lake Victoria with its own circulation system of air masses mainly influences the precipitation in this region. Several publications dealing with objectives to Kakamega Forest deliver different information about precipitation and temperature, but in average over the last 60 years the annual rainfall measured at different weather-stations around Kakamega Forest was about 2000 mm per year. Jätzold & Schmidt (1982) deliver rainfall figures from various stations having at least 10 years records from 1921 up to 1976. Rainfall records for 1976-1981 at Kakamega Forest station show that the forest receives 2215 mm of rain per year (Cords

1987), while at the Agricultural Research Station in Kakamega records for 1923-1983 show an annual rainfall of 1956 mm (Greiner 1991).

Precipitation

A great change between dry and wet season can not be observed in Kakamega Forest, but authors of different publications differ in their information about that. KIFCON (1994) shows that around Kakamega Forest the highest rainfall in the country can be measured. This rainfall is well-distributed over the year, but most of the rain falls from April to November. A short dry season can be observed between December to March. Kalinganire et al. (2001) agree with this view and found out that the wettest months of the year are May and September. Schultka (1975) delivers information that rain falls throughout the year and that a dry season does not exist. The months with the lowest precipitation are December and January. Available records from the Isecheno Forest station confirm these observations.

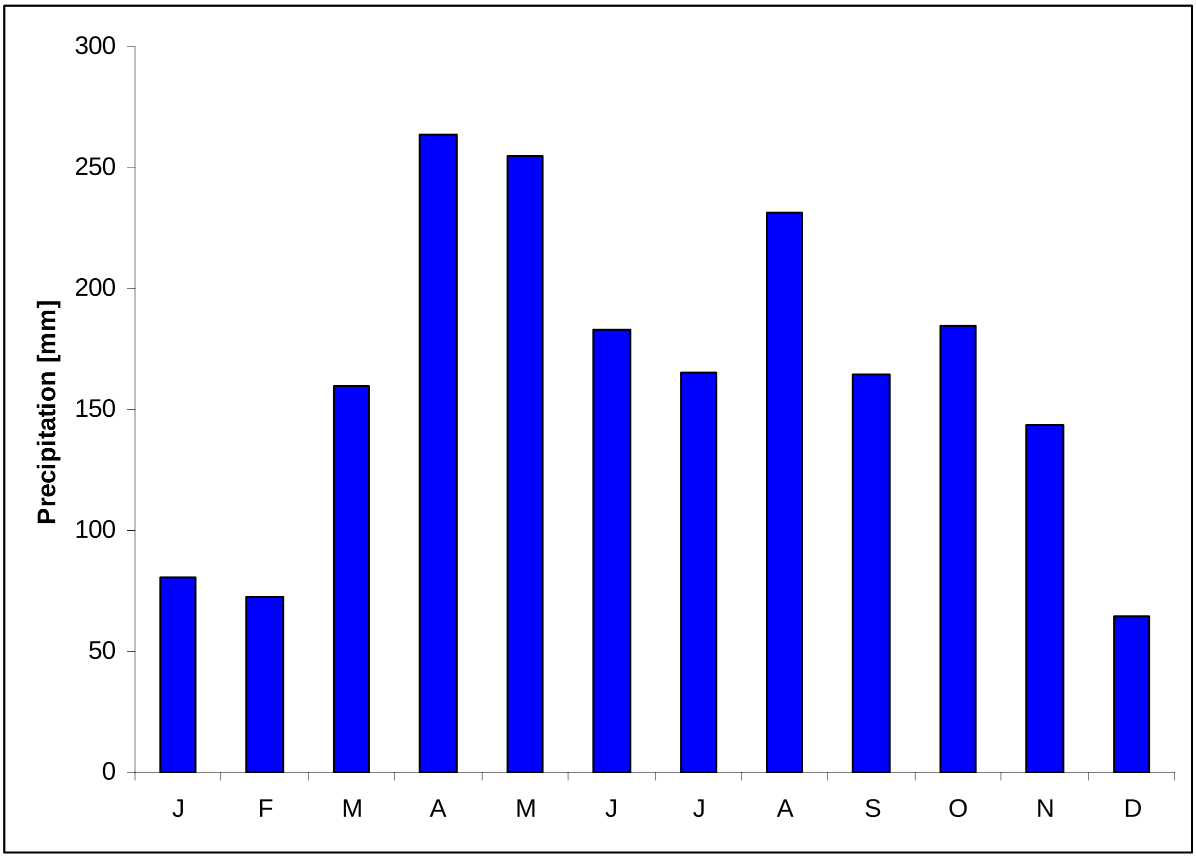


Fig. 5: Meteorological data of Isecheno Forest Station for a period from 1982 to 2003. Mean monthly rainfall [mm], data collected by the Isecheno Forest Department.

Data from the southern part of Kakamega Forest, from the Isecheno Forest Station show the distribution of rainfall over a period of 20 years (fig. 5). A rainfall peak can be observed around April, June and July have fewer rain and the lowest levels were measured in

December and January. Data recorded at the BIOTA meteorological station near the KWS office in the Buyangu National Reserve shows that in the study year 2002 the sum of the annual precipitation amounted to 1.500 mm m^{-2}. Most rainfall events from 2001 to 2004 occurred in the months April to July and October/November. The yearly mean temperature in 2002 was 20.0 +/- 4.8° C (Steinbrecher 2004). Kakamega Forest itself influences the precipitation. The biomass of the forest vegetation is a big watersystem catchment. This leads to high transpiration rates during the day. In the afternoon the developed clouds release the moisture as rain. In case, that a forest is highly disturbed or fragmented, the pattern of precipitation changes. A movement from moderate to heavy rainfalls happens. Soil surfaces without forest vegetation or with a sparse vegetation cover heat up more during a day than surfaces covered with forest vegetation. These hot air masses are transported in higher atmospheric strata than air masses developed over the forest. The higher the hot air masses are transported the more likely they come in contact with the cold air in the higher strata. This leads to heavy hailstorms with strong rain. This phenomenon happens over Kakamega Forest and could be observed during this study. The fragmentation and clearing of the forest does not lead to fewer rainfall, instead provokes heavy rainfalls mixed with hail (Rainer Steinbrecher, E 02, pers. comm.).

Temperature

The diurnal changes in temperature are greater than the seasonal changes, therefore the climate is called “Tageszeitenklima”. Beside that the temperature is influenced by the altitude. Information about the average monthly minimum and maximum temperature depend again on the timeframe and on the station they were measured, for example the Isecheno Forest station in the south of the forest or in the nearby town, at the Kakamega District Office. Average minimum monthly temperature ranges from 11 – 21° C and average maximum monthly temperature ranges from 18 to 29° C measured from Cords (1987) at the Isecheno Station. The coldest month in the year is July due to higher rainfall which cools the forest inside, whereas the hottest daily temperature can be measured in January and February.

To measure the microclimate at the study sites two types of Gemini Data Loggers: Tinytag Plus H°C/%RH (measuring air temperature and humidity) and Tinytalk 0/95 %RH (measuring humidity) were laid out. The position of the Data Loggers were imbedded in ArcView 3.X in cooperation with subproject E 02. Data Loggers were layed out at nine positions inside the forest. They were fixed at tree strunks at a height of about 1.50 m in shadowed places except for the Data Logger in Kisere which was fixed at a height of about five meter in a crotch. They were placed in the main forest block as well as in every fragment. One measurement was taken per hour. Tab. 1 shows that the average temperature does not vary strongly between the forest sites, whereas the maximum temperature was highest in Buyangu Hill and Yala and not as expected in the Camp forest which achieves a lot of sunlight due to its open, penetrable canopy. Humidity correlates with the environment conditions of the studied site. The more open a canopy was and the more sunlight could reach the ground, the lower was the measured humidity. The Camp forest inside heats up more than the forest sites of Isecheno or Yala where dense vegetation occurs. There is an exception in Kisere, here the Logger overtops the dense vegetation of the lower canopy, because of its position in the crotch, and thus gets more sunlight than on the dense forest floor resulting in a low average humidity.

Tab. 1: Microclimate measurement at nine sites in Kakamega Forest. Shown are average humidity and temperature, as well as the lowest and highest temperature measured during recordation.

site	H [%]	T [° C]	T (min.)	T (max.)	timeframe
Malava	67.2				01.02 - 03.01
Kisere	44.7	18.1	12.8	27.2	03.01 - 01.04
Camp forest	21.7	17.8	11.2	27.2	09.01 - 04.03
Buyangu Hill	59.0	18.3	12.8	31.8	09.01 - 07.03
Isiukhu	62.8	17.9	12.8	27.9	03.02 - 11.02
Salazar	68.6				01.02 - 01.03
Isecheno	79.4	18.0	12	26.5	03.02 - 07.03
Ikuywa	57.8				01.02 - 01.03
Yala	83.8	17.4	11.2	29.4	01.02 - 07.03

Kakamega Forest extent

There is still an ongoing debate over whether Kakamega Forest ever extended further north or east in the past. Furthermore, it is possible that the Bunyala, Malava, Kisere and North Nandi forests were never connected with each other or to the Kakamega Forest block. Undoubtedly on the west and south sides the forest shrunk dramatically. Mitchell (2004) collected numerous information about the former size of the forest in his report. His conclusions and theory about the circumference of Kakamega Forest are summarized here: Around the settlements whereof Kakamega Town developed the first colonisers described the natural vegetation as “insanitary bush and rank vegetation”. The Kakamega district was further described as covered with thick vegetation with litte pure thick forest, except for the Kakamega Forest. In the late 1920’s mostly no forest fragments or patches were left beyond the forest boundary. The map of 1916 shows that the former official western border is basically the same as today’s (Mitchell 2004). In addition oral tradition approve that in the early 20th century the forest had already been converted to grassland with shambas whereas some isolated forest patches remained. Some evidence that the forest existed further to the west provide the villages' names. A lot of villages adjacent to the western border of the forest are named after indigenous forest tree species. But whether the forest covered the complete areas or only occurred in small patches for example in river-bed areas is still uncertain. On the eastern side, towards the North Nandi forests, the area seems to be free of a dense forest cover and maybe the two forest sytems were never connected. The absence of village place-names relating to forest trees is again supporting the evidence that dense forest did not occur when the area was settled for the first time around 1912 and again in the 1950's.

Fragmentation

Kaimosi forest was connected with South Nandi Forest and Kakamega Forest until 1965, Brooks et al. (1988) show a map drawn from aerial photographs to prove that they are separated thenceforward. The dramatic forest loss in this area is therefore only about 40 years ago and came along with the disruption of the Yala and Ikuywa areas from the Isecheno forest. Aerial pictures from 1948 and 1965/67 already show the same distribution of the forest in all directions like today. The adjacent forests in the north were not connected with Kakamega Forest. But in the following years Kakamega Forest was divided up between the Isecheno and Yala areas because of broad commercial logging. Furthermore, the connection between Kaimosi and South Nandi forests was disrupted.

The first maps and oral traditions led to the assumption that Kisere and Malava forests were not connected with the Buyangu area in recent history. Kisere and Malava forests were described and drawn on the maps as an aggregation of forest patches or scattered bushland. It is said that Kisere forest even has been expanding its limits since the early 1900's. However, Kakamega and Kisere forests could have been connected over riverine forests along the Isiukhu and Nandamaywa rivers (Tsingalia 1988). In recent history the adjacent forests north of Kakamega Forest were not connected with each other. Therefore, Kakamega Forest consists of several patches.

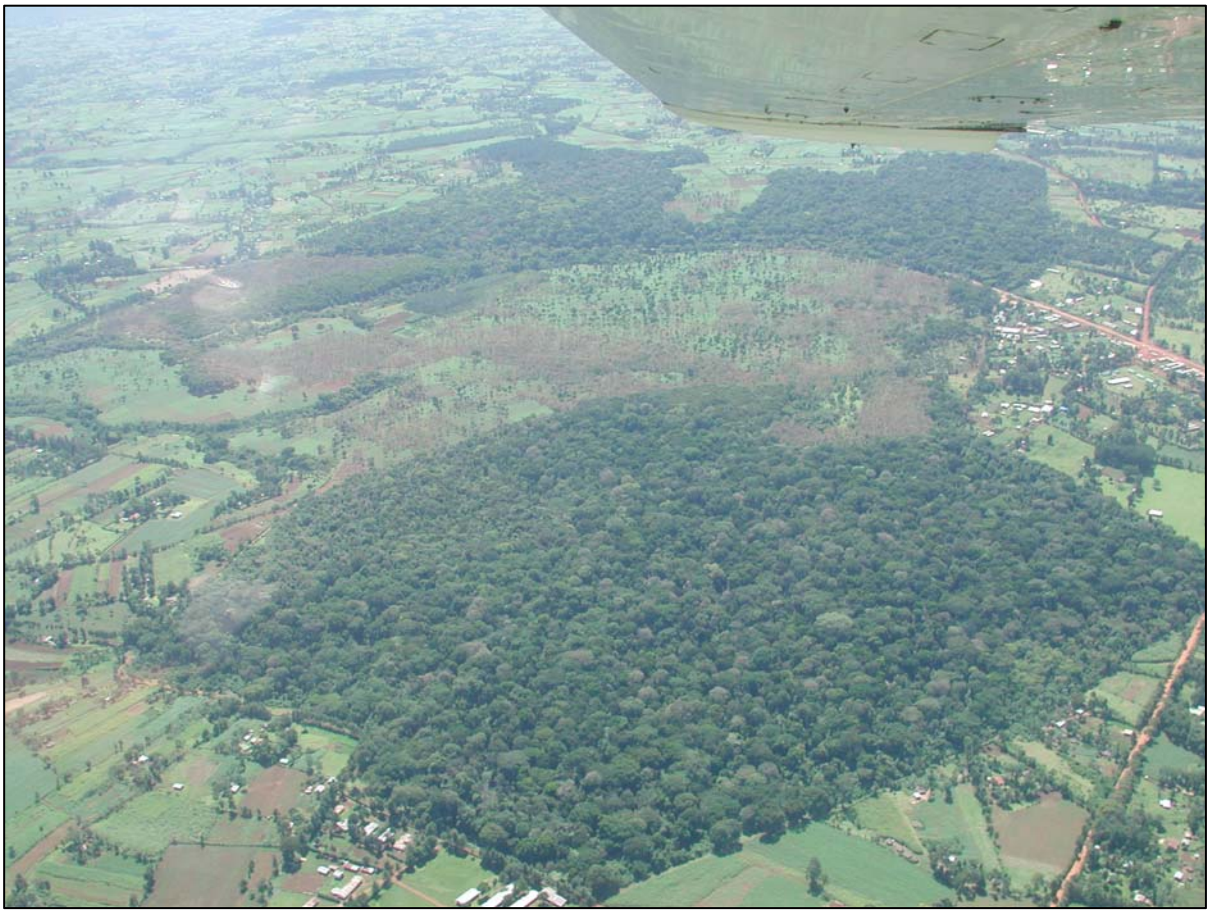


Fig. 6: Aerial picture from Malava Forest along the Kakamega-Webuye road. Source: R. Steinbrecher, IMK-IFU, Garmisch-Partenkirchen.

Fig. 6 shows an aerial picture of Malava Forest. The vicinity of the settlements can be seen clearly. The above fragment consists of different plantations of *Eucalyptus saligna* (top left) and *Bischoffia javanica* (middle), which is obviously recognisable by their homogenity.

Tab. 2: The current status of the expansion of the forest and the official forest boundaries since 1933, not available for Kaimosi forest; information delivered from Gertrud Schaab, BIOTA-E02, personal communication.

area	**ha**	**ha gazetted in 1933**
Malava	190	703
Kisere	420	458
Kakamega Forest (main forest block)	8,537	23,632
Ikuywa	1,370	within main forest block
Yala	1,199	within main forest block
Kaimosi	132	-
sum	**11,848**	**24,793**

Table 2 gives a comparison between the expansion of Kakamega Forest 70 years ago, before the broad clearing of the forest started and nowadays. The official boundaries from 1933 are the same as today. Attention has to be paid to the size information. In 1933 not only the indigenous forest cover was included and due to the technology it was difficult to estimate the real expansion of the forest. The information about the current status of the forest is based on a visual interpretation of contrast-enhanced Landsat scene of 05 Feb 2001 from which different vegetation classes were indentified. Therefore the different sizes of the forest in the past and today cannot be compared exactly. But nevertheless it is clear that in 1933 Ikuywa and Yala forests were not separated from the main forest block, and the forest cover in each mentioned forest patch shrunk dramatically since then. Fewest forest loss can be found in Kisere. Due to its status of a reserve since 1967 and the strictly protection by the KWS it faced less disturbance in the past. There is reliable information that about 10,000 ha - one half - of indigenous forest cover were lost over the last 70 years caused by human disturbance. Thereof over 20 % of the forest cover was lost in the last 30 years (Lung & Schaab 2004). Kenya covers an area of about 582,600 km² which includes about 10,700 km² of lake area, principally Lakes Victoria and Turkana. An estimated number of 2.9 million people live within 5 km radius of forest areas. An analysis indicates that 1.24 million ha of closed canopy of indigenous forest is left, out of an original possible cover of 6.8 million ha. This amounts only 2 % of the land cover of Kenya (Wass 1995). Thus, the forest loss in Kenya is reflected by the loss of the Kakamega Forest.

Management status of the forest

In the early 1900's first surveys by the Survey of Kenya were done on the forest expansions, resulting in a map of the year 1916 (Mitchell 2004) which shows that in this time Malava and Kisere forests were separated. The two forests were only drawn in as groups of trees. Furthermore, the Isecheno as well as the Ikuywa and Yala region were connected with each other and with the south Nandi forest system. Until 1931 Kakamega Forest was managed by the local people especially from the village elders and were then brought under the control of the Forest Department (FD) which gazetted the forest as Trust Forest in 1933. Enumeration of the forest stand started as well as reforestation and silvicultural improvements which included eviction of the local people out of the forest. First plantations with the exotic tree species *Eucalyptus salgina* from Australia were established between 1936 and 1938 (Mitchell 2004). After the forest was declared as Central Government Forest in 1964 (Blackett 1994), three small Nature Reserves in Isecheno (295 ha), Yala (460 ha) and Kisere were officially created in 1967. The motivation was to protect these areas from exploitation and to preserve the different forest types of Kakamega Forest. Kisere forest and part of the northern Kakamega

Forest, were declared as Buyangu National Reserve in 1986 and fell under the management of the Kenya Wildlife Service (KWS). The Buyangu National Reserve covers an area of about 4,270 ha, of which Kisere covers 458 ha and the Buyangu area 3,812 ha. But the main part is still Forest Reserve under the control of the FD with legal use of the forest inventory. The areas outside the Nature Reserves of the Forest Department are reserved to the forestry. Here trees are planted because of their economic values, whereas KWS established more stricter rules to conserve the forest. Any use of the forest under the control of KWS is forbidden. One of their goals is to protect natural resources and to share this revenue with the local communities. Tourism is thought to be one source of long-term income for the KWS and the local people, while direct benefits for the locals lie in employments as field guides or field assistents for several research projects on the unique wildlife flora and fauna in Kakamega Forest, for example. To summarise, Kakamega Forest comprises of two different management regimes, the Forest Department and Kenya Wildlife Service and of different protection priorities. The Buyangu National Reserve under the control of KWS is regular patrolled by game rangers to enforce the conservation and protection of the wildlife resources. In the two Nature Reserves of FD conservation is accomplished and no logging or clear-felling take place, but grazing of livestock or collecting of firewood is allowed. The overall aim of the FD is not only to conserve and protect indigenous forest, but also to improve the production of timber (Wass 1995). In the remaining forest sites these guidelines are applied.

Human impact

History

Different waves of migration took place at the border area of today’s Uganda and Kenya, which has been described as a “melting pot of different ethnic groups” (Haupt 2000).

Between 500 AD and the late 18th century Bantu, particulary from eastern Uganda, South-Kushites and South-Nilotes came in contact to each other. From theses groups the Luhya community developed which is now the dominant tribe living adjacent to the forest. The Luhya culture is mainly influenced by the Bantu and their agricultural applications were undertaken. The Luhya live in direct neighbourhood to the Nandi tribe and especially in the 19th and 20th centuries clashes between the two tribes were common. A view on the eastern side of Kakamega Forest and on the Nandi forests leads to the conclusion that the pastoral Nandi demonstrate a possibility to live alongside the forest without destroying it (Mitchell 2004). The western side with the Luhya tribe nearby has been much more destroyed during the last 100 years. One tribe among the Luhya, the Tiriki who were living in and around the southern part of the forest had and still have the tradition that land is communally owned. It is man’s job to break new ground and clear bush or forest. Also collection of medicinal plants is most often done by men. Whereas collecting of dead wood as fire wood is the job of women (Mitchell 2004). Young men among the Tiriki traditionally had to spend a certain time period inside the forest in a specific, sacred area to learn about the values of the forest. This forest areas were protected, but other were broken off to make new land accessible for the growing population, for example for the shifting cultivation.

Studies of the traditional spiritual beliefs around Kakamega Forest show that spiritual affiliations are mostly on forest tree species and not to the forest in general (Mitchell 2004). The Tiriki clan believes that *Antiaris toxicaria* holds the spirits of their ancestors and should be protected and not cut if you do not want to meet your ancestors in your dreams. Nevertheless, the use of trees and shrubs from the forest is widespread. Haupt (2000) studied the medicinal uses of different parts of the plants like leaves, barks and roots. Barkcutting for medicines was one of the greatest disturbances in the survey of Mutangah in 1996. Trees like *Trichilia emetica*, *Diospyros abyssinica* or *Aningeria altissima* were affected by this traditional application to get medicinal extractions.

Due to the formerly low population density around the forest and the sustainable use of the forest products human disturbance was bearable at that time.

The population density around the Kakamega District is now one of the highest in Kenya. In 1994 Blackett noted an average of 600 people per km² and even an average density of 713 people per km² in the thirteen sub-locations adjacent to the forest. In average the population growth rate is 2.8 per cent a year (KIFCON 1994). The still growing population around Kakamega Forest leads to land pressure. Land has become scarce goods and therefore the land where the forest grows is under pressure, too.

The fast growing population made the traditional way of leaving land fallow to rejuvenate while other land is cultivated impossible. Instead the owned land has been divided up into smaller parcels. That, together with the exhausted soils on their farmland, forced people to use again the forest resources with consequences in illegal farming or livestock grazing inside the forest.

Although the agricultural potential is high, because of the good climate and soil conditions, the population cannot live on farming without a heavy utilisation of the forest land and its resources. They need alternatives in trade, industry and services to survive and to conserve the forest at the same time. About 70 % of the local people live on agriculture. Around the forest the environment is dominated by small-scaled farms where the people grow food crops for household consumption and the local market. Furthermore, major cash crops in the district are tee, coffee, sugarcane and sunflowers (Haupt 2000). A tea-zone was established along the forest margin on the eastern side, near Isecheno to offer new income for the people and to establish a belt to prevent encroachment through illegal farming. To reduce illegal farming and to have a control, the FD introduced a program called shamba-system in the late 1940’s. Cleared land from the FD was cultivated by the farmers. They were allowed to build their shambas (huts) on these land. In return they had to plant tree saplings which were protected inside the crops. After some years they had to leave that piece of land to provide an opportunity for the trees to develop into a forest stand. Because of abuse the shamba-sytem was dropped in the 1980’s (Mutangah et al. 1994). Nowadays a different system named taungia-system exists. The farmers receive land up to five acres of cleared land from the FD and can cultivate this land for three years, but are not allowed to live on it. Unfortunately there is not enough cleared land for every interested farmer (Haupt 2000). When at the beginning of the 20th century the government exercised control over the forest to evict the local people and to reduce the exploitation, the traditional bonds of the people to the forest broke. The traditional uses of the forest were reduced to a minimum level and are now forbidden in most areas. Intensive crop production and the influence of the colonists led to increasing opening of areas for farming and settling. Beside the introduction of cash crops by the colonists, the plantation of exotic and indigenous trees, and the intensive timber felling, like for the construction of the railway from Mombasa to Kisumu in the early 1900’s, led to social and economic changes of the locals.

Illegal activities

After the locals were forbidden to cover their daily needs from the forest they were allowed to use the forest again in the years 1959 and 1964. But in 1984 and 1988 official bans from the presidential directive were enacted to stop the cutting of indigenous trees and the conversion of indigenous forest in plantations (Mitchell 2004). Beside of the intensive, commercial use from local pitsawyers and the timber industry, illegal charcoal-burning and pit-sawing is the most endangering local use of the forest nowadays (Waas 1995).

Since that time grazing and cultivation inside the forest is forbidden, but local people are allowed to collect fire wood and graze their livestock like cattle, sheep and goats outside the Nature Reserves. Although charcoal burning and fuel wood cutting is forbidden since 1975, because of the need to conserve the exhausted forest, charcoal burners and pit-sawyers are still operating illegal which of course affects the conservation of the forest (see fig. 7 and 8).

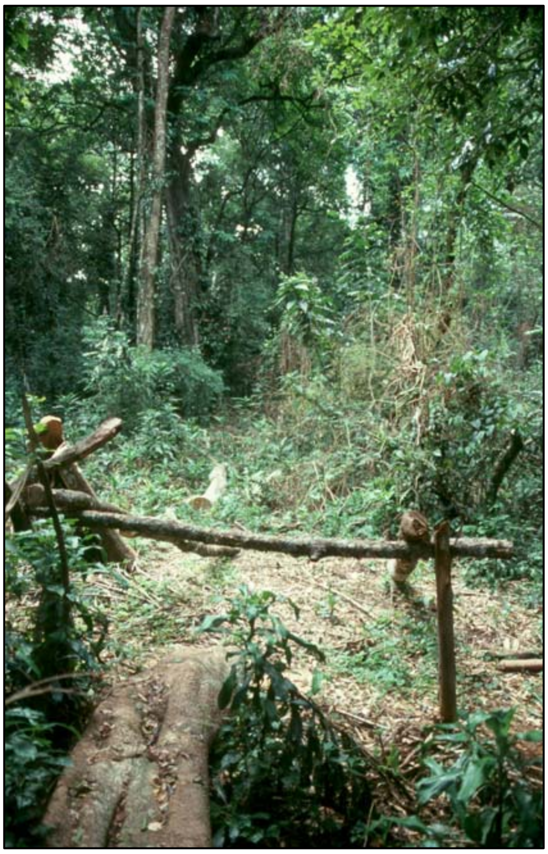


Fig. 7: Illegal saw construction in Ikuywa forest.

Fig. 8: Illegal cut tree.

To reduce illegal timber extraction out of the forest, the local people are encouraged to grow woodlets for firewood and poles on there own land. Together with their poultry and pigs they have to keep them around their households. Only on the glades of non-protected areas inside the forest grazing is allowed for a fee of 33 Ksh per animal and month (Haupt 2000). But illegal grazing of livestock still happens inside the forest.

Despite the official rules that prohibit the use and the exploitation of the forest inventory, several illegal activities can still be observed in Kakamega Forest. Pit-sawing is a serious problem in the forest, documented by several cut stems and numerous sights of previous cutting in Malava, whereas in more undisturbed forest parts snares could be found. In the southern part of the forest in Isecheno cattle grazing is still a major problem (Oyugi 1996). Local people living adjacent to the Isecheno forest, graze their cattle in the Kalunya-glade, which is not illegal but the paths through the forest back to their homes are trampled (see fig. 9). The proper forest floor can soak up unlimited rain, but the hoof-hardened paths collect pools and turn to mud. Regeneration of seedlings is thus impossible (Rowell 1982). Beside cattle grazing local people still collect firewood, vines for tying, bark and moss for medicine, poles for building and and charcoal burning like in Ikuywa (see fig. 10). Utilization of medicinical plants are e.g. described in Kokwaro (1993).

Fig. 9: View on Isecheno area, in the middle one of the biggest glades in the forest – the Kalunya-glade.

Fig. 10: Charcoal burning place, near Vihiga.

Timber extraction

Commercial logging of valuable trees all over the forest resulted in a decline of the forest size and in fragmentation of Kakamega Forest and its adjacent forests.

Different tree species were interesting for commercial logging and were divided up into two classes, the hard- and softwood tree species. Among these valuable trees were *Zanthoxylum gillettii* and *Olea capensis*. The indigenous forest was replaced by plantations with fast growing exotic trees like *Eucalyptus saligna*, *Cupressus lusitanica*, *Pinus patula* and *Bischoffia javanica* (see fig. 11). Because of the destruction of the forest stand the FD began to replant the cleared areas with indigenous tree species like *Prunus africana*, *Olea capensis*, *Markhamia lutea*, *Croton megalocarpus* or *Maesopsis eminii*. There are plantations in a pure stock or in combination, even exotic with indigenous tree species. Near the Forest Station at Isecheno tree nurseries are located.

Fig. 11: Aerial picture from Lirhanda Hill and the plantations of exotic and indigenous tree species. Source: R. Steinbrecher, IMK-IFU, Garmisch-Partenkirchen.

Kakamega Forest has been fragmented into two main forest blocks by the commercial logging activities. Most of the clear-felling was done in the southern half of the forest, therefore the fragmentation from the northern part including the Buyangu area with the KWS head office and the Isecheno area with the Forest Department station was separated from Yala and Ikuywa. These two southern fragments Yala and Ikuywa are still connected in a small area. The clear-felled area between the northern and southern fragments is to the greatest possible extent covered with plantations. Exploitation of the forest stand took place by means of different techniques, the clear-felling and the selective logging. Several sawmills and pit-sawyers were participated. Beside exploitation of valuable timber trees europeans started mining gold at the beginning of the 20th century. But due to the low appearance it was financially never viable.

When the gold mining started in 1932 the FD gave out the first logging concessions in 1933 by the demand of pit prop. At this time the operation of effective sawmills started. In the mid-1980's they shut down, because of the presidential decree for stopping the exploitation of indigenous trees (Mitchell 2004). Between the 1950's and 1970's no forest fragment appears to have been clear cut, but about 1970 the biggest forest exploitation with far-ranging clear-felling, mostly in the southern part, started. The northern half of the forest was more affected by selective logging than the now southern fragmented half. During the big timber exploitation the way of cutting tree species changed several times. Before the two World Wars people cut only good timber trees, whereas during the World Wars most types of tree species were cut, because of the need of fuel wood, railway sleepers or baulk timber. After the wars people went back to exploit only good timber trees until 1970. The FD was responsible for the decision which forest area fell under the timber extraction and was engaged in that business by receiving a percentage of the market price of the particular tree species (Mitchell 2004).

Pit-sawyers were deployed in two ways. On terrain where it was too difficult to bring the single tree individual out of the forest they sawed the trees at the place of felling, later they cut several trees in Kakamega Forest areas where clear-felling was not conducted. The sawmills cut the trees by saws and brought them out of the forest by oxen or caterpillar tractors. The used tracks are still visible, for example north of the Kalunya Glade near the Isecheno Forest Station. Clear-felling means that the mill company cuts out single valuable timber species and then turns the remaining trees into charcoal or fire wood for sale (Mitchell 2004). From 1955 on the sawmill companies felled merchantable single tree species. Then pit-sawyers removed all trees they could use followed by the charcoal burners who cleared the forest completely. Beside clear-felling selective logging was chosen to avoid soil erosion and allow the forest to regenerate for later exploitation. But the “natural regeneration” was advanced by group or line planting. In the 1970’s the potential timber harvest was more wanted than the possibility for the forest to regenerate (Mitchell 2004). Beside that clear-felling was done in a more vaster form, because it was much cheaper than the time-consuming selective logging. The cleared places then were recovered by large plantations with *Eucalyptus*, *Cupressus* or *Pinus* which are fast-growing and have more commercial value than these slow-growing indigenous forest species.

In the year 1975 clear-felling was officially banned, and instead the left 12,500 ha of indigenous forest were divided up into coupes in which different species and different sizes of trees were allowed to be cut or not.

Three studies were done on the amount of timber exploitation per year in Kakamega Forest, but they do not agree with each other which depends on the very partial data and inclompete timber statistics (Tsingalia 1988, Mutangah 1996, Mitchell 2004). Therefore only some facts will be presented here. Two major sawmills were situated in the south of Kakamega Forest. For the Kakamega Sawmill *Olea capensis* was the most cut tree, because of its hard wood useful as timber in general and in the furniture industry in the early 1930's. Records from the Rondo Sawmill between 1948 and 1953 show that the most used species were *Celtis mildbraedii* (835 m³) followed by *Cordia africana* (630 m³) and *Trichilia emetica* (383 m³) (Mitchell 2004). Due to the upcoming plywood industry new softwood species were included in the timber extraction like *Antiaris toxicaria*, *Maesopsis eminii* and *Polyscias fulva*.

The technology between the 1930's and the 1970's was not able to cut trees exceeding a diameter of about 130 cm. Therefore, bigger trees were left to the pit-sawyers. The new plywood technology offered the possibilty to use trees of smaller diameter which resulted in new licences to cut smaller trees in Kakamega Forest. The FD gave areas of "poor forest" to the charcoal and fuel wood contractors, where the trees were not large enough for commercial logging or they operated in the clear-felled areas.

To summarise, all parts of Kakamega Forest and its adjacent forest systems were under different exploitation during the last 70 years caused by different levels of disturbances, different selective logging of species and different protection status through the FD and KWS.

Fauna

The wild animal fauna was much more diverse than it is nowadays. Several species became less common or extinct. Until the early years of 20th century herds of buffalos and elephants lived in Kakamega Forest. It is not known whether they were visitors from the nearby Mt. Elgon or residents. Another possible origin could be from the now uninhabited savannah around Kakamega as its is for several antilopes and their predators like lions and leopards. The last report of lions was in the 1950's whereas leopards are still supposed to live in the forest.

The local people always hunted animals inside and around Kakamega Forest with several forms of traps or with spears, bows and arrows (Mitchell 2004). They also burnt the glades to attract the wild animals to the fresh grass regrowth in order to kill them there. In addition the europeans brought in guns and declined the population of wild animals (Tsingalia 1988). During the First World War the hunting increased, because the local population relied heavily on the wild animal population to satisfy their hunger (Mitchell 2004). Beside that, several diseases like the rinderpest and sleeping disease caused the decline of not only domestic but also wild animal species in the late 19th century.

Different monkey species occur in Kakamega forest which are now under protection. But red-tailed monkey (*Cercopithecus ascanius*) and blue monkey (*Cercopithecus mitis*) are still hunted for their meat. Black-and-white colobus (*Colobus guereza*) and baboons (*Papio *ursinus*) were not eaten and are still present in high numbers (Cords 1987). There are 330 bird with several endemic species. Kakamega Forest is one of the most important conservation bird areas in Kenya and the avifauna is very similar to that of Central Africa like in the forests of Nyungwe in Rwanda or Kibale Forest in Uganda (Collar & Stuart 1988). The Forest's special relevance for birds in Kenya is due to its composition of lowland, montane and forest dependent and grassland species (Bennun & Njoroge 1999). One of the noisiest species, very abundant and easy to recognise is the Black-and-White Casqued Hornbill (*Ceratogymna subcylindricus*). An indicator for the forest's origin in the Congo-basin is the occurrence of many West and Central African species in Kenya only in Kakamega forest like the Great Blue Turaco (*Corythaeola cristata*) or the Blue-headed Bee-Eater (*Merops muelleri*) (KIFCON 1994). Due to the unique bird fauna several studies were conducted (Collar & Stuart 1988, Prigogoine 1978, Zimmermann 1972). Beside the birds 400 butterfly species are on highest interest for researchers and tourists (Spawls 1978).

Among the diverse animal species living now in the forest are: several antilopes like the Red Duiker (*Cephalophus natalensis*) or the Bushbuck (*Tragelaphus scriptus*), three squirrel species, bats and several monkeys. Among them de Brazza's Monkey (*Cercopithecus neglectus*), a Central African species and very rare in Kenya (Muriuki & Tsingalia 1990). Snakes mainly originate from West Africa are the Forest Cobra (*Pseudonaje goldii*), Gaboon Viper (*Bitis gabonica*) and the Rhinoceros-horned Viper (*Bitis nasicornis*). Impressing insects are the Goliath Beetle (*Goliathus goliathus*) and the army ants (*Dorylus* spec). In the BIOTA-framework several subprojects are enganged in Kakamega's fauna (Freund & Patt arthropods, especially beetles; Bleher & Boehning-Gaese, birds and seed-dispersal; Lötters & Veith, amphibians; Kühne & Häuser, butterflies and moths; Kraemer & Bergsdorf, insects, pollination biology; Clausnitzer, dragonflies).

Study sites

The present study was conducted at 19 different study sites in Kakamega Forest and its adjacent forest patches.

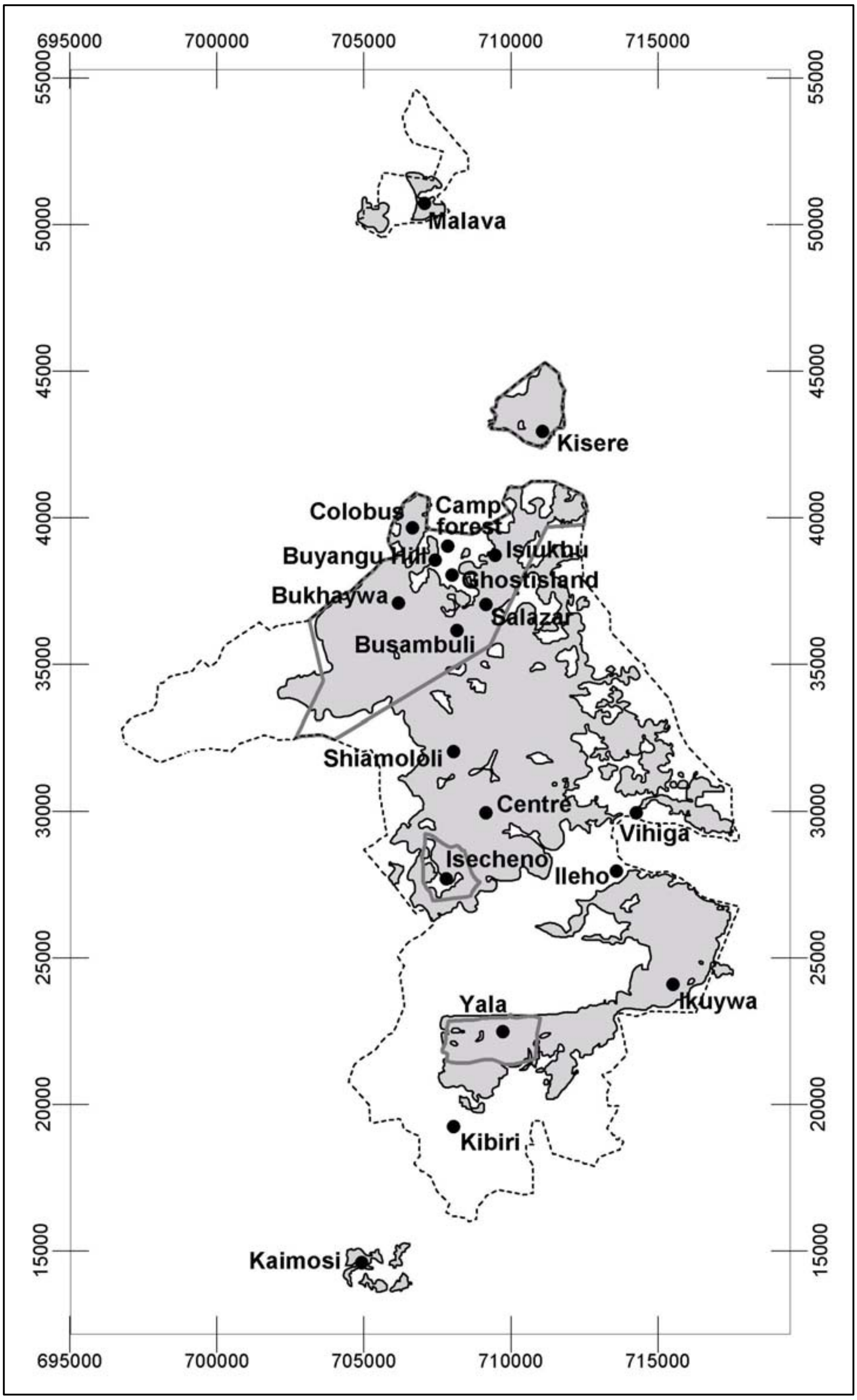


Fig. 12: Overview map of the study sites in Kakamega Forest. Shown are the position of the study sites (black dots) and their nomination. Also the official forest boundary gazetted in 1933 (dashed line) and the Buyangu National Reserve in the north and the Nature Reserves Isecheno and Yala in the middle and south of the forest (grey line) are noted. Black lines represent the extensions of mature forest as derived by visual interpretation of contrast enhanced band combination 5/4/3. Source: Gertrud Schaab, E02, FH Karlsruhe. UTM projection: transverse mercator, grid:UTM Zone 36, Unit of measurement: meters.

Fig. 12 is an overviewmap of the nineteen study sites which shows that the study was conducted all over Kakamega Forest, trying to cover every fragment and to establish areas from north to south in the main forest block.

Tab. 3: Visual interpretation of distances between different forest patches derived by visual interpretation of contrast enhanced band combination 5/4/3. Source: Gertrud Schaab, E02, FH Karlsruhe.

Forest patch	**Nearest forest patch**	**Distance [km]**
Malava	Kisere	6.2
Malava	main forest block	9.8
Kisere	main forest block	1.6
main forest block	Ikuywa	1.5
main forest block	Yala	3.6
main forest block	Kaimosi	11.4
Yala	Kaimosi	5.8

Table 3 shows the distances between the forest patches to get an imagination of the expansions of Kakamega Forest and its adjacent fragments.

During five field phases from September to November 2001, March to April 2002, October to November 2002, June to August 2003 and March 2004 three different methods were applied which are described in the following chapters (see Tab. 4). Within this study in every from BIOTA established biodiversity observatory (BDO) research were done (fig. 3).

Tab. 4: Overview of the study sites, where the three different methods were conducted. Va = variable-area.

Study site	relevés	transects	va-transects
Malava	+		+
Kisere	+	+	+
Colobus	+	+	
Camp forest	+		
Buyangu Hill	+	+	
Isiukhu	+		+
Ghostisland	+		
Salazar	+	+	
Busambuli	+	+	
Bukhaywa		+	+
Shiamololi	+		+
Center		+	
Vihiga	+		
Isecheno	+		
Ileho	+		
Ikuywa	+	+	+
Yala	+		+
Kibiri	+		
Kaimosi	+		

In the field data about coordinates, distances and cardinal points were taken by Garmin eTrex. In cooperation with subproject E 02 under the supervision of Gertrud Schaab all positions of the conducted relevés and transects were digitalised in a geographic system (GIS) and visualised in ArcView 3.X. Information about the stand structure, distribution of plant communities and succession stages were connected with the information about the position of the investigated areas. The survey of the state of the forest based on a computer assisted classification enabled us to carry out long-term monitoring for conservation needs.

Single maps of the locations of relevés, transects and variable-area-transects are presented in Figures 13 – 21. The shown forest patches are ordered from north to south; for abbrevations, symbols and colour see legend (fig. 22).

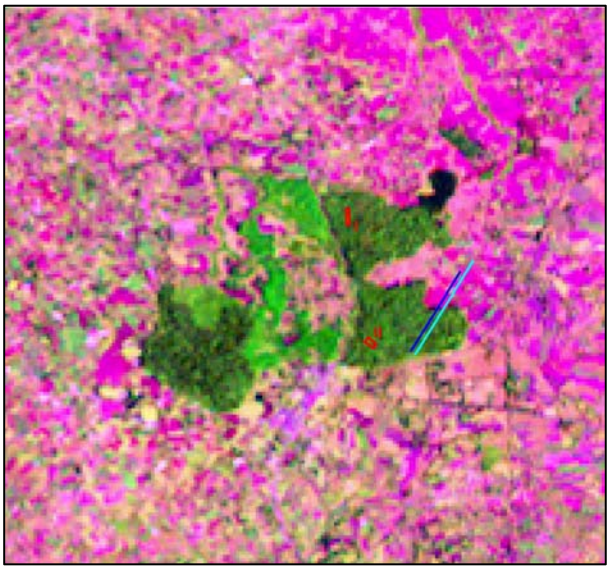


Fig. 13: Malava Forest.

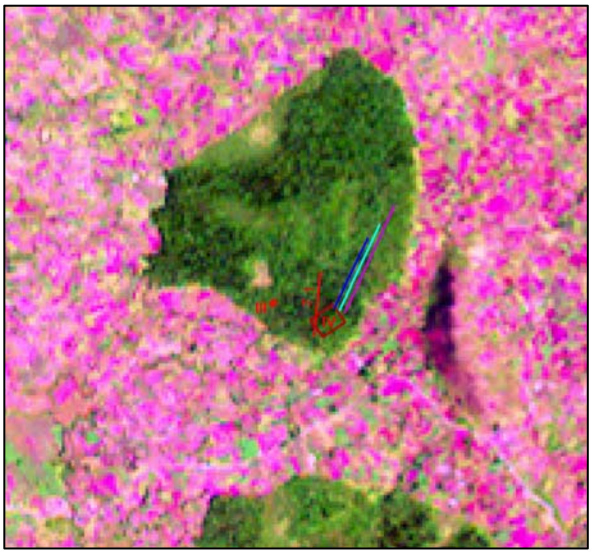


Fig. 14: Kisere Forest.

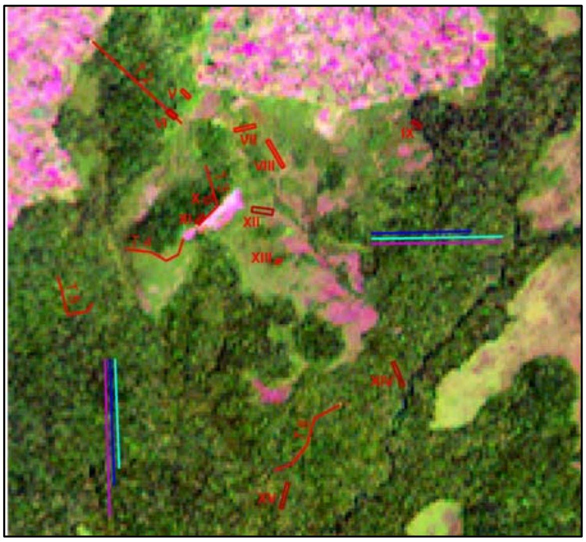


Fig. 15: Colobus, Buyangu Hill, Camp Forest, Isiukhu, Ghostisland, Bukhaywa, Salazar and Busambuli.

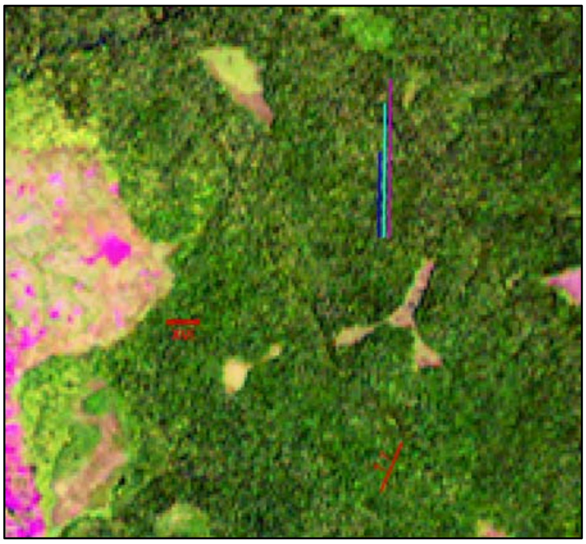


Fig. 16: Shiamololi and Center.

Fig. 17: Isecheno and Kalunya-glade (triangle).

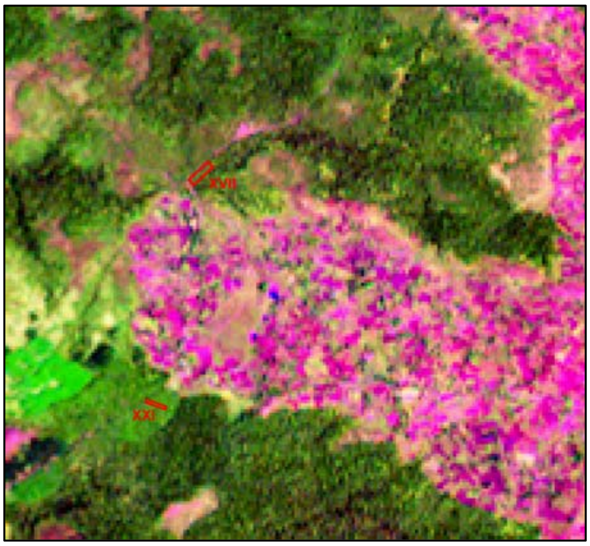


Fig. 18: Vihiga and Ileho.

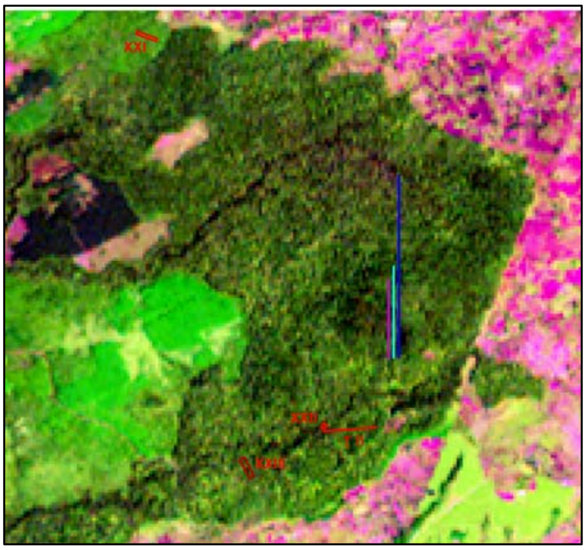


Fig. 19: Ileho and Ikuywa.

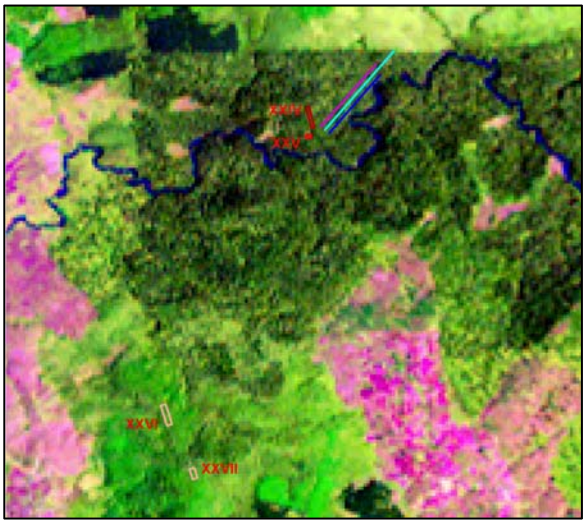


Fig. 20: Yala and Kibiri.

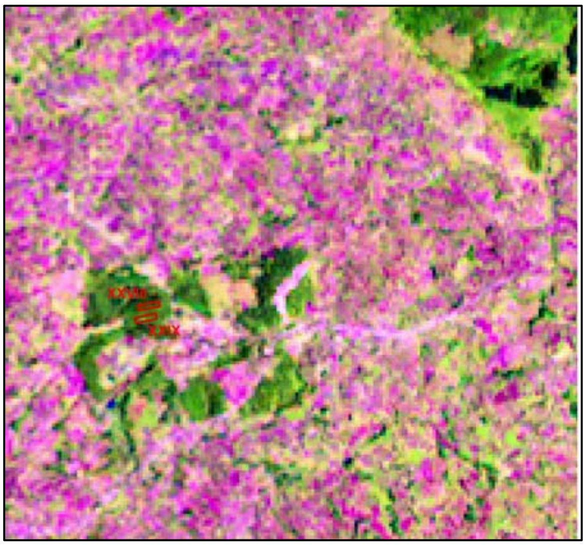


Fig. 21: Kaimosi Forest.

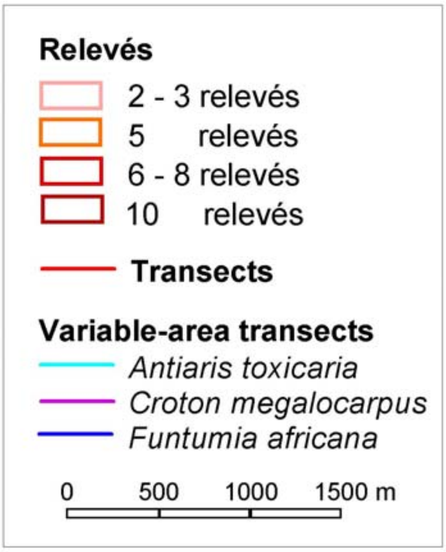


Fig. 22: Legend.

Site description of the relevés is presented in appendix 1. In ArcView 3.X where the single maps were obtained not every single relevés was imbedded, instead rectangles mark the positions. Information about the coordinates of the different study sites can be read off the UTM-grid given in fig. 12.

In the following the nomination Kakamega Forest includes the main forest block with the Buyangu area in the north and the Isecheno area in the south, as well as its fragments Yala, Kaimosi and Ikuywa. Although it is not sure, whether the adjacent forests Malava and Kisere are remnants of Kakamega Forest and when they were separated, these forest patches were defined as fragments of Kakamega Forest, too.

3. Floristics

Introduction

Forest development in Eastern Africa

Only presumptions can be made whether the African rainforest belt ever covered Central Africa from west to east up to the coast of Kenya. Alternatively, small forest islands advanced piecemeal and connected with each other during humid conditions. Under dry conditions grasslands expanded which surrounded the forest islands, whereas random firing retained their extents. Water availability was one of the dominant influence factors on the distribution of forests in the quaternary. Increases or declines of forest vegetation depend on climate conditions. During the last glacial period from 70,000 to 11,000 B. P. with a maximum at 18,000 B. P. the climate in tropical Africa was characterized by aridity (Hamilton 1981). An estimated temperature decline of 4 +/- 2 ° C in the last glacial period and a mean annual rainfall decreased by 30 %, resulted in a significant contraction of the humid forests (Bonnefille et al. 1990). Forests survived only in particular refugial areas permitting many species to move freely between these isolated ecological islands (Hamilton 1981). They were surrounded by savannah or bushland where it was too dry to support forest. Distribution patterns of some afromontane plant species nowadays perfectly reflect these refugia like of several *Impatiens* species or the giant lobelias (Fischer 2000 a). At the beginning of the postglacial at 12,000 to 10,000 B. P., the climate conditions changed again throughout the world. Rainfall and temperature in Africa increased. A period of maximum humidity is documented between 10,000 and 6,000 B. P. As a result the forest spread from the former refugial areas. Such forest refugia were located at the coast of West Africa, in Central Africa mainly on the volcanoes or the lowland and montane forests in the Usambara Mountains in Tanzania. Further minor forest refugia are assumed north of Lake Victoria (Hamilton 1981). Kakamega Forest developed in that postglacial period. Its relative poverty of plant species is a consequence of its distance from the main Central African lowland forest refugium. An increasing distance to the refugia results in a decline of species. In the neighbouring country Uganda a gradient of increasing species poverty from west to east across the country can be recognized (Hamilton 1981). Kakamega Forest is the only reasonably large patch of Central African lowland forest type in Kenya. However, it is somewhat atypical, because it contains a number of montane species probably derived from populations that survived the last glacial and arid period in montane forest refugia in Kenya. Furthermore, Kakamega Forest has a low endemism rate because of its young age. In addition the Lake Victoria region, where

Kakamega Forest is situated, is known for its low endemism. Probably even no endemic genera exist (White 1983). Around 6,000 B. P. the african rainforests reached their maximum expansion (Lovett & Wasser 1993). Afterwards the climate got drier again and the African rainforest belt shrunk. Additionally the increasing human populations converted these forests into bush or savannah leaving small island of the today called Guineo-Congolian rainforest. Such remnants can be found in Uganda (for example the Budongo forest) or in Congo (Hamilton 1981).

Classification of Kakamega Forest

According to Knapp (1973) Kakamega Forest belongs to the transition zone between the Guineo-Congolian and the Sudanian floristic regions. Another classification delivers White (1983), regarding the studied forest as related to the Lake Victoria regional mosaic. This region includes most of Uganda, the whole eastern Rwanda and Burundi and small parts of Congo, Kenya and Tanzania. The Lake Victoria regional mosaic is a meeting-place of five distinct floras: the Guineo-Congolian, Sudanian, Zambezian, Somalia-Masai and Afromontane flora.

Most of the Guineo-Congolian species have their easternmost limit in Kakamega with the Nandi Escarpment acting like a distribution border.

Guineo-Congolian floristic elements are for example tree species like *Bequaertiodendron oblanceolatum, Aningeria altissima, Harungana madagascariensis, Maesopsis eminii* and *Monodora myristica* (Friis 1992, White 1983). The dominant climber species occuring everywhere in Kakamega Forest, *Piper guineense,* also belongs to the wetter lowland forest of the Congo basin and is restricted in Kenya to Kakamega (Beentje 1994). *Dracaena fragrans,* an abundant shrub with a high coverage of the undergrowth, is very typical for that forest, is also restricted in Kenya to that region and belongs to the West African species.

Typical species from the highlands of East and Central Africa, called afromontane species, are *Olea capensis*, *Prunus africana*, *Strombosia scheffleri*, *Turraea holstii* and *Chrysophyllum albidum* (Schmitt 1991, Bussmann & Beck 1995, Hamilton 1981, White 1973). Some of the afromontane species might have originated from the close Mt. Elgon. Appendix 2 gives a comparison of the investigated trees, shrubs and lianas. The amount of Guineo-Congolian species in Kakamega Forest is about 41 %, about 33 % are of afromontane origin. About 26 % are species where a differentiation between these two elements is difficult and which could be named as transitional species.

Kakamega Forest is influenced by different biogeographic elements and therefore consists of a unique composition of plants and animals. One can say that the forest is a continuum between the distinct biogeographical regions of the Congo Forest and the East African Highland Forest.

A number of different classification systems and terminologies have been proposed for the forests of Eastern Africa (see Lovett & Wasser 1993). White (1983) truncated the Guineo-Congolia region at Lake Victoria and regarded the Eastern Arc forests below the afromontane zone as part of an Eastern Coastal Zanzibar-Inhambane region. Instead, Lovett & Wasser (1993) regarded all forests in the Eastern Arc mountains phytogeographically as Guineo-Congolian forests. According to this the Taita Hills in Kenya are the easternmost remnant of the Guineo-Congolian forest belt. Surely a lot of species belonging to the Guineo-Congolian flora occur in the lowland coastal forests in Eastern Africa, like the tree species *Funtumia africana* and *Antiaris toxicaria* which are the most common tree species in Kakamega Forest. But the amount of species with their main distribution in the Congo-basin is very low. Therefore, we regard Kakamega Forest as the easternmost relic of that equatorial forests as stated by Schultka (1975) and by Kokwaro (1988). Because of the lower humidity and its altitude the forest is described as Semi-Evergreen High Forest, but has its origin in the lowland rainforest of the Congo-basin. Forest of similar types are the Budongo or Mabira Forests and several other forest patches in Uganda at altitudes between 1100 and 1700 m (Knapp 1973).

In the defintion of vegetation types of Beentje (1994) Kakamega Forest is defined as rainforest with copious rainfall spread over the whole year and with a continuous stand of trees taller than 10 m with interlocking crowns.

The classification of forests in East Africa is based on two elements, altitude and moisture. Many authors classified purely on physiognomic and floristic composition features (Greenway 1943), but others combined vegetation attributes with environmental factors like altitude and moisture. Depending on the altitudinal graduation of several authors Kakamega Forest is described as montane forest (Lovett & Wasser 1993), as lowland or rather semi-montane forest (Lind & Morrison 1974) and as mid-altitudinal (Bleher et al. 2005). A comparison with the floristic composition of East Africa’s montane forests (Hedberg 1951, Hamilton 1981, Polhill 1989, Bussmann & Beck 1995, Schmitt 1991, Wesche 2002) shows that Kakamega Forest is not related to these forest systems. White (1983) declares Kakamega Forest as lowland forest, but we suggest that its altitude of 1500 to 1700 m is too high to name it “lowland”. In addition Fischer (1996) mentioned that at an altitude between 1500 and 2000 m no lowland forest occurs, instead it is defined as transition forest. Another classification is presented by Trapnell & Langdale-Brown (1962). Their definition of wet intermediate and semi-deciduous forests fits to Kakamega Forest. Typical tree species of these forest types in East Africa are *Entandrophragma angolense, Celtis midlbraedii, Aningeria altissima* and *Diospyros abyssinica*, all species well known and in part dominant in this forest. According to Lind & Morrison (1974), Knapp (1973) and White (1983) we conclude that Kakamega Forest is a dry peripheral semi-evergreen Guineo-Congolian transitional rainforest. The forest is related to the Congo-basin, but has a higher altitude and a cooler and less humid climate.

Forest glades

Kakamega forest comprises several glades. The glades are commonly included when measuring the forest expansion, therefore the exact area of indigenous forest is usually overestimated.

It is uncertain of which origin the glades inside of Kakamega Forest are. There is also an ongoing debate over the origin of glades within forests in other countries. The edaphic situation, the climate conditions in history or the anthropogenic influence are discussed to be explanations for their origin (Tsingalia 1988). The FD tried to grow indigenous trees in the glades, but their attempts were without success. This could be an advice that the soil over the murram rock is too thin to provide enough drainage and depth to support trees (Mitchell 2004). After the climate conditions changed thousands of years ago, forests spread from west whereas forest islands developed which included the previous grassland vegetation (Hamilton 1981). This could have happened also in Kakamega Forest. Another possible explanation for the glades inside the forest is the occurrence of large grazing herbivores such as elephants and buffalos in previous times. Tsingalia (1988) mentoined that the physiognomic characteristics are not similar to glades on the plains and that the species composition reflects the intensity and frequency of grazing and burning.

Later on the human presence maintained the glades. Furthermore, families have been living in the glades in the 1920’s and cultivated the land. Until today the names of the glades are related to the families that lived there. Several glades shrink since cattle grazing and firing are forbidden.

Floristic inventory

Some publications present checklists of vascular plant species of Kakamega Forest (Kokwaro 1988, Tsingalia 1990, KIFCON 1994, Mutangah 1996) and there are several unpublished plant lists at the East African Herbarium (Mutangah 1996). For plant determination several books of neighbouring countries were consulted. Nevertheless, with the information of Beentje (1994) and the volumes of Flora of Tropical East Africa (FTEA) the flora of Kakamega Forest is quite well covered. Kakamega Forest has its own unique mixture of species from the once great Guineo-Congolian belt from West Africa over Congo to the east coast of Kenya, consisting of species from the afromontane volcanoes and coastal forest species. The disjunct distribution of species occuring in Kakamega Forest and in the coastal forest areas is an evidence for the once existing rainforest belt crossing central Africa from the West to the East.

One aim of this study was to get a comprehensive data-base of the vascular plant species of Kakamega Forest and to compare it with available literature. The new species that were found and identified for this forest were commentated. Also problems with the identification and used determination books will be mentioned. This is to get a closer insight in the forest inventory and to present the base for the identification of the plant communities and to get a better understanding of the plant composition. In the framework of subproject E 04, where this study was conducted, also lichens and bryophytes were collected to get a first inventory of Kakamega Forest. The obtained data are published separately (Fischer et al. 2004, in prep.). Therefore, in the inventory and analysis of the plant communities in the present study no lichens and bryophytes were included. Nevertheless, a short overview is given in the result part.

Methods

During the four field sessions specimens mainly of dense forest and the gaps inside were collected. We tried to cover all surrounding fragments, the main forest block as well as different succession stages and different habitats. All species were determined to species level in the field when possible and collected by the first appearance. About 29 specimens could not be identified to species level. A species list is given in appendix 3. One set of vouchers is deposited in the University of Koblenz-Landau, the duplicates of most of the specimens have been sent to the National Museum of Kenya (NMK) in Nairobi. Since our focus was only on forest vegetation with its different succession stages and gaps, no collection of grassland or pathway vegetation was done. Nomenclature of all families followed Turill et al. (1952 ff.)

and Beentje (1994), except for ferns and monocotyledons which followed Johns (1991) and Agnew & Agnew (1994).

Identification of woody plants and herbs followed Agnew & Agnew (1994), Beentje (1994), Dharani (2002), Flore du Congo Belge et du Ruanda-Urundi (Robyns et al. 1960 ff.), Flora of Ethiopia (Hedberg & Edwards 1989), Flora of Tropical East Africa (Turrill 1952 ff.), Hamilton (1991), Kokwaro (1994), Letouzey (1986), Seyani (1991), Troupin (1982), Troupin (1983); orchids after Stewart & Campbell (1996); ferns followed Agnew & Agnew (1994), Johns (1991), Tardieu-Blot (1964) and Poaceae followed Troupin (1987), sedges and rushes followed Haines & Lye (1983). A cross-check with available literature and species lists was done to analyse whether new species for Kakamega Forest could be found and whether this study provides a satisfactory database. Additionally identification of specimens was done in the herbaria of the National Museum in Nairobi, Kenya and of C.R.S.N. (Centre de Recherche en Sciences Naturelles) at Lwiro near Bukavu in Congo.

Not only the occurrence of species is of interest, but also their ecology, their geographical position, their distribution in Kenya and occurence depending on different succession stages. Information about the ecology of trees, shrubs and lianas of Kakamega Forest acquired in this study were taken from the available determination literature. Observations during this study as well as the long experience of the field assistent Bonny Dumbo were incorporated. The definition of pioneer and climax species follows Swaine & Whitmore (1998) and Whitmore (2001). Pioneer species are fast growing, light-demanding with seeds only germinating in full sunlight and with seedlings not surviving in the shade. These species are the first members of a succession stage. All plant species following the pioneer species are called climax species in the present study. Since climax species occurred in different succession stages, we divided them into two groups: the early and later climax species. A different categorisation of primary and secondary species is presented in Swaine & Hall (1983). The present study avoid these terms to keep them apart from the terms primary and secondary forests.

A checklist of native vascular plants with information about their ecology and distribution is given in appendix 2. The K-numbers indicate the rough distribution area (see fig. 23).

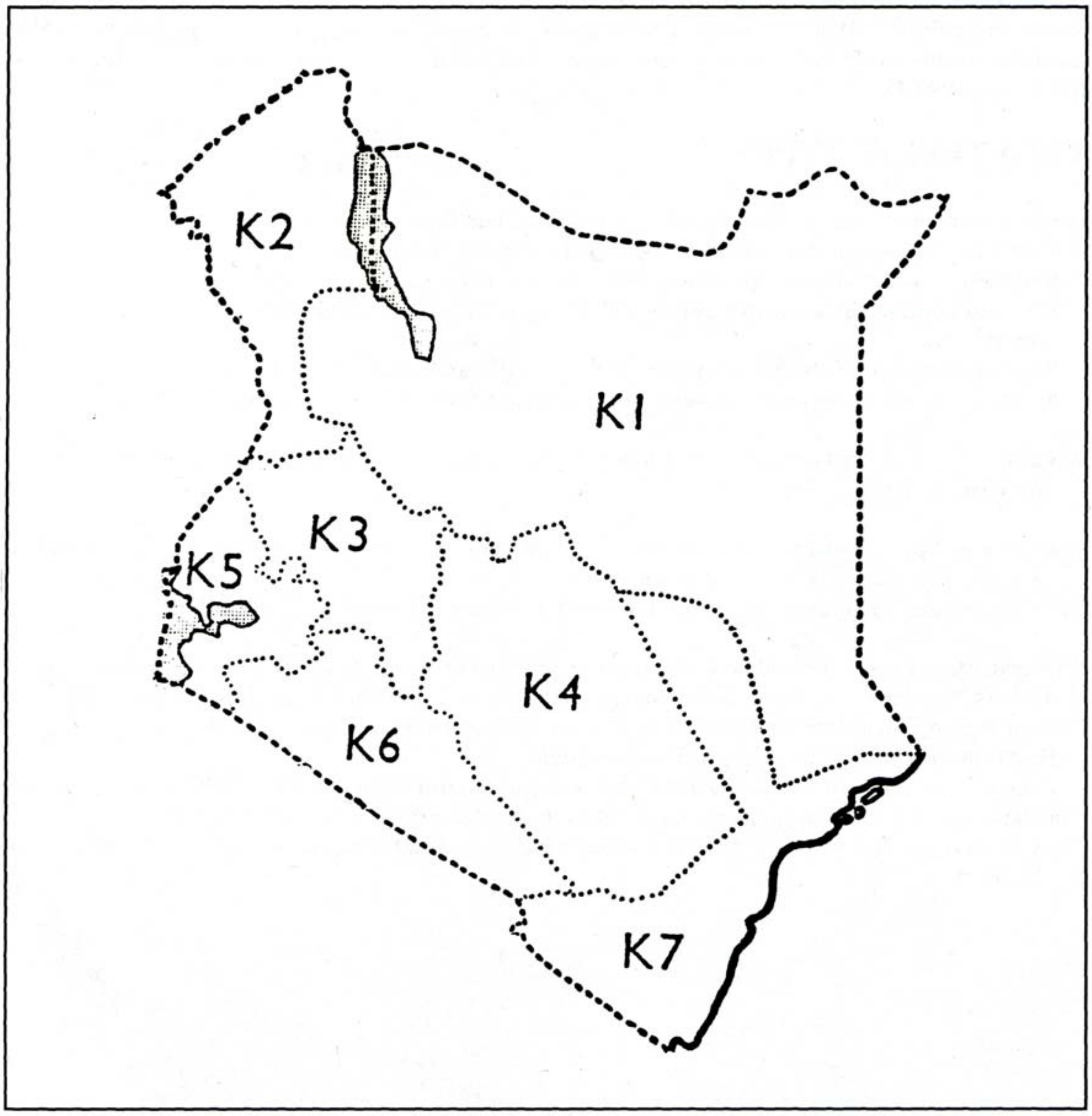


Fig. 23: Distribution map according to Beentje (1994), the division K 1, 2, 3, 4, 5, 6, 7 is that of Flora of Tropical East Africa (FTEA).

Results

Lichens and bryophytes

Due to the lack of knowledge about the epiphytic flora and the structur and composition of their communities (Fischer 2000 b), several new taxa were found during the study in the framework of BIOTA. A total of 150 epiphytic and foliicolous lichens have been identified up to now. Altogether 11 species are new for Kenya and about 20 species are new records for Kakamega Forest. Additionally 229 morphospecies of bryophytes could be distinguished. Interestingly, the lichens are suitable bioindicators for disturbed ecosytems, while bryophytes are indicators for more or less undisturbed forests. For further details on lichens and bryophytes see final report of the BIOTA-phase I (Fischer 2004).

Vascular plants

Life form structure

The vascular plant species of Kakamega Forest can be grouped into five life form categories: trees, shrubs, climbers, herbs and ferns (see fig. 24).

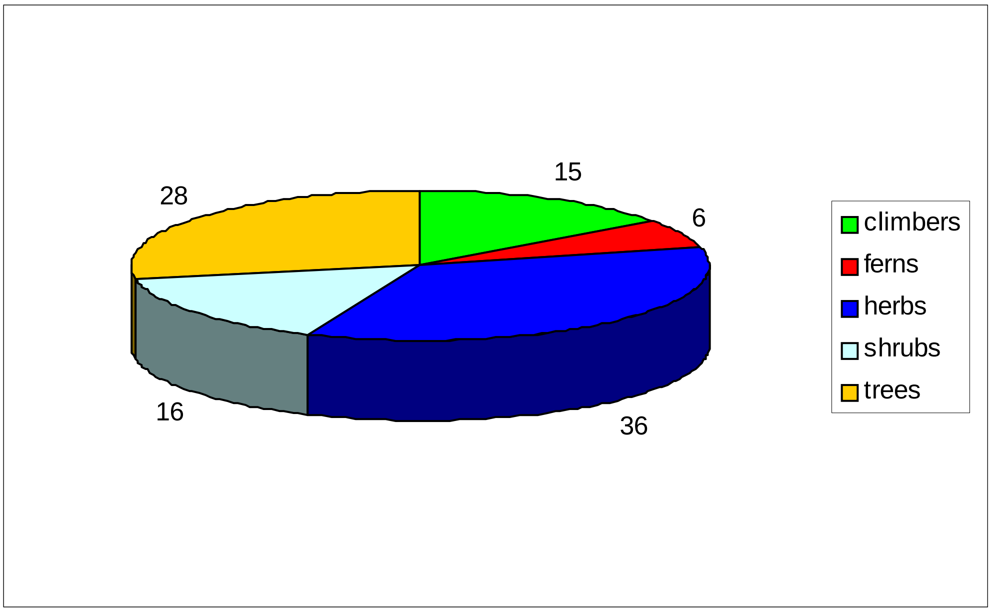


Fig. 24: Percentage values of the different life forms.

More than half of all recorded species are woody plants most of them being trees (fig. 24). Altogether a number of 112 tree species could be identified during this study. The group of shrubs (62 species) were nearly commensurate as the group of climbers (58 species). Among them a high amount of woody climber species occur. The high number of herbs (141) depends on several gap species which do not belong to the mature forest vegetation and build up the pioneer initial vegetation in the open canopy areas. The smallest group are the ferns with 24 species recorded.

On family level the floristic composition shows a high amount of the family Rubiaceae followed by the families Euphorbiaceae, Asteraceae, Acanthaceae, Fabaceae and Moraceae. Together they make up 46 % of all families (see fig. 25). The plant familiy composition reflects the result of former research in tropical rainforests (Gentry 1988).

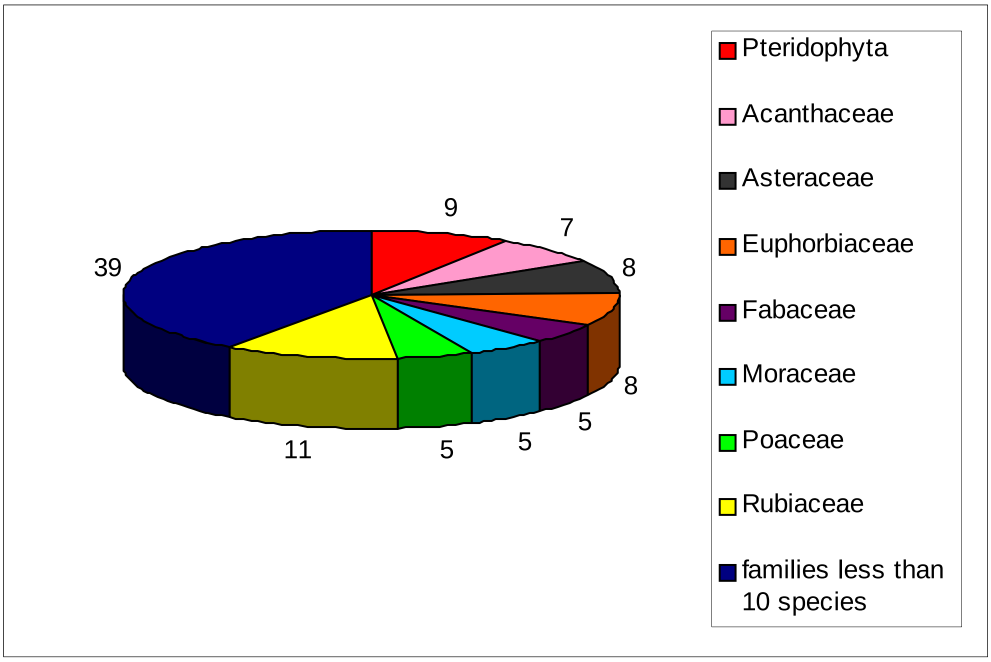


Fig. 25: Percentage values of all groups and families of vascular plants found in Kakamega Forest.

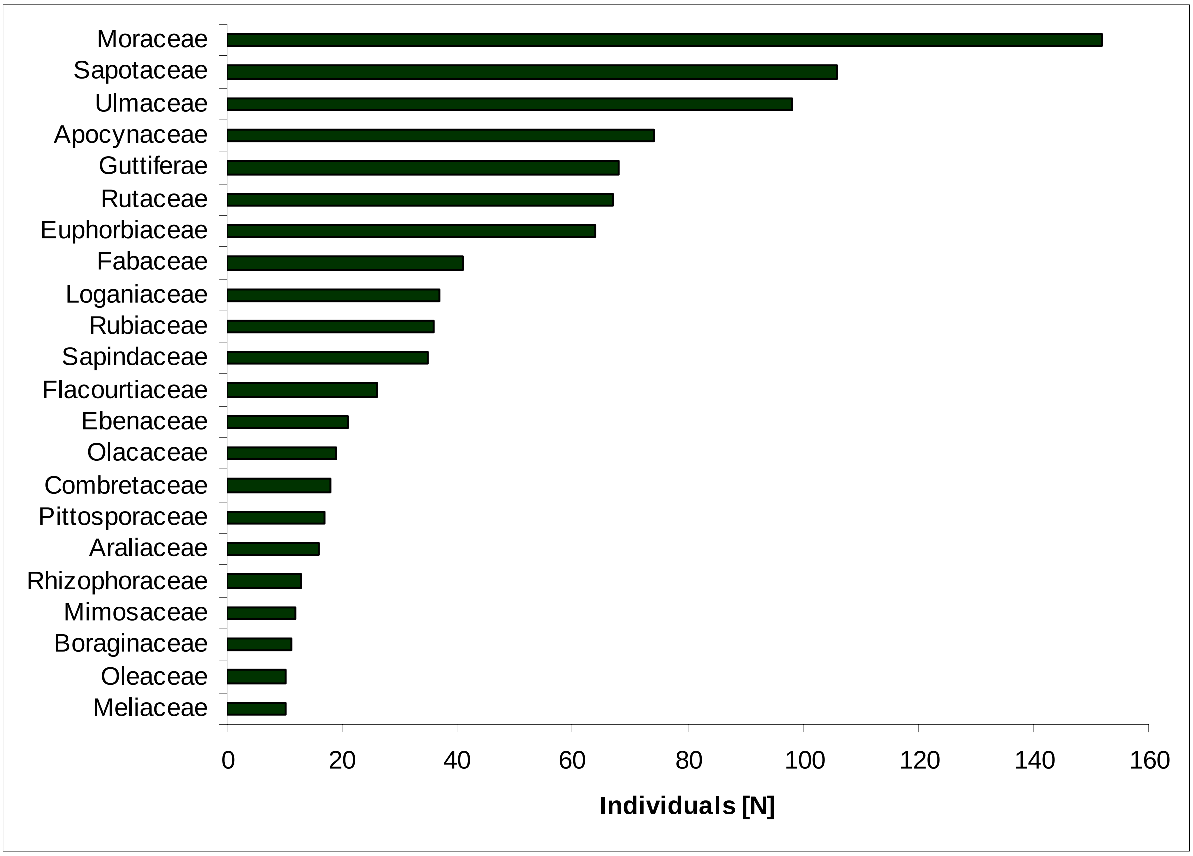


Fig. 26: Occuring tree families. Shown are the individual numbers, sorted after their dominance.

Fig. 26 shows the families that contain the most abundant tree species and only tree families with more than 10 individuals. The number of tree individuals was analysed in ten study sites in Kakamega Forest and the surrounding fragments. Moraceae, Sapotaceae and Ulmaceae are the tree families with the highest individual numbers. Species like *Antiaris toxicaria*, *Bequaertiodendron oblanceolatum* and *Celtis mildbraedii* belong to these families.

Also the families Rutaceae, Euphorbiaceae and Rubiaceae play an important role comprising tree species like *Teclea nobilis*, *Croton megalocarpus* and *Heinsenia diervilleoides*.

Records

A total of 93 families consisting of about 400 taxa were found in the relevés and in the plots of the line transects, additional records are denoted also (see appendix 3). It is not a complete species list of all plants of Kakamega Forest, because species of grasslands and pathways are underrepresented. In comparison to any other published list our check-list shows the highest amount of species although no epiphytes were collected. Only the list of Kokwaro (1988) comprises a nearly comprehensive database (see table 5). Several genera are difficult to identify, this leads to different species or genus names for the same taxa like *Mussaenda* ssp., *Oncoba* ssp., *Solanum* or *Maytenus* ssp. Depending on the aims of the investigations done by the different authors of the plant species lists, some groups of plants were preferably sampled. In this thesis the epiphytes and the grassland species were underepresented and are missing on the species list. A cross-check on genera level shows not many differences in the check-lists, but on species level it seems that there is a problem with a satisfactory identification. It is far beyond this work to draw any conclusions about the identification of plant species in the past, but there are many differences between the mentioned checklists, our list and the information about the distribution of the plant species in Kenya in the used determination books. Difficult groups for determination were the Asteraceae, Lamiaceae, Fabaceae, Flacourtiaceae, Rubiaceae, Orchidaceae, Euphorbiaceae, Acanthaceae, the ferns and the grasses and sedges.

Tab. 5: Comparison of different plant check-lists of Kakamega Forest. FTEA = Flora of Tropical East Africa. Given are species numbers.

BIOTA (2005)	*Kokwaro (1988)*	*Kifcon (1994)*	*Beentje (1994) & FTEA*
400	370	145	213

A comparison between the present list, the information of the determination books, and published check-lists leads to the following conclusions: Only one species is endemic for Kakamega Forest and its vicinity, *Commelina albiflora* (see fig. 27) the common but not abundant herb in older, shadowed forests. This plant is the only consistently pure white-flowered species of *Commelina* in Kenya (Faden 1994).

Fig. 27: Flower and leaves of *Commelina albiflora*

Fig. 28: cf. *Fernandoa magnifica*

According to Beentje (1994) *Tiliacora kenyensis* should be endemic in Kakamega Forest, but we could not find another specimen with different petioles and female flowers in spikes than the identified and abundant *T. funifera*.

First records

First records for Kakamega Forest are the following species: The tree species *Argomuellera macrophylla*, *Chrysophyllum viridifolium* and cf. *Fernandoa magnifica* are known for Kenya, but were found in Kakamega Forest for the first time. *Argomuellera macrophylla* is a small tree belonging to the family Euphorbiaceae and is mostly known from riverine forests. Until now there was only one known *Chrysophyllum* species, *C. albidum*, but we also identified *C. viridifolium*, a smaller tree with glabrous leaves and without golden-brown hairs beneath. Altogether five species of Bignoniaceae occur in Kakamega Forest: *Kigelia africana*, *Markhamia lutea*, *Spathodea campanulata*, *Stereospermum kunthianum* and cf. *Fernandoa magnifica*. Cf. *F. magnifica* could only be sampled without reproductive units at Buyangu Hill. During the three years of our study it never flowered or fruited (see fig. 28). But the habit of these specimens is different from the known species of Bignoniaceae of Kakamega Forest and after cross-check with herbarium material of the National Museum of Nairobi (NMK) it seems to be closely related to *Fernandoa magnifica* which is only known as a coastal species in Kenya. Several species have this kind of a disjunct distribution in Kenya, occuring at the coast and in the inland area only in Kakamega Forest and its vicinity again (called K 5 after Beentje 1994 and Turrill 1952 ff.) like *Antiaris toxicaria*, *Funtumia africana*, *Trilepisium madagascariense*, *Celtis mildbraedii* and *Ficus exasperata*. This is evidence for the disjunct distribution of populations caused by the changed climate during the glacial period.

A terrestrial, white-flowered orchid is a new record for Kenya. Specimens of *Oeceoclades ugandae* were collected in secondary forest sites (see fig. 29 + 30). It is a typical element of the Guineo-Congolian flora (Perez-Vera 2003).

Fig. 29: *Oeceocladus ugandae*

Fig. 30: *Oeceocladus ugandae*

The beetle *Goliathus goliathus*, which is widely distributed from Western to Eastern equatorial Africa and is also present in Kakamega Forest, is an indicator for more or less undisturbed rainforests. Because of its occurence we looked for the adults’ main hostplant *Vernonia conferta* (see fig. 31 + 32). At a place near the river Yala, giving the name of this forest fragment, we were successful. It is the first record not only for Kakamega Forest, but even for whole Kenya. This shrub has its easternmost limit here and its origin is in West and Central Africa.

Fig. 31: Goliath beetle

Fig. 32: *Vernonia conferta*

Further species with their first record for Kakamega Forest are the climbers *Connarus longistipitatus*, *Dregea abyssinica*, *Monanthotaxis buchananii*, *Basella alba* and *Smilax anceps* (see fig. 33 + 34). Except for *S. anceps* and *B. alba* the mentioned climbers are all climax species most abundant in later succession stages.

A further new Euphorbiaceae tree species were found in the forest for the first time. *Suregada procera* is an afromontane species occuring in Kenya on the high-altidutinal zones around Nairobi and the Kericho District.

Fig. 33: *Monanthotaxis buchananii* with fruits

Fig. 34: *Smilax anceps*

Another shrub of the family Rubiaceae, *Meyna tetraphylla*, is new for Kakamega Forest. It has long spines and four leaves at each node. Normally it occurs in riverine woodland or rocky bushland, but here we found it in young disturbed secondary forest. It is obviously not a forest-dependent species, but migrated from the open surrounding bushland into the forest edges.

We found another *Turraea* species beside the already known shrub *T. holstii*. *T. holstii* has light-green, small leaves and white-cream flowers with long filament tubes. Instead, the leaves of *Turraea abyssinica* are much more broader and darker and it is rare in this forest.

A highly abundant but new species for Kakamega Forest is the Poaceae *Leptaspis cochleata*. It has red rounded or elliptic flowers and grows nearly everywhere on the forest ground in more or less undisturbed shadowed forest and is a forest-dependent species.

Several members of the family Zingiberaceae were found in Kakamega Forest. Until today one *Renealmia* species is known. Investigations on flowers and fruits lead to the conclusion that there are two different species and it is not sure whether one of it is really the species *R. engleri* as identified in former studies. The specialist Prof. Jean-Baptiste Dhetchuvi from Butare University in Rwanda will make further investigations to answer the question which and how many species in Kakamega Forest occur. Also with his help we will try to identify the two more found *Aframomum* species *A.* cf. *subsericeum* and *A.* spec. The latter has white-lilac flowers and is, to our knowledge, a new species in that genus (see fig. 35).

Fig. 35: *Aframomum* spec. (new record)

Fig. 36: *Impatiens niamniamensis* s.l.

Further investigations are also needed to identify a new *Dorstenia* species of Kakamega Forest. It could be found only at one place at the Isiukhu-river. The specimens are light-green and succulent. The other species, *D. brownii*, is very abundant in shadowed undergrowth of the forest.

A fourth new species of *Impatiens* (Balsaminaceae) is found in Kakamega Forest near the river systems of Yala in the south and Isiukhu in the north: *I. niamniamensis* s.l. with bright red, yellowish-greenish and waxy coloured flowers (see fig. 36).

Difficult specimens

We had a problem with a proper identification of two Flacourtiaceae species, *Casaeria battiscombei* and *Casaeria gladiiformis*. According to information from older check-lists, *C. battiscombei* is the abundant species in Kakamega Forest. This species is larger than the other with lanceolate subentire leaves and 12 – 20 pairs of rather irregular curved secondary veins. In contrast, *C. gladiiformis* is a smaller tree with broader entire or undulate leaves with 7 – 10 pairs of curved veins. Surprinsingly, the abundant specimens during this study had the characteristics of *C. gladiiformis*. After the investigations with help of FTEA (Sleumer 1975) we identified the abundant one as *C. gladiiformis* instead of *C. battiscombei*, contradictory to former studies.

A species of the family Sapindaceae was difficult to identify, too. A species in the forest is called *Lepisanthes senegalensis*. According to the determination book of Beentje (1994) its former name was *Aphania senegalensis*. Bonny Dumbo, the field assistant, knows our specimens from Ruanda and the Congo basin as *Pancovia golungensis* whose former name after Troupin (1982) is again *Aphania senegalensis*. The species *L. senegalensis* is not known in Ruanda (Troupin 1982) and the species *Pancovia golungensis* is not known in Kenya (Beentje 1994). The question was now, which species we had found: *Lepisanthes senegalensis* or *Pancovia golungensis*. The description from *P. golungensis* of the used determination books from Rwanda and Congo fits to that specimens collected in Kakamega Forest, so we identified it as this species. But a revision of that species and the mentioned genus is needed in the future.

There are differences in the identification of some shrubs comparing our studies with former ones. One of the most abundant shrubs everywhere in the forest is identified as *Allophylus abyssinicus* in this study. Kokwaro (1988) and KIFCON (1994) named this species *A. ferrugineus*. Additionally there is one more *Erythrococca* than the known *E. atrovirens* in the forest, *E. trichogyne*. Beside the two known *Rothmannia* species, *R. longiflora* and *R. urcelliformis*, there is a third new one, but not clearly identified until today. The collected specimens are without flowers or fruits, but obvisously different from the two known species. It looks similar to *R. longiflora* and has light-green lanceolate leaves, too, but with less primary veins and the stipules are smaller. Further collections from that species and of course with the reproduction units are needed.

A more or less rare shrub in Kakamega Forest is *Canthium* spec. After revision work in the past several species of this genus were renamed and transferred into the genus *Keetia*. The species *Keetia gueinzii* is very abundant in disturbed, young secondary forest in this study in Kakamega Forest, but there are different specimens. These were identified as *Canthium* spec. The available literature for Kenya does not note any *Canthium* species in that forest, but our specimens are very closely related to that genus. Unfortunately we never found flowers or fruits, so further investigations are also needed in this case.

Disaccord exists by the determination of an Apocynaceae tree species which is very rare in Kakamega Forest: Although a revision for *Tabernaemontana* exists (Leeuvenberg 1991), the including information and described characteristics fit not with our specimens. It is not sure, if these are *Voacanga thoursaii* or the very similar *Tabernomontana ventricosa* and if there are one or two species and which name should be used. We assume that our specimens found in the Kaimosi fragment are *T. ventricosa*.

In Beentje (1994) there are two *Kigelia* species noted for Kenya, *K. africana* and *K. moosa*. They should differ in the number of leaflets, but after consultation with Dr. Rainer Gormann from the “Freie Universität” of Berlin, a specialist for the family of Bignoniceae, we decided that this character is not sufficient to separate the different specimens into two species. Therefore, all the *Kigelia* specimens were determined as *Kigelia africana* which is an abundant and very well known species for East Africa.

Exceptional position of Kakamega Forest

Although Kakamega Forest does not consist of many endemic species due to its development history, the forest offers one of the few places for forest plant species to exist in Kenya or East Africa in an environment heavily affected by agriculture and settlements. Beside the shrub *Vernonia conferta* or orchids like *Oeceoclades ugandae* which are very rare in Kakamega Forest another herb species, *Aframomum zambesiacum*, can persist in this forest.

A. zambesiacum has a disjunct distribution in West and East Africa, therefore Kakamega Forest is one of the few habitats for this ginger plant (see fig. 37).

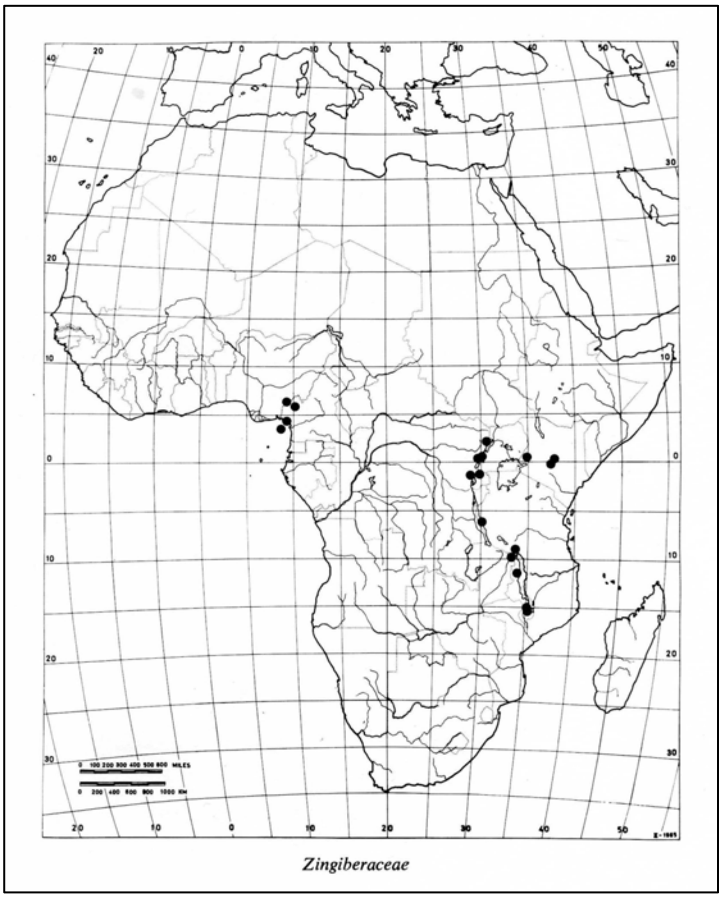


Fig. 37: Distribution map of *Aframomum zambesiacum*.

Interesting species not found on old lists are: *Ficus bubu*, collected only once in one study site, the so called “Ghostisland” near Buyangu Hill. It is a small forest island in the middle of a *Psidium guajava* - and *Harungana madagascariensis* - bushland. Beentje (1994) gives information that the occurrence of this species in that area is not sure. Maybe this species was always a rare one in the forest. It seems to grow only in old climax stages with a low amount of disturbance, like in Ghostisland. Local people do not enter this place, because they are afraid of a “ghost” which is in fact a bird called Hoopoe (*Upupa epops*).

Another rare species is the “African Mahagony” *Entandrophragma angolense*. Mahagony trees are growing very slowly and therefore offer very hard and not splintering wood. This is the reason why their wood is very valuable for timber products, and they were heavily logged in the past. Thus, their rareness is not astonishing. *Entandrophragma angolense*, known in Kenya only from that area, was reduced in its number (Kokwaro 1988). A big tree was found in march 2004 in the Yala fragment with a girth of about 8 m, but occupied from an epiphyt strangler fig tree *Ficus thonningii*, and is because of that not usable for timber. At this place reproduction took place marked by several seedlings and saplings. But the tree is still very rare and vulnerable and if there is no protection of the left specimens it will become extinct in this forest.

Kakamega Forest’s unique mixture of the two main floral regions from the Congo-basin and the montane forests of the afromontane region, is expressed by the comparison of the recorded trees, shrubs and lianas. About 41 % of 212 analysed woody species are of Guineo-Congolian origin and about 33 % are related to the afromontane forest systems. About 26 % of the recorded species could not be assigned to either of the groups and are therefore transitional species.

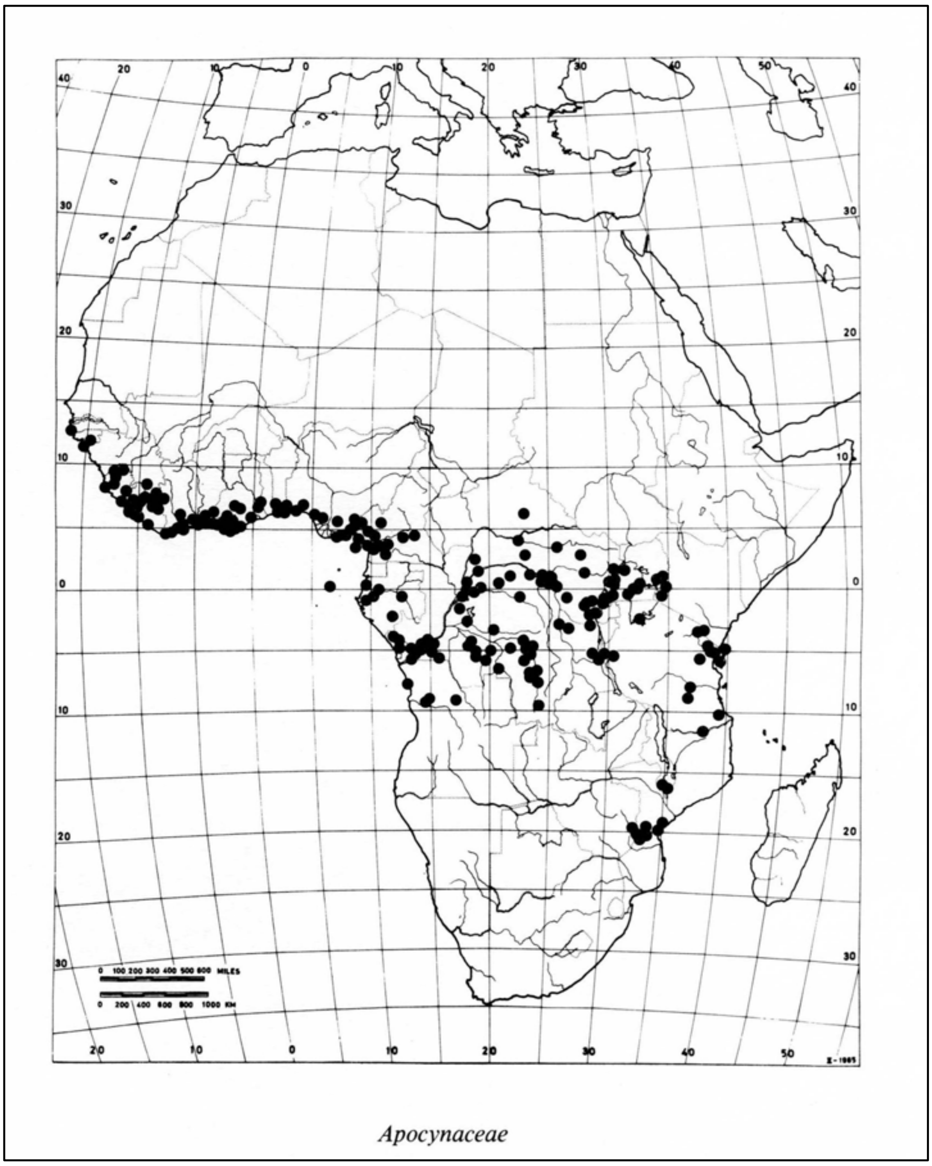


Fig. 38: Distribution map of *Funtumia africana*.

Floristic affinities to the equatorial forest belt to the west are shown by tree species like *Diospyros abyssinica*, shrubs like *Dracaena fragrans* or *Pseuderanthemum ludovicianum* and herbs like *Pollia condensata*. An example for the distribution along the former great equatorial forest belt of Africa shows the distribution map of one of the most dominant tree species in Kakamega Forest *Funtumia africana* (see fig. 38).

27 species of the analysed woody species occur in Kenya only in the Kakamega Forest (see appendix 2). Another evidence for the need to conserve that unique habitat. Among them are Guineo-Congolian tree species like *Aningeria altissima* or *Bequaertiodendron oblanceolatum*, as well as afromontane elements like the trees *Cassipourea ruwensorensis* and *Chrysophyllum albidum*.

To summarise, 15 woody species were recorded as new for Kakamega Forest, e.g. the climber *Agelaea pentagyna* or *Artabotrys likimensis* and *Dregea abyssinica*. Among the shrubs the *Rothmannia* spec. (Rubicaceae) is probably a new species for science.

4. Plant communities

Introduction

One aim in vegetation ecology is to study and identify plant communities or different vegetation types. Not only the simple listing of plant species in a particular area is interesting but also the combination of plant groups. Plants typically occur together in repeating groups of associated plant species (Mueller-Dombois & Ellenberg 2002). Groups of plants are identified by their most abundant or most characteristic species. These typically associated groups of plants determined by a group of characteristic species are called communities. These communities are influenced by their environment and have some influence upon one another. Therefore, vegetation ecology not only tries to identify the plant communities of a given area, but also the determining and influencing environmental factors.

In East Africa classification of vegetation types respectively plant communities were done mainly in mountain areas with emphasis on vegetation zonation and the impact of disturbance on the species composition. Some of the comprehensive work using the approach of Mueller-Dombois & Ellenberg (2002) to classify and describe the vegetation of subalpine and alpine zones are the following:

- Mt. Kenya (Kenya): Rehder et al. (1981), Rehder et al. (1988), Beck et al. (1990), Bussmann (1994), Bussman & Beck (1995)
- Aberdare Mts. (Kenya): Schmitt (1991)
- Mt. Elgon (Kenya/Uganda): Beck et al. (1987), Wesche (2002)
- Mt. Kilimanjaro (Tanzania): Klötzli (1958), Beck et al. (1983), Schmidt (1987)
- Ruwenzori Mts. (Rwanda): Schmitt (1985)
- Virunga Mts. (Rwanda): Fischer & Hinkel (1992)
- Kahuzi Biega (Congo): Fischer (1996).

In contrast, studies about submontane and montane forests of East Africa are rare, among them are Kerfoot (1964) with description of the south-west Mau forest and Hamilton & Perrott (1981) with detailed surveys of Mt. Elgon’s vegetation.

A detailed description of the plant communities of a tropical lowland rainforest in Kenya, the Shimba Hill, is provided by Schmidt (1991). Bussmann (2002) conducted a syntaxonomic survey of forest vegetation of Kenya’s smaller mountains and highland areas with comparable plant communities to Kakamega Forest.

To date a comprehensive description of plant communties in Kakamega Forest has not been done. There are only studies about the species composition of trees (Beentje 1990, Mutangah et al. 1994, Mutangah 1996) and a first publication about succession in different study areas with an analysis of the community structure of the different succession phases of initial pioneer vegetation (Schultka 1975).

Methods

Vegetation sampling

A survey of the whole forest and its vegetation units is too time consuming to be performed, therefore the description of vegetation segments or plant communities is based on samples. First the entities of a given area, here Kakamega Forest, were recognized then the size and shape of the sample were chosen. The last decision we made what should be recorded in the samples which were established. In this study only forest sites were chosen. Plant communities of the forest should be identified, grassland or gap vegetation was not analysed on community level. The survey of vegetation sample, called relevé, followed the approach of Braun-Blanquet (1964).

In different parts of Kakamega Forest and in every surrounding fragment 200 phytosociological relevés were established to describe the plant communities. Study sites were chosen where the recognized vegetation segments were most typically represented and 5 - 10 relevés were established. The principal of relevés is to find sample sites with homogenous and seemingly typical vegetation, therefore the sample sites were chosen subjectively. To get a meaningful average of the vegetation in a given study site the requirement of relative homogeneity throughout the relevés is necessary. The estimation of a minimum area by the nested plot technique failed due to this small-scaled mosaic structure of the forest. To avoid heterogenous samples with gaps, small paths etc. inside, the relevés size 10 x 10 m was chosen because the forest is a small mosaic of different vegetation types side by side. The KIFCON Vegetation Survey Programme (Mutangah et al. 1994) chose the same size to analyse floristic composition and structure of trees of Kakamega Forest. Following one major aim of the BIOTA - project some of the relevés are situated in every established Biodiversity Observatory (BO), so that the other subprojects have information about the vegetation in their studied areas. By means of satellite images and aireal photographs made available from subproject E02 other relevés were allocated through the whole forest. The approach follows the method of estimating species quantities for different vegetation layers separately (Braun-Blanquet 1964, Mueller-Dombois & Ellenberg 2002):

- **T**: tree layer > 5 m
- **S**: shrub layer 1-5 m
- **H**: herb layer < 1 m

The tree layer was not separated in lower and higher tree layer, because with a division we could not get further or more detailed information about the plant communities. Mutangah (1996) found that the upper tree layer (> 20 m) was almost missing and the overall tree canopy cover was less than 50 %, showing that the forest was not intact but variously disrupted by selective logging. Multiple appearances for each vegetation strata of the species were allowed. Trees outside the boundaries of the relevés that were part of the treelayer inside, were measured separately. The coverage of every vegetation stratum was estimated additionally in 5 % intervals.

The cover was estimated by the LONDO scale (Londo 1971); cover classes and range of cover (%) are given as follows:

.1	< 1	**2**	15-25	**6**	65-75
.2	1-3	**3**	35-45	**7**	75-85
.4	3-5	**4**	45-55	**8**	75-85
1	5-15	**5**	55-65	**9**	85-95
				10	95-100.

A habitat description was done for every relevé: the height of the vegetation, the declination, the exposition, the soil surface, coverage of litter and the amount of human disturbance were recorded. The relevés were calibrated by GPS-readings (Garmin eTrex) and mapped in ArcView 3.X by subproject E 02 (see study site). Information on the relevés are presented in appendix 1. Vegetation profiles were hand-drawn for every studied area or plant community to get further information about the vertical structure of the different forest sites (Vareschi 1980). Repeated sampling of the relevés were not conducted, because the change between dry and wet season has no major influence on the vegetation composition. But it has a slight influence on the undergrowth vegetation and on the occurrence and abundance of seedlings and saplings, especially of forest trees.

Classification of plant communities

There are different criteria and systems for classifying vegetation or plant communities depending on which properties are emphasized (Mueller-Dombois & Ellenberg 2002). Here the concept follows floristic criteria like species composition and their quantitative variations. Certain groups of plant species which are statistically derived were identified. Classification of plant communities is based on the floristic-physiognomic approach according to the continental European floristic association system of Braun-Blanquet (1964). All relevés were transferred into a single table. The individual relevés were sorted in relation to site factors, vegetation height and presence or absence of certain species. The floristic information of all relevés were compared with each other. First, the percent constancy was calculated for each species. This refers to the number of relevés a given species occurs. The table is then rearranged in a new order from high to low species constancy. In this "constancy" table species with intermediate constancy were used to group the relevés into vegetation classes. Species with a constancy between 10 to 60 percent were potential differential species. The next step is to recognise groups of species which occur together in several relevés or which have a similar distribution. Species which group relevés into community types should be present in at least 50 % of the relevés and should be absent or only sparsely present in others with 10 % constancy or less. Differential or separating species are the key species for identifying vegetation units. The table was then rearranged again to group the relevés with the same differential species. The relevés are presented in order of their diagnostic-floristic similarity in a "differentiated" table. During the comparison of the relevés on their similarity in species combination the presence or absence of a species is more weighted than its quantitative value, the cover in a given relevé. For a diagnostic of species groups the program Juice 6.2.53 was additionally used (Tichy 2002). One application in Juice are the so called "cocktail-groups" which analyses the amount of fidelity of one species to occur with another. The aim is to find a group of species which show high fidelities to occur together. Afterwards the relevés are sorted by the analysed "cocktail-groups".

The cocktail algorithm (Bruelheide 1995, 2000) was designed for statistical forming of sociological species groups. This application can be used to select differential species or to define vegetation units, like plant communities, by a group of differential species (http://www.sci.muni.cz/botany/juice/mang.htm).

The final sorting of relevés in an ecological significant order was done by "hand-sorting" described by Dierschke (1994) and Mueller-Dombois & Ellenberg (2002) resulting in a comprehensive vegetation table (see appendix 4).

In Central Europe the analysed vegetation units are assigned to floristic categories of the Braun-Blanquet's hierarchical system. A similar hierarchical system is not yet available for East Africa. But first attempts were made for montane vegetation by Bussmann (1994), Bussmann & Beck (1995), Bussmann (2002) which, however, are only based on local observations. Nevertheless, comparisons with published vegetation units and plant communities of comparable forest systems in East Africa were done in the following.

The defined vegetation units were sorted in the vegetation table in order of their ecological relevance. The nomination "association" in term of Braun-Blanquet (1964) was avoided, because after a first analysis of the plant communities of Kakamega Forest we are not in the position to determine wheter these vegetation units are variants, subassociations, associations and so on. But a grouping along site factors and succession stages was possible. The term "communitiy" was chosen instead of association and these were grouped into "alliances". The term "subcommunitiy" was chosen, when the differential species were not strictly restricted to a given number of relevés in an alliance. Character species in the sense of Braun-Blanquet were not described, because most of the diagnostic species are neither restricted exclusively to one association nor a decision could be made about their territorial or local occurrence (Barkman et al. 1976). In a last step the defined communities were summarised in a column following species constancy in a condensed constancy table (see appendix 5).

Constancy can be expressed either in percent or in five classes that are designated by Roman numerals as follows:

I > 0 - 20 %
II > 21 - 40 %
III > 41 - 60 %
IV > 61 - 80 %
V > 81 - 100 %.

Statistics

Beside classifications of derived plant data where boarders between data sets were analysed and groups of samples were identified, ordinations of data along axes were additionally conducted. All data of the 200 relevés were transferred in a "species by sample matrix". To every investigated relevé (sample) several species (variables) were measured by their coverage. Therefore, the data set is multivariate and multivariate statistics is necessary. Several techniques of multivariate statistics are used in vegetation science (Jongman et al.

1995). The Detrended Correspondence Analysis (DCA) is a useful method for ordination of multivariate data sets. Another well-established method, the Principal Component Analysis (PCA), could not be applicated, because the used floristic data set was too heterogenous (Franklin et al. 1995, Jongman et al. 1995). Several species were quite dominant and rare species had low occurences. A simple Correspondence Analysis (CA) comprised a significant error, the artifical arch effect (Gauch 1994). Therefore, detrending was preferred (see Hill & Gauch 1980). The resulting axes displayed in an ordination diagram describe gradients. The length of gradient, S.D.-unit (average standard deviation of species turnover) is a measurement for β-diversity. The more S.D.-units an axis has the more species turnover along the gradient could be observed and the more heterogenous a data set is. A short multivariate gradient is less than 2 S.D. units. In an ordination diagram, where the samples (or relevés) are scattered along a gradient over 4 S.D. units, the samples have no species in common.

DCA is an indirect ordination method, where one floristic data set is analysed. A pattern of species or samples is mapped in the ordination diagram and the gradients are interpreted in a second step. One possibility e.g. is to add information about the site factors. Symbols were assigned to the sample points and a pattern about the distribution along the diagram axes could be observed (Wesche & Leyer 2005). Analyses were carried out with the software program Canoco 4.5 (ter Braak & Smilauer 2002). The “species by sample matrix” was modified before the analysis started. Species which are detected in several vegetation layers were merged, because each species should receive one occurrence in a given sample (relevé). Because the matrix is zeroloaded and several dominant species occur the data were log-transformed to obtain normal distribution. Rare species were downweighted, because an interpretation of the axes or rather gradients should not be done on the basis of rare species.

Results

Multivariat analyses separated the 200 relevés in four groups by their occurrence in Kakamega Forest and their species composition: relevés of the northern part of the forest, relevés of the middle and southern part, relevés of highly disturbed forest sites and relevés of forest areas where trees were logged and plantations occur. In a DCA analysis all relevés were ordinated along two main axes (see fig. 39). An indirect gradient analysis was conducted. The ordination diagram shows the four different groups. The distribution of the relevés is mainly influenced by the disturbance level and the occurrence in Kakamega Forest. Beside disturbance site factors are important, because forest sites of the northern part differ from forest sites of southern parts. Forest sites with less disturbance were scattered in the ordination diagram along the north-south gradient. It seems that in higher regenerated forest sites the site factors are more dominant. Disturbed relevés reflect young succession stages. Relevés with mainly exotic planted tree species were ordinated along the disturbance gradient. The planted forest sites were matured and reach similar heights like the more or less undisturbed forest sites in Kakamega Forest, but the understorey vegetation is dominated by pioneer species and species from young succession stages.

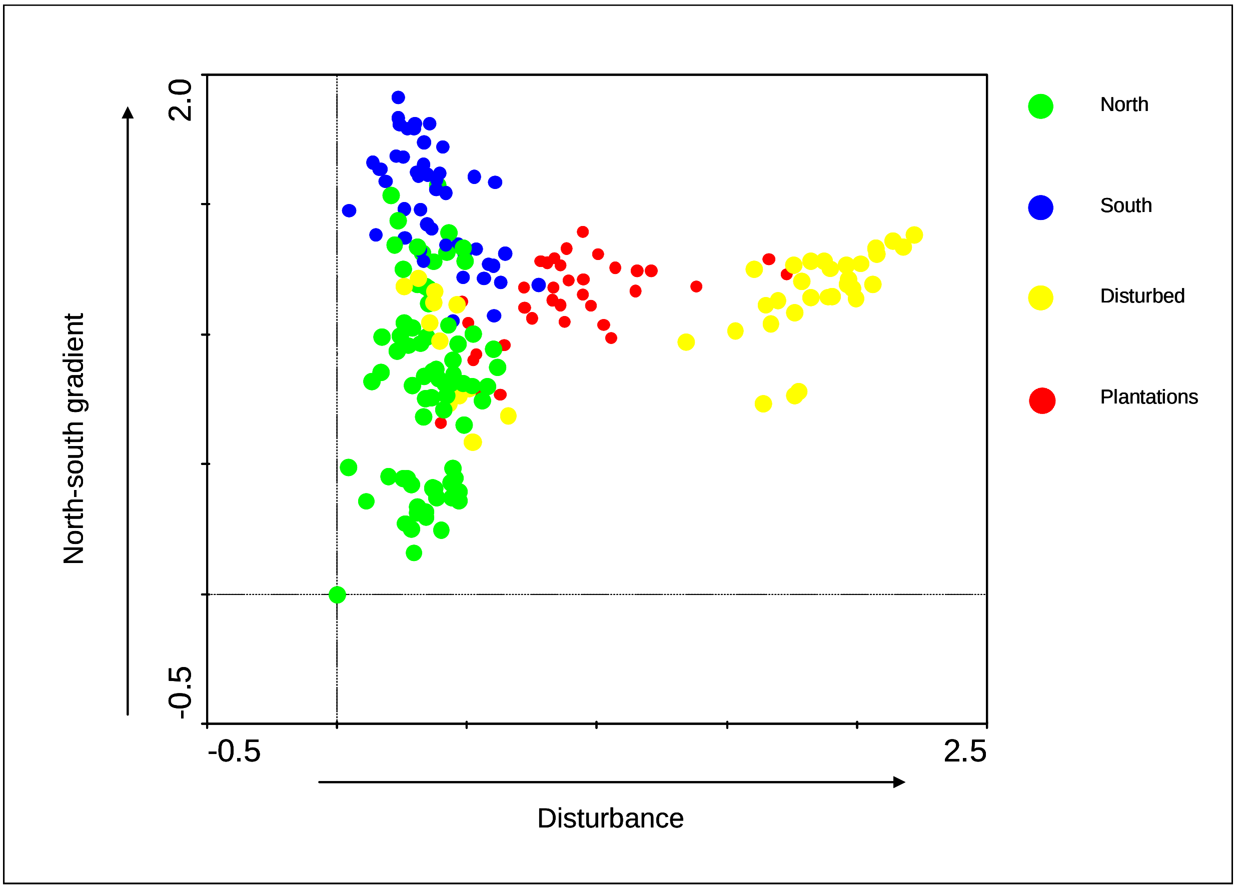


Fig. 39: DCA of all 200 relevés. Symbols indicate the four distinguished vegetation groups.

All species recorded in the 200 relevés were also analysed with a DCA. The ordination diagram shows which species occur together and what kind of influence this distribution has caused. Again the site factor (northern or southern part) and the disturbance level seem to have an effect on the species distribution (see fig. 40).

Species scattered on high disturbance level are mainly pioneer species reflecting the age of the succession stages, whereas some species are more dominant in northern parts than in the southern part. This grouping of species is a first analysis for the determining of plant communities. Beside this information the four distinguished groups of relevés separate the main “species by sample matrix” in four categories. On this base the analysis of the plant communities of Kakamega Forest was continued.

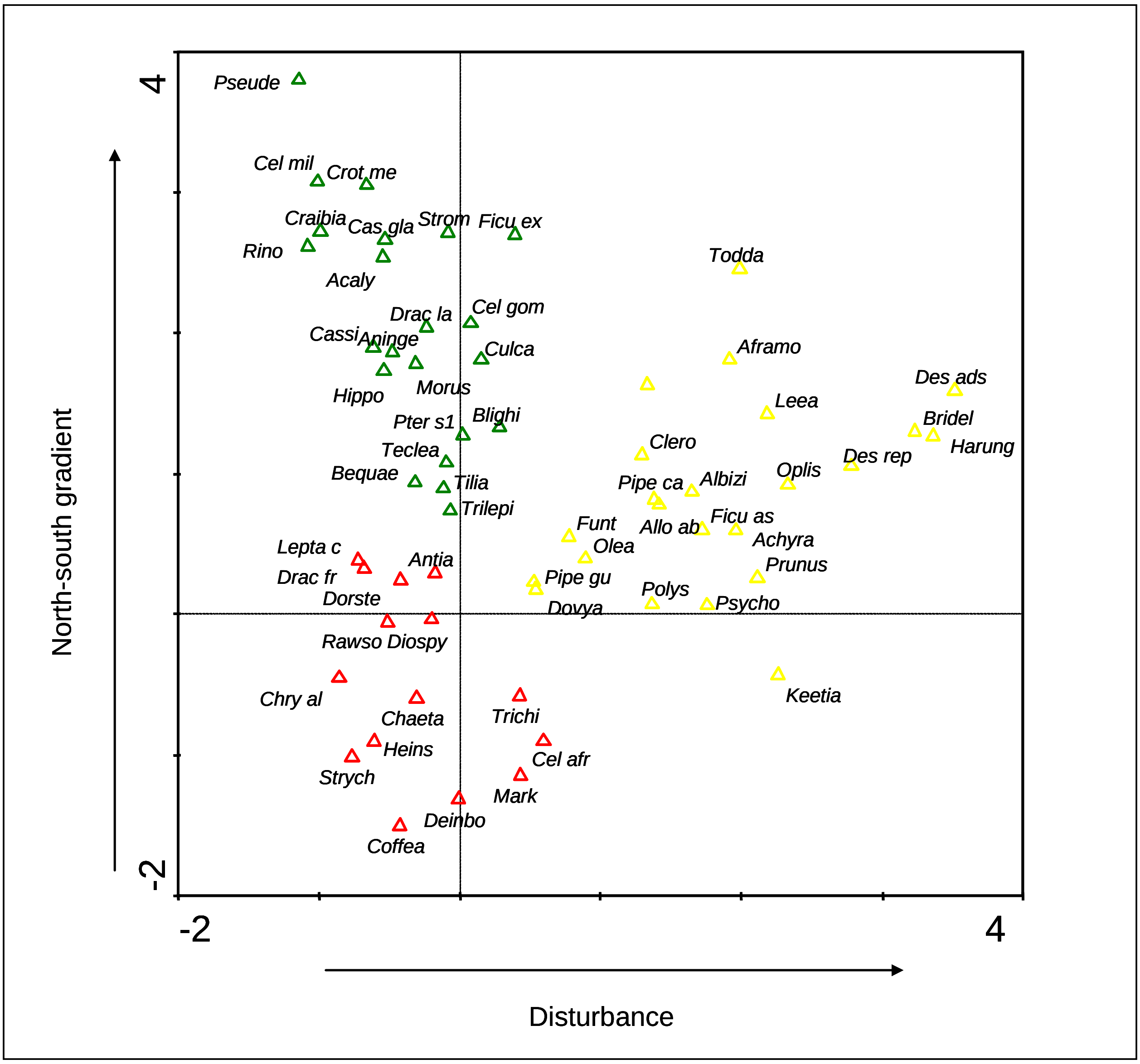


Fig. 40: DCA of all plant species recorded in the 200 relevés, shown are only the 60 most frequent species. Red triangles indicate species from northern parts of the forest, green triangles species of southern parts and yellow ones are species which occur in young, disturbed forest sites. Species names are shortened.

The plant species shown in figure 40 are some of the characteristic species of the plant communities represented in the following. The northern forest sites are dominated by trees like *Deinbollia kilimandscharica*, *Markhamia lutea*, *Antiaris toxicaria* or *Diospyros abyssinica*. The shrublayer consists of *Rawsonia lucida*, *Heinsenia diervilleoides* and *Coffea eugenioides*. In contrast to this species composition in the southern forest sites are characterised by the trees *Celtis mildbraedii*, *Croton megalocarpus* and *Craibia brownii*. Beside frequent trees in lower treelayer like *Strombosia scheffleri* and *Ficus exasperata* the shrub species *Pseuderanthemum ludovicianum* is dominant there. Typically species in disturbed forest are the trees *Harungana madagascariensis* and *Bridelia micrantha*. Dominant herbs are *Desmodium repandum* and *D. adscendens*, and several *Aframomum* ssp., respectively.

Tab. 6: Overview of the different vegetation units and plant communities defined for Kakamega Forest in the present study.

I *Antiaris toxicaria* – *Diospyros abyssinica* – Alliance

1. *Deinbollia kilimandscharica* – *Markhamia lutea* – Alliance
    - 1.1. *Trichocladus ellipticus* – subcommunity
    - 1.2. *Ficus cyathistipula* – subcommunity
    - 1.3. *Uvariopsis congensis* – community
    - 1.4. cf. *Fernandoa magnifica* – community
    - 1.5. degraded *Rapanea melanophloeos* – riverine – community
    - 1 .6. pure *Deinbollia kilimandscharica* – *Markhamia lutea* – community
        - 1.6.1. *Deinbollia kilimandscharica* – *Markhamia lutea* transitional – subcommunity

2. *Celtis mildbraedii* – *Craibia brownii* – Alliance
    - 2.1. *Suregada procera* – subcommunity
    - 2.2. *Pseuderanthemum ludovicianum* – subcommunity
    - 2.3. *Strombosia scheffleri* – community
    - 2.4. pure *Celtis mildbraedii* – *Craibia brownii* – community

II *Harungana madagascariensis* – *Desmodium adscendens* – Alliance

3. *Maesa lanceolata*– subcommunity

4. *Pittosporum viridiflorum* – community

Plant communities

Table 6 presents the analysed thirteen plant communities of Kakamega Forest and its fragments. There are two major groups called alliances I and II. Alliance I indicates the mature and more or less undisturbed forest sites and alliance II the young, initial forest stages. The *Antiaris toxicaria – Diospyros abyssinica* alliance is split into two more alliances, the *Deinbollia kilimandscharica – Markhamia lutea* and the *Celtis mildbraedii – Craibia brownii* alliances. The first alliance is divided up into four communities and three subcommunities. The second alliance comprises two communities and subcommunities, respectively. Alliance II is separated by one community and one subcommunity.

Alliance I is the group of forest sites which yield in fact disturbances, but are clearly distinguished from the young succession stages, representing the most disturbed and initial forest sites with the highest amount of pioneer species. The *Deinbollia kilimandscharica – Markhamia lutea* transitional subcommunity represents the transition zone between alliance I and II. The forest sites which were heavily logged and replanted are omitted in the overview in table 6, because they are not part of the natural development or succession of Kakamega Forest. Nevertheless, their species composition is of interest. Furthermore, their position within the described plant communities should be analysed. Hence, they will be presented as well in the following. In the vegetation and constancy tables in the appendix 4 and 5 the abbrevation A to R will be repeated in the following context in the title of the now described plant communities. The plant communities in the constancy and vegetation tables are ordered by the succession stages and their position in Kakamega Forest. In these two tables on the left sides the climax stades are presented and to the right sids the younger stades followed by the groups of planted forest sites.

Antiaris toxicaria – Diospyros abyssinica Alliance **I**

Most of the study sites of Kakamega Forest belong to this vegetation unit. The alliance contains forest with canopy heights between 20 and 35 m and some emergents which can reach heights up to 40 m. A dominant tree species is *Antiaris toxicaria* which is one of the highest trees in Kakamega Forest and has a straight bole with pale grey bark. The fruits are ellipsoid and scarlet and during fruiting the forest floor is covered with this conspicuous dispersal units. In Kenya it only occurs around the Lake Victoria region and at the coast and is a characteristic member of the guineo-congolian flora. The second frequent tree, which reaches heights of about 30 m in the forest is *Diospyros abyssinica*. This tree is an afromontane element with a grey bark and a long, straight bole, too. Both tree species demonstrate the unique composition of afromontane and guineo-congolian elements. Furthermore, *A. toxicaria* is an indicator for moist forest and *D. abyssinica* is typical for dry forests, reflecting the classification “dry semi-evergreen rainforest” of Kakamega Forest. In the herblayer *Dorstenia brownii* is one of the frequent herbs. It is an indicator for more or less shadowed forest sites and is dominant where less disturbance exists. Companions of the alliance I are trees like *Bequaertiodendron oblanceolatum* and *Trilepisium madagascariense*. Both trees are characteristic for the lower treelayer and for the shrublayer in the forest. In Kenya Kakamega Forest is the only habitat for the abundant tree *B. oblanceolatum*. *T. madagascariense* is an abundant tree in this alliance, too. It is an evergreen tree with a straight bole without butresses and dark purple fruits which are eaten by monkeys. Further small trees, which are abundant in the shrublayer and lower treelayer, are *Trichilia emetica*, *Heinsenia diervilleoides*, *Cassipourea ruwensorensis*, *Morus mesozygia* and *Chrysophyllum albidum*. *T. emetica* is an evergreen tree which occurs in moist or riverine forests. An infusion of its roots is emetic, this attribute gives the name to this plant. A small tree which can be found in the lower treelayer, in the shrublayer and even very abundant with numerous saplings and seedlings in the herblayer is *Heinsenia diervielleoides*. The flowers are white and spotted pink inside, the fruits are greenish-purple. Its shiny, bright green leaves with reddish veins beneath are easily recognized in the forest. The habit of *C. ruwensorensis* is very similar to the former species, but the reddish veins beneath the leaves are missing. This species is the only member of the family Rhizophoraceae in Kakamega Forest and occurs in Kenya only in this forest and the Nandi Forest. *M. mesozygia* can reach heights up to 24 m, but only few tree individuals have similar heights in the forest. In most cases the species can be found as shrub in the forest undergrowth. In Kenya the only occurrence is again Kakamega Forest. *C. albidum* is uncommon as big tree in the forest. It is more abundant as shrub or only as small tree in the forest. As well as the former species it occurs only in the studied forest. There are six different *Acalypha* species in Kakamega Forest. Due to the fact that the specimens without flowers or fruits are difficult to recognise, the species were summarized to *Acalypha* spec. The following *Acalpyha* species were recorded in the forest: *A. bipartia*, *A. ornata*, *A. neputinca*, *A. racemosa*, *A. psilostachya* and a not clearly identified *A.* spec.

Typical for Kakamega Forest is the occurrence of the highly abundant shrub species *Dracaena fragrans*. It is easily recognized by its straight stems and whorled leaf pattern and is very conspicuous during fruiting with its bright, orange fruits. A dense cover of the plants reaching heights between 3 and 5 m sometimes makes it impossible to cross the forest. The second occassionally abundant member of the family Dracaenaceae is *Dracaena laxissima*. It looks quite different from its related species with a small habit and distichous leaves which are evenly distributed along the stem. Under the mostly dense canopy cover lianas like *Tiliacora funifera*, *Hippocratea africana* or *Culcasia falcifolia* occur. *T. funifera* is one of the large lianas in the forest. The flowers are greenish and hanging in racemes up to 25 cm from the stem; the liana is cauliflorous. The second large liana is *H. africana* with three-shared fruits and winged seeds. From both lianas numerous seedlings and saplings could be found on the forest floor. *C. falcifolia* is much smaller and can often be found as epiphyte at the tree stems or on branches. In the southern forest sites near rivers fern species could be found in high coverages. Otherwise several fern species have only patchy occurrences in the forest. Some fern species of Kakamega Forest in alliance I are: *Asplenium dregeanum*, *A. lunulatum* var. *erectum*, *A. protensum*, *Doryopteris kirkii*, *Pteris catoptera* and *P. preussii*. Dominant species of the herblayer are the grass species *Leptaspis cochleata*, the nettle *Laportea ovalifolia* and *Geophila repens*. *G. repens* is a creeping herb with heart-shaped leaves and small, white flowers and red fruits. It is distributed pantropical in evergreen forests. Regeneration of all mentioned plant species is quite good, everywhere in the study sites seedlings and saplings could be observed even in alliance II of the disturbed forest sites. The occurrence of seedlings in the young succession stages is an indicator for the potential of these forest sites to develop into the natural mature forest with the species composition of alliance I which is characteristic for Kakamega Forest.

Deinbollia kilimandscharica – Markhamia lutea Alliance 1.

Two major groups of mature forest can be found in Kakamega Forest. The northern part of the forest, which includes the Kisere fragment and forest sites in the Buyangu National Reserve, is separated by two tree species *Deinbollia kilimandscharica* and *Markhamia lutea* from the middle and southern forest sites. Forest sites of Salazar, Busambuli and Isecheno are defined as “middle” part of Kakamega Forest and the southern site includes Yala and Ikuywa. The Malava and Kaimosi fragments are a special category of heavily logged and replanted forest sites as well as Ileho and Kibiri. Their species composition will be described later.

D. kilimandscharica is a less frequent shrub species with broad, shiny leaflets. Its main occurrence are forest sites around Buyangu Hill, sites in Colobus trail and Shiamololi. *Markhamia lutea* is a tree and can reach heights up to 30 m, but in Kakamega Forest it occurs mainly as shrub in a similar frequence like *D. kilimandscharica*. Because *D. kilimandscharica* provides hard, tough wood, it is used for poles and buildings. Ostentatious are the great yellow flowers in axillary or terminal thyrses. Alliance 1. consists of succession stages of middle-aged, old secondary and near primary forests.

Trichocladus ellipticus – subcommunity (1.1., A)

Most of Kakamega Forest is dominated by so called middle-aged forest. Forest sites of a climax stage are very rare. The highest developed and oldest stage of forest sites in Kakamega Forest can be found in Kisere (fig. 41). Due to its disturbance history it is not quite clear, whether and which dominant tree species are probably missing and build up the typical climax stage of the forest. Only presumptions can be made. But parts of the Kisere fragment faced less disturbance in the last 50 to 100 years and are therefore defined as “near-primary” forest. The *T. ellipticus* community represents this climax stage. The differential species *T. ellipticus* is very rare in Kakamega Forest and only occurs in the Kisere fragment. This species is presented in the shrublayer and has leaves which are silvery or yellowish brown beneath. It is the only member of the family Hamamelidaceae in Kakamega Forest and in whole Kenya. The existence of trees of *Diospyros abyssinica* and *Strychnos usambarensis,* which are dominant in undisturbed forests in high developed phases, is an indicator for a well conserved forest. *S. usambarensis* is a tree with a grey bark and white-yellow flowers in axillary cymes and occurs mainly in dry or riverine forests. Characteristic species in the understorey are the prickly shrub *Rawsonia lucida* with its serrate leaf margin and *Craterispermum schweinfurthii*. *R. lucida* is an indicator for moist or riverine forest. *C. schweinfurthii* is a shrub which is used in traditional medicine. On several individuals cuts in the bark could be observed, the extracted juice is used as an aphrodisiac. This species is rare in Kakamega Forest and its occurrence is restricted to this forest in Kenya. There is a low cover of herbs and a dense canopy. Trees and shrubs of the lower and upper canopy layers are interlocking and inhibit sunlight to reach the forest floor. Additionally a high coverage of *D. fragrans* suppresses herb species to grow there.

Interestingly only some individuals of *Markhamia lutea* occur here. *Deinbollia kilimandscharica* and *M. lutea* are indicators for middle-aged forest and their frequent occurrence is an indicator for a still regenerating forest. The regeneration in parts of Kisere is nearly completed and the less pronounced species become less abundant. Nevertheless, rejuvenation is taking place in these forest sites, but on a smaller scale, in gaps. The species turnover of the tree species is slower than in younger succession stages, where pioneer species were replaced by climax species after some years.

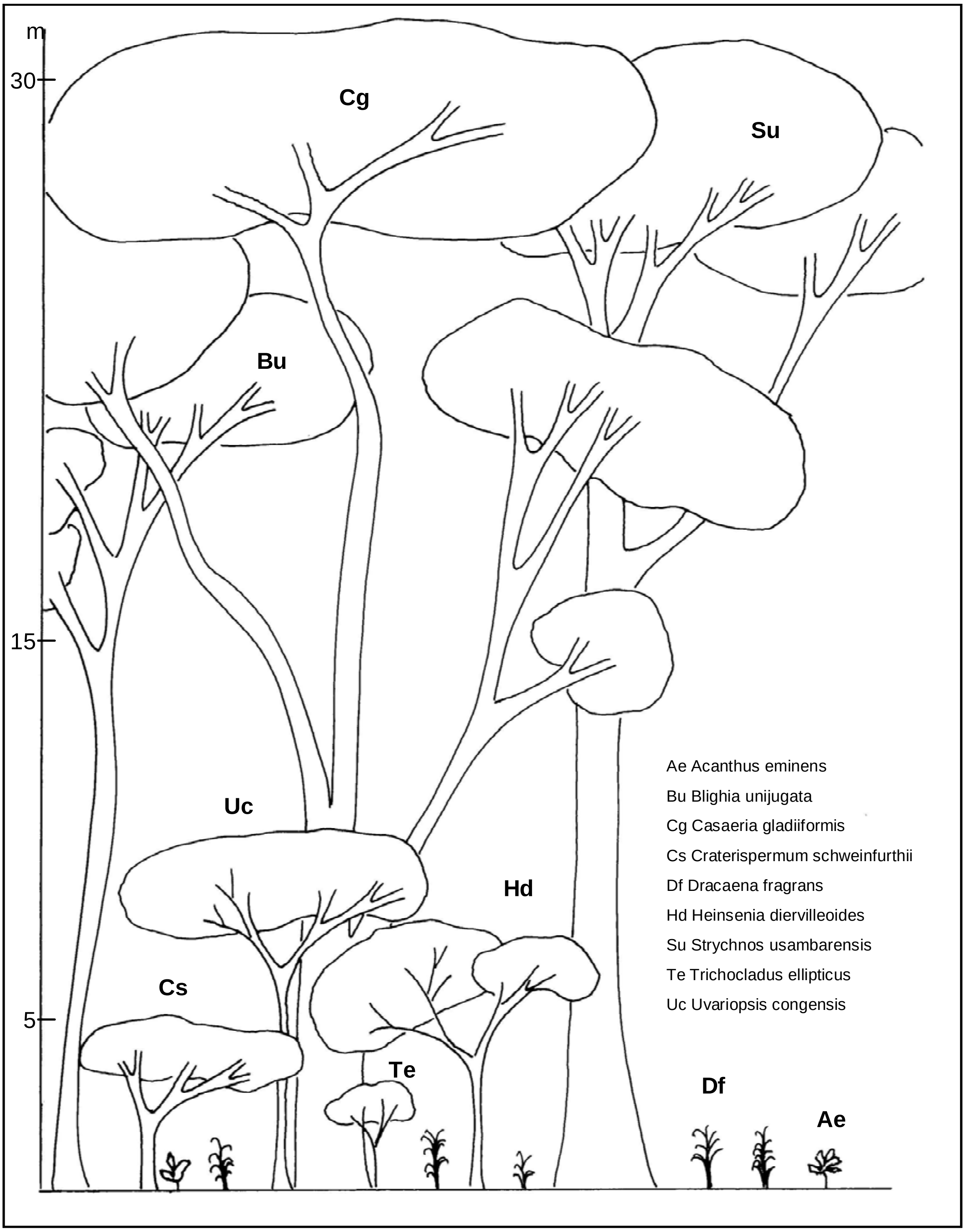


Fig. 41: Profile diagram of the *Trichocladus ellipticus* – community. Kisere forest.

Ficus cyathistipula - subcommunity (1.2., B)

The relevés where this community was found are placed in a small forest remnant in the Buyangu National Reserve surrounded by *Psidium guajava* - bushland.

The level of succession is similar to Kisere, but the forest is a remnant and several indicators for disturbance could be observed. Close to the relevés tree species like *Polyscias fulva* and shrubs like *Solanum mauritianum* occur. The shrub or small tree *S. mauritianum* is an indicator for disturbance. In forests it mainly occurs in gaps. This species is not a natural member of secondary forest and not a typical pioneer species in the succession phases. Instead, it escaped from cultivation from larger towns. The nomination of this forest island is "Ghostisland" as mentioned before in the "floristics" part. Two tree species could only be found here and nowhere else in Kakamega Forest: *Ficus cyathistipula* and *Ficus bubu*. *F. bubu* was not collected in a relevé there, but at the forest island edge. No indicators for rejuvenation, seedlings or saplings, could be found, thus the two very rare species face extinction. *F. cyathistipula* is a small tree, occasionally epiphytic and evergreen. In western Kenya it only occurs in Kakamega Forest. Like in *Trichocladus ellipticus* - community lianas like *Hippocratea africana* and *Agelaea pentagyna* hang between the trees and shrubs and could be found as seedlings and saplings in the forest undergrowth. *A. pentagyna* is also a scandent shrub, but in the forest most specimens are lianas. Noticeable are their seeds with white arils. *D. kilimandscharica* and *M. lutea* are scattered as shrubs between the trees in the forest island and are indicators for the lighter conditions there. Although, the forest island faces much disturbance, its still unique species composition defines the site as old secondary forest. This kind of succession stage is very rare in Kakamega Forest.

Uvariopsis congensis – community (1.3., C)

The characteristic species composition of the two former plant communities is similar to the *Uvariopsis congensis* - community. But this community is characterised by the missing of *Trichocladus ellipticus* and *Ficus cyathistipula*. The differential species of this community, *U. congensis* is again a rare species in the forest and occurs in Kenya only here. It is a guineo-congolian element with a fissured and greygreen bark. The branches are used to make bows. The species occurs in forest sites with lighter conditions, thus where few disturbance happened. Nevertheless, it is not an indicator for young succession stages, but an indicator that the forest sites where it could be found, were disturbed e.g. by selective logging. Fewer trees like *Antiaris toxicaria* and *Diospyros abyssinica* occur in that forest sites, but light-demanding tree species like *Funtumia africana* or *Celtis africana* are dominant there. *F. africana* occurs everywhere in Kakamega Forest and is often found in every measured vegetation layer, but here several trees could be counted. *C. africana* can reach heights up to 27 m, but in the forest it is abundant as shrub or small tree, only some individuals are very high. It can be easily recognized by its serrated, bright-green, shiny leaves which are pubescent or sometimes sandpapery. This plant community is restricted to forest sites at

Kisere, Buyangu Hill, Colobus and Ghostisland and belongs to the middle-aged secondary forest.

cf. *Fernandoa magnifica* – community (1.4., D)

This plant community occurs in places at Kisere, Buyangu Hill and Colobus. In the shrublayer the main companions are *Rawsonia lucida*, *Strychnos usambarensis*, *Deinbollia kilimandscharica* and *Markhamia lutea*. Regeneration of every pronounecd species take place, seedlings and saplings could be recorded in the relevés. The differential species cf. *Fernandoa magnifica* is a new record for Kakamega Forest and occurs as small tree or shrub mainly at Buyangu Hill (see fig. 42). Further descriptions are presented in "floristics". The canopy constructive trees are *Antiaris toxicaria*, *Deinbollia kilimandscharica*, *Prunus africana* and in gaps, developed from selective logging or after a treefall by heavy storm and rain, the pioneer species *Polyscias fulva* occurs. Such forest sites can be found at Colobus. *P. fulva* can easily be recognized by its candelabralike branching. Figure 43 shows a forest site of Colobus with gaps filled out with *Polyscias fulva* individuals and compared to this figure 44 shows a more undisturbed forest site of Colobus. Tree individuals of *P. africana* are patchy distributed in the forest. Since it is an excellent timber tree, used for housebuilding or furniture, trees were selevticely logged in the past. Additionally the bark is used for prostate medicine and the Luhya used the infusion of barks as a purgative. Nevertheless, in some weeks of the year hundreds of seedlings can be counted on the forest floor. The red fruits are eaten and the seeds are dispersed by small rodents. Thus, regeneration of the characteristic tree species proceeds. Shrubs like *Bequaertiodendron oblanceolatum, Coffea eugenioides, Heinsenia diervilleoides* and *Trilepisium madagascariense* are abundant in the understorey layer.

B. oblanceolatum has characteristic leaves, which are obovate and finely appressed-pubescent below. Two new shrub species occur here in the younger succession stages compared to the three above mentioned plant communities, *Acalypha* spec. and *Chrysophyllum albidum*. A dense canopy cover is typical for that plant community and the interlocking of crowns of smaller trees and shrubs could be observed, but more light can reach the forest floor and the herblayer has high coverages. Shrubs like *Chaetacme aristata* are abundant there. Beside that, species like *Morus mesozygia* and *Celtis africana* are occassionally common. *C. aristata* has often typical zigzag branches with long spines and yellow-green flowers. The plant community belongs to the middle-aged secondary forest, too.

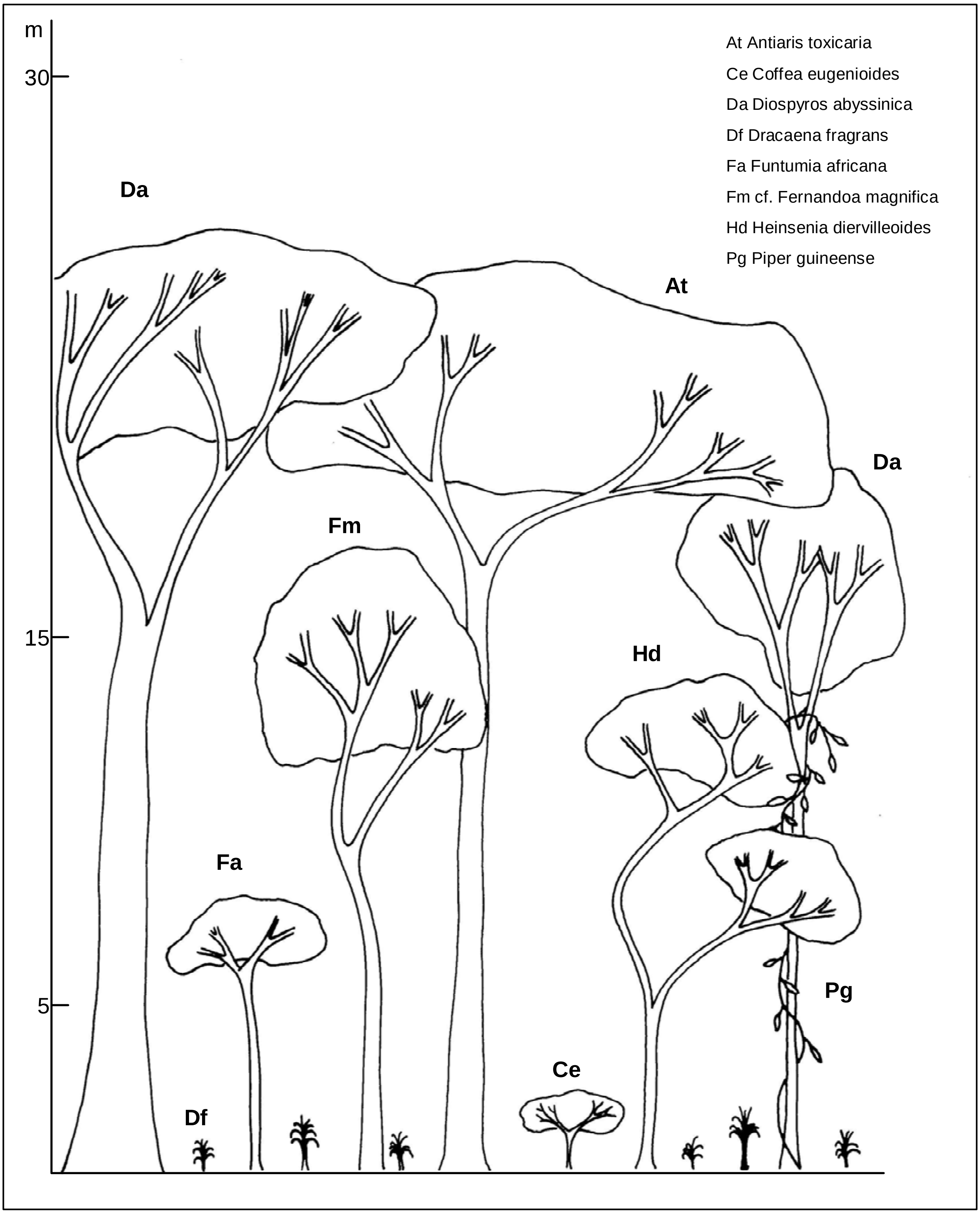
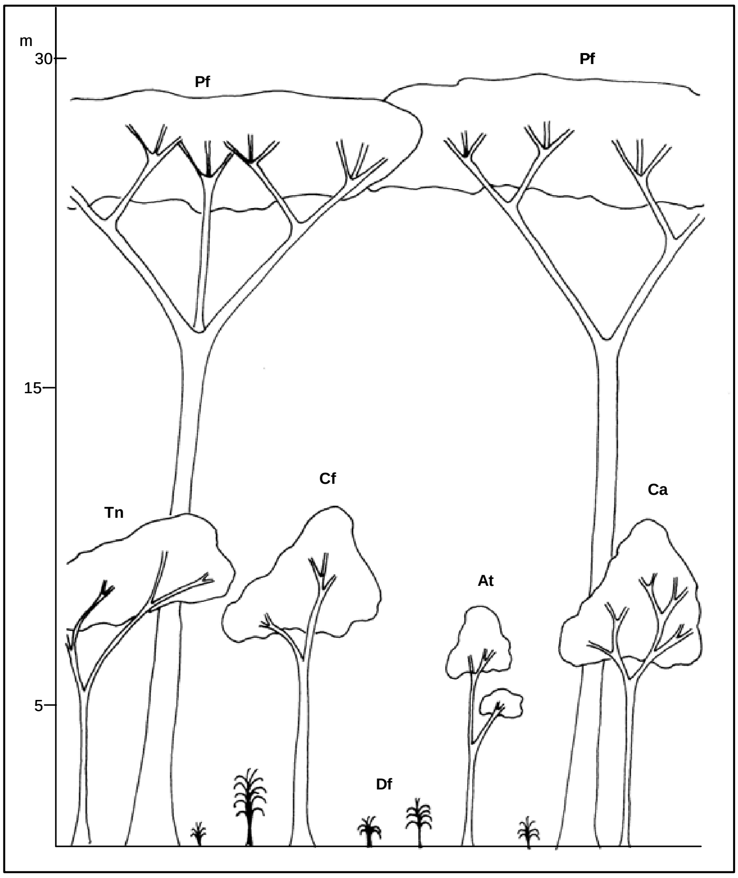
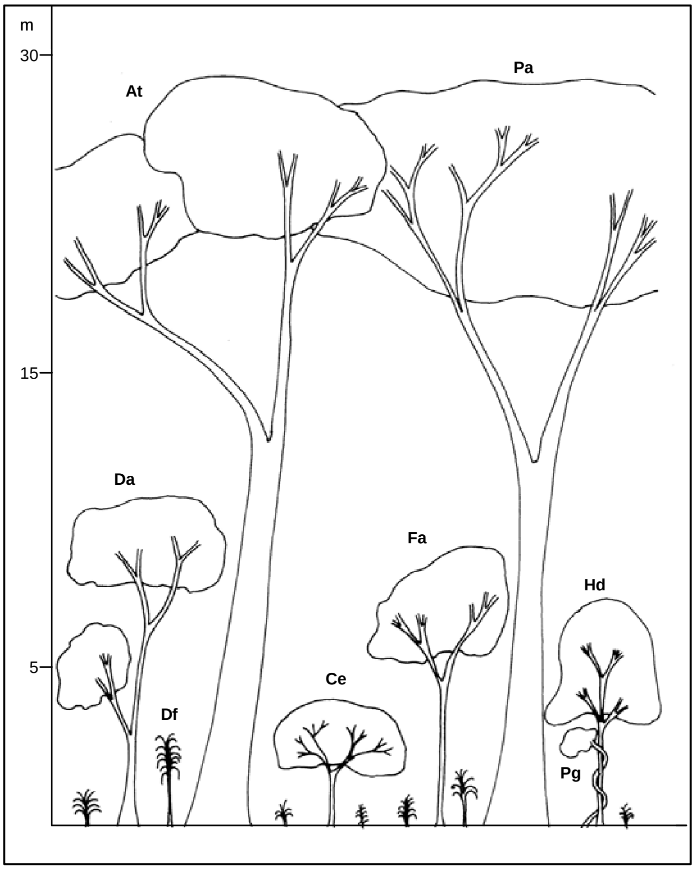


Fig. 42: Profile diagram of cf. *Fernandoa magnifica* – community at Buyangu Hill.



At Antiaris toxicaria
Ca Chrysophyllum albidum
Cf Celtis africana
Df Dracaena fragrans
Pf Polyscias fulva
Tn Teclea nobilis

Fig. 43: Profile diagram of Colobus forest with gap succession.



At Antiaris toxicaria
Ce Coffea eugenioides
Da Diospyros abyssinica
Df Dracaena fragrans
Fa Funtumia africana
Hd Heinsenia diervilleoides
Pa Prunus africana
Pg Piper guineense

Fig. 44: Profile diagram of Colobus forest with less disturbance.

Degraded *Rapanea melanophloeos* – riverine – community (1.5., E)

Along the Isiukhu river typical riverine forests can be found, but the studied forest sites are disturbed (fig. 45). The treelayer is about 15 m high and a dense shrublayer exists. The plant community belongs to the middle-aged secondary forest, but also several species which are characteristic for disturbed and young stages occur there. The characteristic species for this community is *Rapanea melanophloeos*. In Kakamega Forest it is typically a shrub with a grey-brown bark which is blood red and granular inside. The species is widespread around Lake Victoria, East Africa and stretches up to western South Africa in upland forests and moorlands. Another characteristic shrub is *Nuxia congesta*. Three leaves arise from one node of that upland or montane forest species. It can also be found on hilltops above the forest margin or in the bamboo zone. *Acanthus eminens* is common everywhere in disturbed places inside the forest with its characteristic oblong, pinnatifid or lobate leaves with spiny margins. But here near the Isiukhu river it has a high coverage and a high constancy in the relevés. Specimens of *Deinbollia kilimandscharica* are missing, but some *Markhamia lutea* shrubs are occassionally common and thus, the community belongs to that alliance. Several indicators of disturbance could be found. *Oncoba spinosa* a much branched shrub with axillary straight spines up to 7 cm long is growing there. It is a typical member of riverine forest or bushland. The second typical small shrub species is *Erythrococca trichogyne* which occurs in Kenya only around Lake Victoria and is characteristic for riverine and forest margins. Due to the disrupted canopy light-demanding seedlings of *Polyscias fulva*, *Phyllanthus fischeri* or *Sapium ellipticum* are abundant. Also lianas of secondary forest or bushland like *Keetia gueinzii* and *Stephania abyssinica* could be recorded near the river.

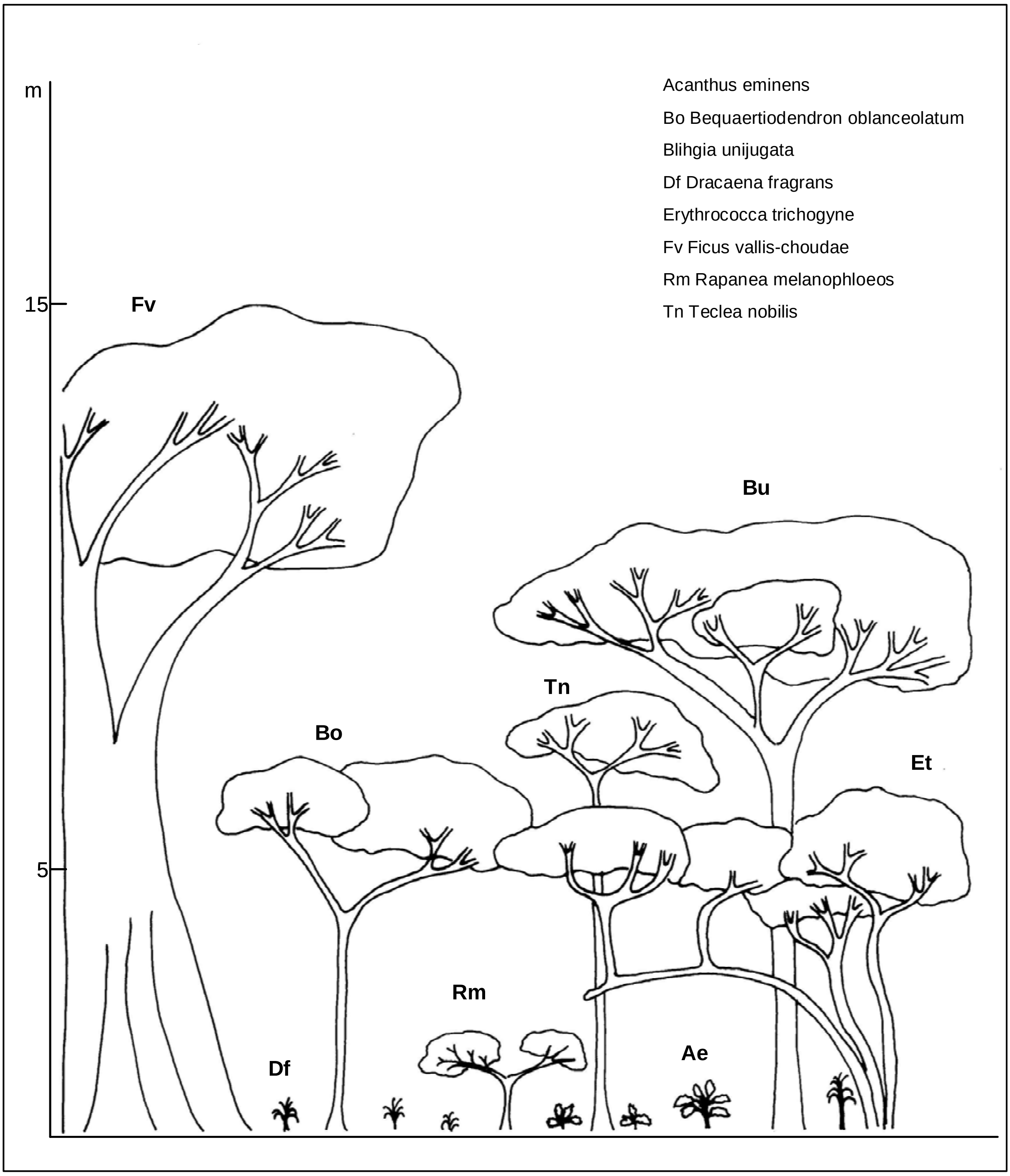


Fig. 45: Profile diagram of degraded riverine community at Isiukhu-river.

“Pure” *Deinbollia kilimandscharica* – *Markhamia lutea* community (1.6., F)

The typical plant community of this alliance is the “pure” *D. kilimandscharica* – *M. lutea* community. Species characterizing this community are *Rawsonia lucida, Strychnos usambarensis* and *Coffea eugenioides*. *S. usambarensis* and *R. lucida* are typical shrub species in the northern and middle part of Kakamega Forest. Both species are less distributed in the southern part. The small shrub *C. eugenioides* reaches heights of about 2 m in Kakamega

Forest and is a typical member of the understorey vegetation. In the villages around the forest it is known under the name Nandi coffee. This plant community is still in regeneration and belongs to the middle-aged secondary forest. Typical climax tree species like *Olea capensis*, *Prunus africana* or *Diospyros abyssinica* are less abundant. The tree layer is up to 25 m high and the crowns are interlocking (fig. 46). The frequent tree of the upper canopy is *Antiaris toxicaria* and for the lower treelayer *Chrysophyllum albidum* and *Manilkara butugi*. In Shiamololi the abundant occurrence of *Aningeria altissima* is astonishing. In that forest area the tree individuals with the greatest stem circumferences of whole Kakamega Forest could be recorded. Due to the fact, that all measured individuals of that tree species have irregular shaped boles with vaulty outgrowths which make it impossible to use the tree for timber production, the trees were left there *A. altissima* occurs in Kenya only in Kakamega Forest. The study site Shiamololi is the only middle part of Kakamega Forest which belongs to alliance 1. The great lianas *Tiliacora funifera* and *Hippocratea africana* are abundant here as well as seedlings and saplings. In cases where the shrublayer is disrupted and not dense the herblayer has high coverages. Although, nearly all forest sites belong to the Buyangu National Reserve human disturbances like selective logging, collecting of firewood and bark cutting could be recorded everywhere resulting in disrupted canopys of the shrub- and treelayer where pioneer or bushland species can invade.

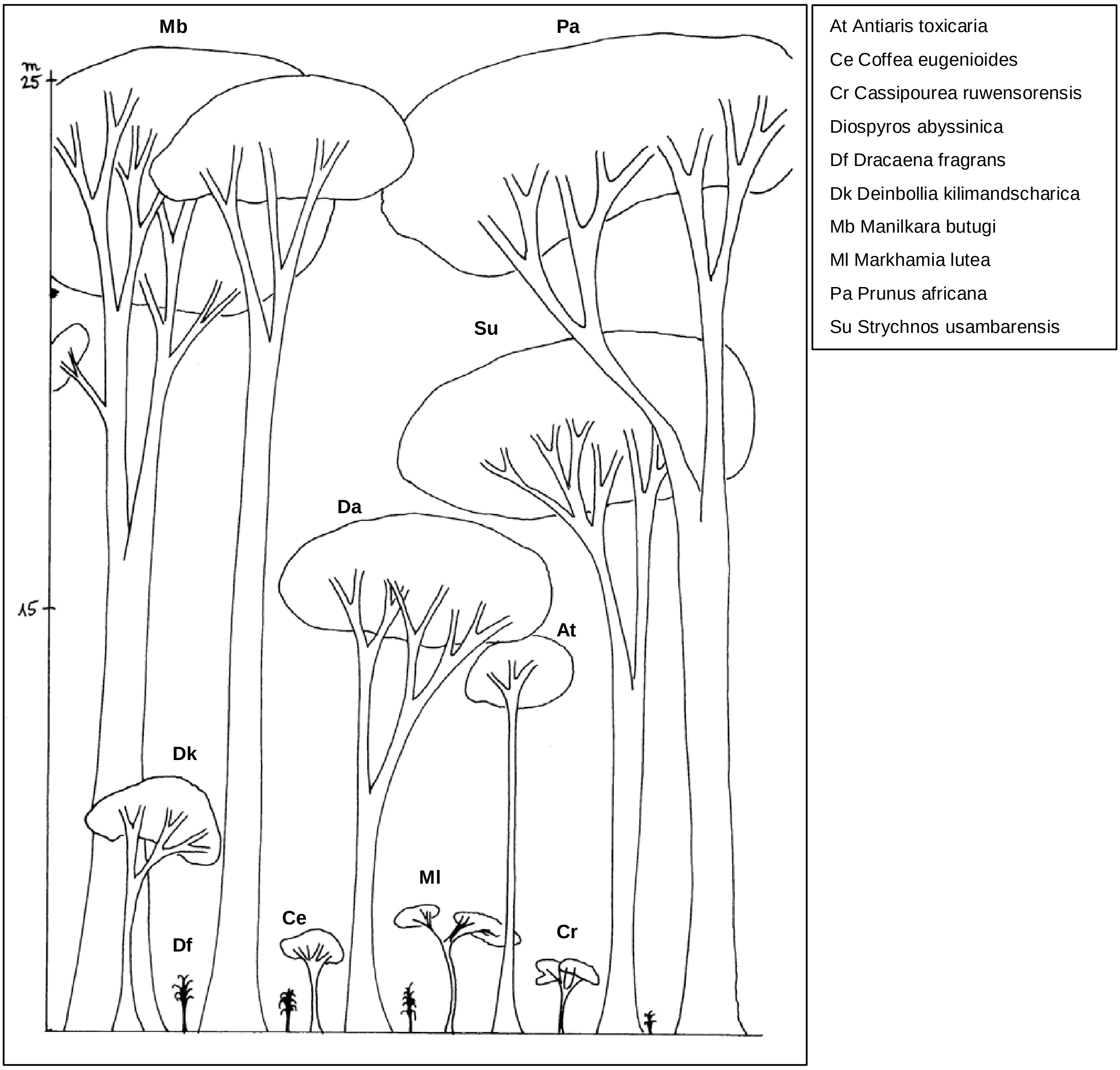


Fig. 46: Profile diagram of “pure” *Deinbollia kilimandscharica – Markhamia lutea –* community at Buyangu-Top.

Deinbollia kilimandscharica – Markhamia lutea – transitional – subcommunity (1.6.1., M)

In the Buyangu National Reserve a campsite for tourists was established where the BIOTA-research station is situated. Forest sites near the camp and in Vihiga belong to the transitional subcommunity. The study sites in Vihiga are mainly young secondary forest like the forest around the campsite. Trees reach heights about 10 m in general and the shrublayer like the herblayer is very dense. A lot of sunlight hits the forest floor and supports light-demanding species. In the older succession stages first appearances of *Deinbollia kilimandscharica* and *Markhamia lutea* could be observed. This is an evidence that after some years of regeneration the forest sites may develop into a middle-aged secondary forest and later on to a near-primary forest which is typical for Kakamega Forest. The young age of this stage is reflected by the occurrence of pioneer tree species like *Maesa lanceolata*, *Harungana* *madagascariensis* and *Combretum collinum* or herbs like *Pavonia urens* and *Desmodium adscendens*. Nevertheless, saplings belonging to older succession stages like *Antiaris toxicaria*, *Trichilia emetica*, *Trilepisium madagascariense* and *Funtumia africana* are occassionally abundant. Further companions of that community are the tree *Ficus exasperata* with its sandpapery leaves and the spiny shrub and near relative of *Acanthus eminens A. pubescens*. Lianas of young and older succession stages grow there together, whereas occurrence of the climax species characterised by seedlings and saplings rather than by adults. *Secamone punctulata* and *Toddalia asiatica* are typical pioneer species of young secondary forest which can also be found in this transitional subcommunity.

Celtis mildbraedii – Craibia brownii alliance 2.

In the middle and southern forest sites the *Celtis mildbraedii – Craibia brownii* alliance is present. The average canopy height is about 25 to 30 m like in the northern forest part. Most of the forest belongs to the middle-aged succession stages, only a small area near Yala river is so called old secondary forest. The study sites Salazar and Busambuli are defined as middle part of the forest and belong to the Buyangu National Reserve under the control of KWS. Isecheno and the two fragments Yala and Ikuywa are under the management of the FD. Although, the forest sites have a similar age and forest structure, the species composition differs from alliance 1. from the northern forest part. The characteristic tree of that alliance *C. mildbraedii* is one of the tallest species of Kakamega Forest. It has sharp buttresses and a pale brown bark and small inflorescences which develop into ovoid-ellipsoid, red fruits. It is a guineo-congolian element and belongs to moist evergreen forests. The second differential species of that alliance is the tree *Craibia brownii*. It can reach similar heights as *C. mildbraedii* of about 24 m, but most of the individuals are smaller. It is widespread in Kenya in afromontane habitats and has a straight bole with a pale grey bark and pink-white flowers. A characteristic companion of the alliance is *Croton megalocarpus*. It is occassionally abundant and is one of the tallest trees of Kakamega Forest. Because it provides hard timber it was selectively logged in the past. The tree is a typical climax species and belongs to afromontane habitats. It mainly occurs in dry upland evergreen or semi-deciduous forests. Further companions of the alliance are two species of the genus *Mimulopsis*. *M. arborescens* is a shrub between 2 and 5 m high. After flowering it dies off and the woody stems stay for a long time in the forest undergrowth. During the study it never flowered or fruited. It occurs in riverine forests or at swampy sites in moist forest. This habitat can be found in the study sites of the southern forest part, where two river systems the Yala and Ikuywa river run. *M. solmsii* is a woody herb or liana which can grow up to 1.8 m in height. Most specimens could be found in Salazar and Busambuli. It is very abundant in forest undergrowth especially where the forest is disturbed. The palm *Raphia farinifera* occurs in Kakamega Forest near river systems. Some individuals are massive trees up to 20 m high. In the middle and southern forest it mainly grows near the rivers Busambuli, Yala and Ikuywa, but specimens could also be found at Isiukhu river but in lower constancy. Shrubs like *Bequaertiodendron oblanceolatum*, *Cassipourea ruwensorensis* and *Heinsenia diervilleoides* are abundant members of the lower canopy like in alliance 1. *Hippocratea africana*, *Culcasia falcifolia* and *Tiliacora funifera* are the most frequent lianas here. Due to the river systems another shrub is characteristic for alliance 2. *Rinorea brachypetala* is mostly a shrub but sometimes it is higher than 5 m and then belongs to the treelayer. It is a guineo-congolian element and is an indicator for rain- and riverine forests.

Suregada procera – subcommunity (2.1., G)

In forest sites of the fragments Yala and Ikuywa the *Suregada procera* – community occurs. The differential species is a tree with heights about 18 m and elliptic, bright-green leaves. *S. procera* is an afromontane element and grows in dry evergreen or riverine forests. The species is very rare in the forest and tree individuals can only be found there. A high coverage of the canopy and of the herblayer could be observed. The trees reach heights up to 30 m, but interlocking with smaller trees or shrubs of lower canopy layers cannot be recorded. Instead the shrublayer is comparatively low. Two fern species, *Asplenium* sp. C and *Asplenium* sp. D are highly abundant and cover the forest floor together with *Dracaena fragrans*. A characteristic liana is *Landolphia buchananii*. This liana has a deeply fluted stem and elliptic leaves with a hairy midrib. The fruit is said to be edible and the young stems are used for ropes.

Selective logging activities in the past reflect the missing of high tree individuals of *Antiaris toxicaria* and *Diospyros abyssinica*. But they occur as small trees, saplings and seedlings in the forest undergrowth. Like in the *Trichocladus ellipticus* – subcommunity of the Kisere fragment *Craterispermum schweinfurthii* is abundant here. In high coverage it is one of the dominant shrubs in that community. Beside the former species *Casaeria gladiiformis* is a dominant tree in the *Suregada procera* – community. The occurrence of these species is evidence for the low disturbance and the high regeneration stage of this forest site. Due to the species composition and the low disturbance in the past the plant community is defined as old secondary forest (fig. 47).

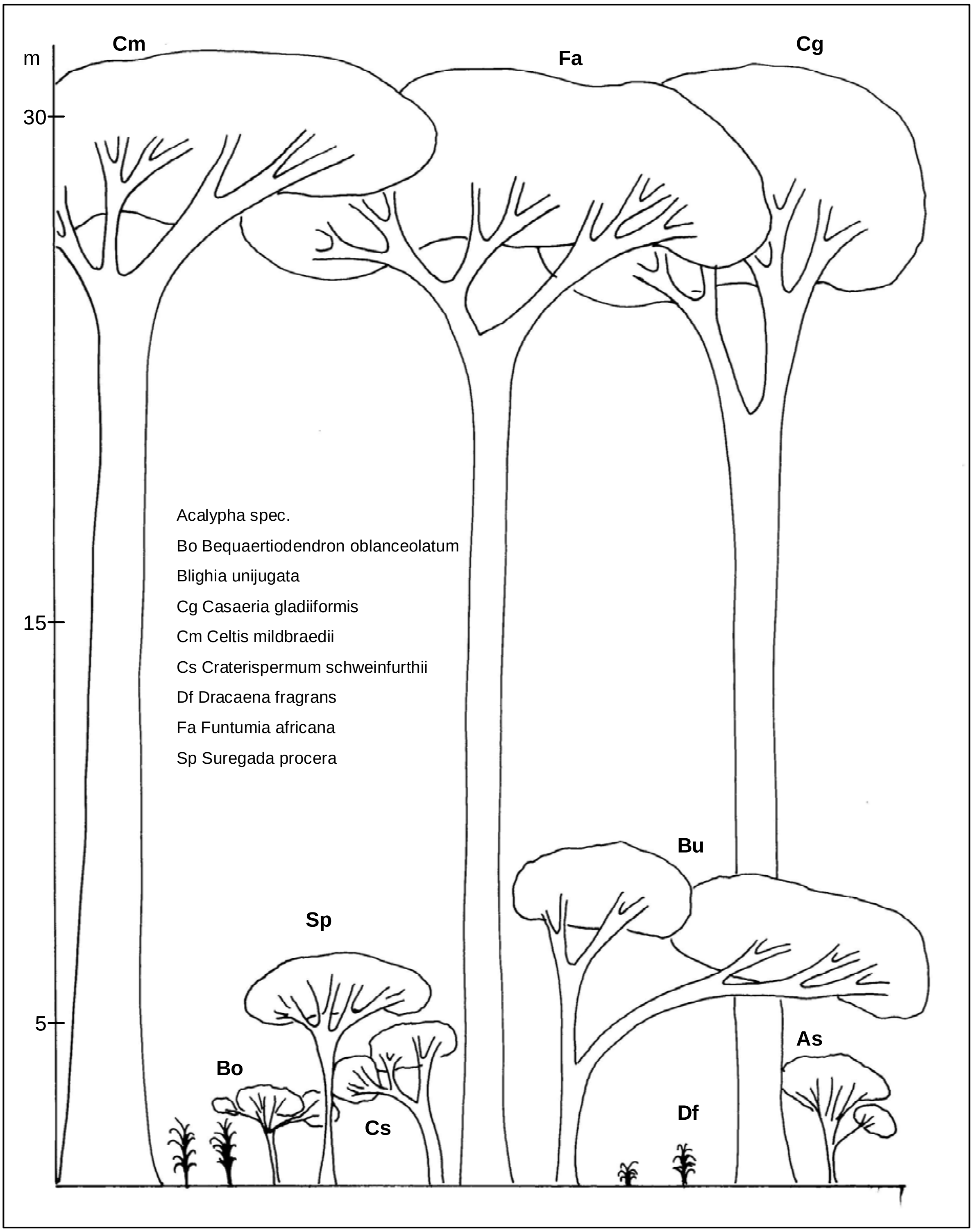


Fig. 47: Profile diagram of *Suregada procera* - subcommunity at Yala.

Pseuderanthemum ludovicianum – subcommunity (2.2., H)

Parts of the study sites Salazar, Busambuli, Isecheno (north of the Kalunya-Glade), Yala and Ikuywa belong to the *Pseuderanthemum ludovicianum* – subcommunity (fig. 48). The canopy is about 25 to 30 m high and is disrupted by several gaps. Because of the open vegetation resulting in lighter conditions, shrubs and herbs are abundant there. Only a few old trees build up the upper canopy. The shrublayer has one vegetation height with a lot of young, small trees and saplings. Trees of ages about 20 to 30 years are missing. Beside *Dracaena fragrans* the herb- and shrublayer is dominanted by the differential species *P. ludovicianum*. In Kenya this species is restricted to Kakamega Forest. Conspicuous are the white flowers with purple spotted petals and long corolla tubes. The plant is a scandent woody herb about 1 to 2 m high and forms a dense cover on the forest floor.

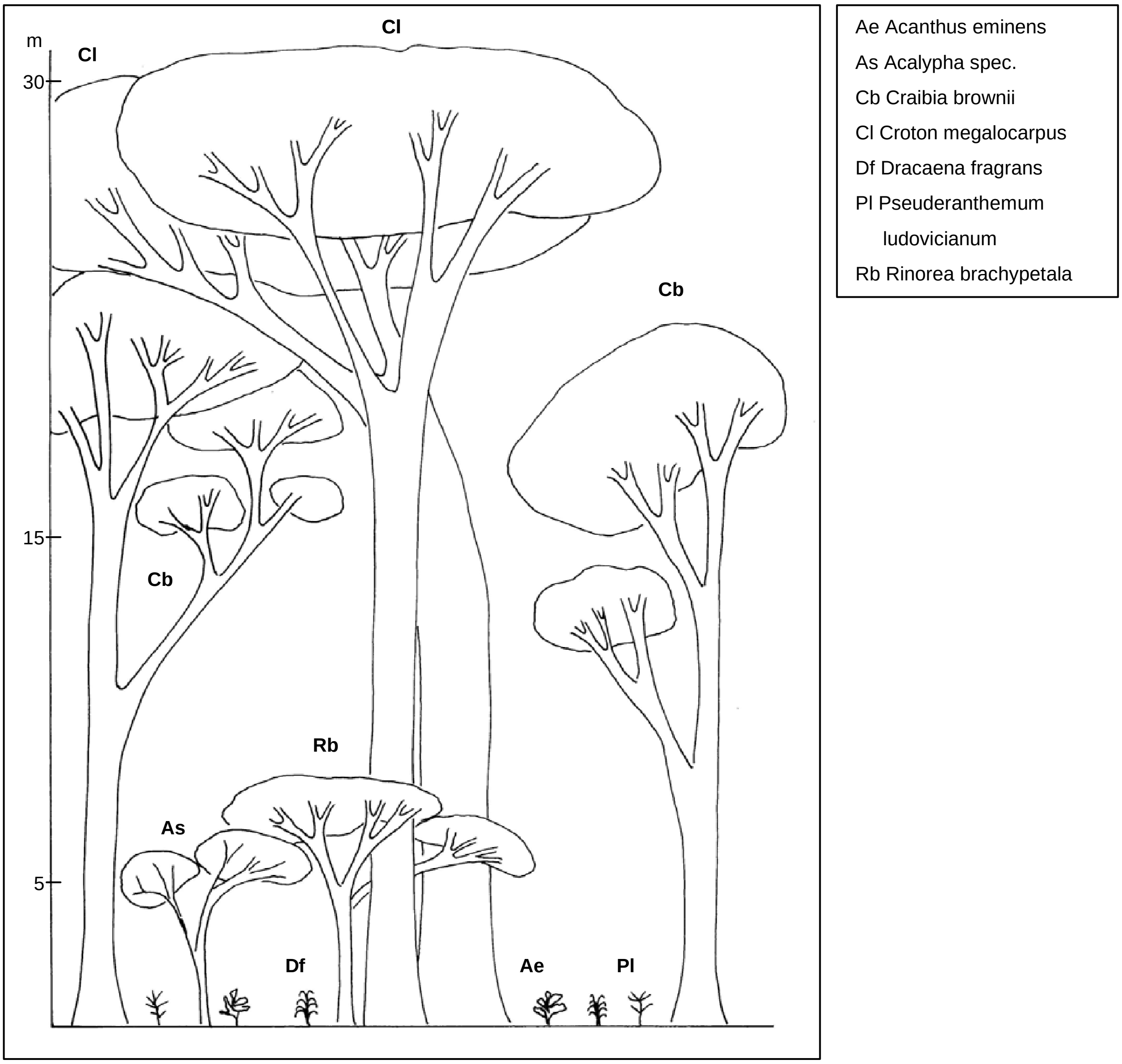


Fig. 48: Profile diagram of *Pseuderanthemum ludovicianum* - subcommunity in Ikuywa.

Strombosia scheffleri – community (2.3., I)

Like the former plant community the *Strombosia scheffleri* – community is defined as middle-aged secondary forest. The treelayer is about 25 to 30 m high (fig. 49). The crowns of the shrubs are interlocking. Ferns and seedlings of *Dracaena fragrans* and *Acanthus eminens* build up a dense cover on the forest floor. A lot of saplings and young trees of *Funtumia africana* occur there. *Pseuderanthmum ludovicianum* is missing, instead the lower shrublayer consists of *Mimulopsis arborescens* and *Acalypha* spec. Again several gaps occur next to the relevés. The differential species is *Strombosia scheffleri*, a tree which can reach heights of about 30 m, but in Kakamega Forest it belongs to the lower treelayers. The leaves are ovate to obovate, broad and dark-green. It is an element of moist forest and is sometimes dominant there. A characteristic companion of the plant community is *Ficus exasperata* a tall tree with a whitish bark and with yellow-red, sandpapery fig-fruits.

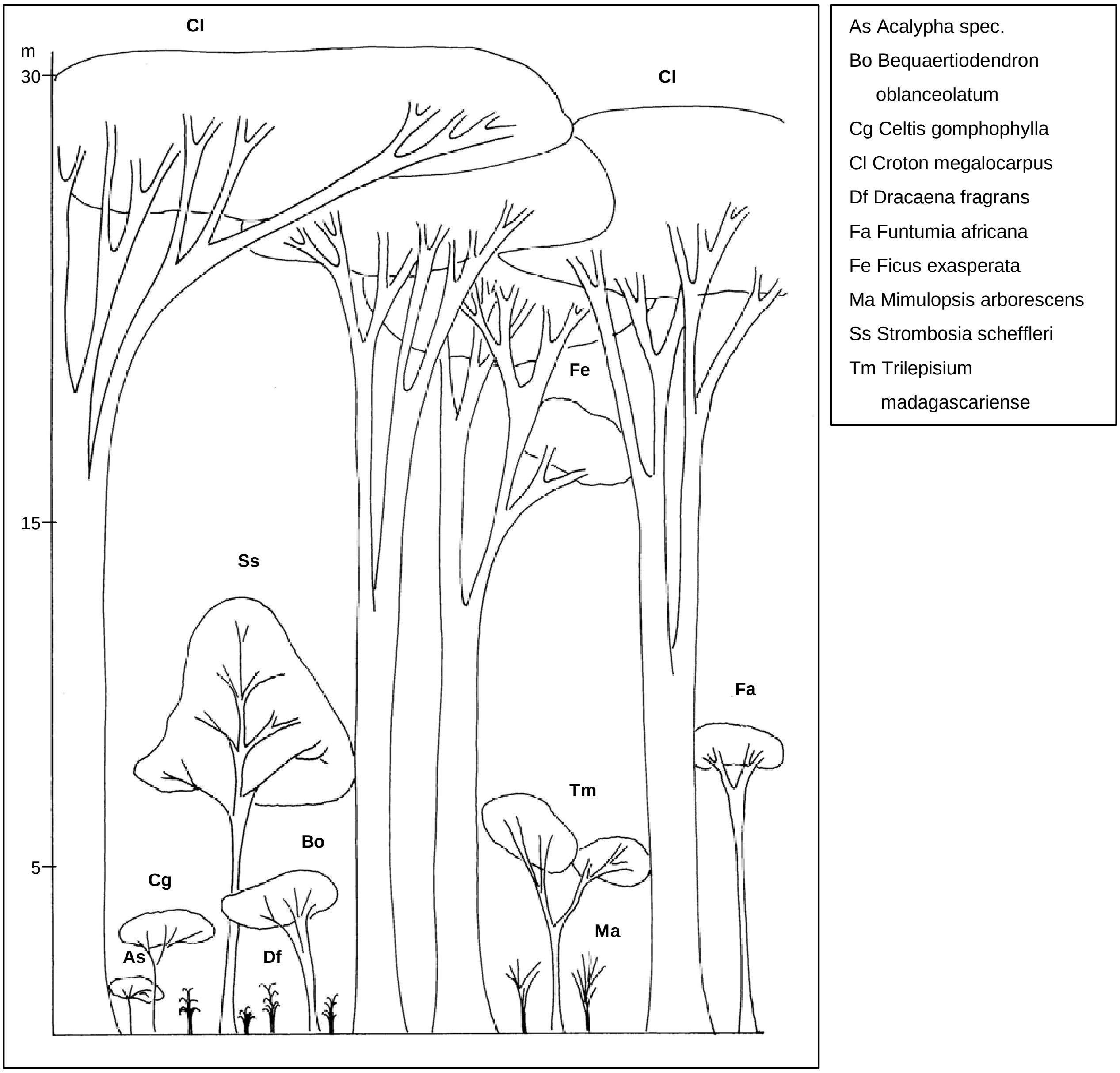


Fig. 49: Profile diagram of *Strombosia scheffleri* – community in Isecheno.

“Pure” *Celtis mildbraedii – Craibia brownii* - community (2.4., J)

In the “pure” *Celtis mildbraedii – Craibia brownii* – communtiy *Pseuderanthemum ludivicianum* and *Suregada procera* are missing. The tree *Strombosia scheffleri* has only a low occurrence in that community (fig. 50). The general tree heights of the canopy constructive trees are about 25 to 30 m. Characteristic trees are *Celtis mildbraedii* and *Craibia* *brownii* which are the species naming alliance 2. *Rinorea brachypetala* is abundant because of the vicinity of several river systems. The small trees *Bequaertiodendron oblanceolatum* and *Chrysophyllum albidum* are the characteristic species of the shrublayer, which is characterised by specimens of different ages with interlocking crowns. Therefore a closed canopy exists.

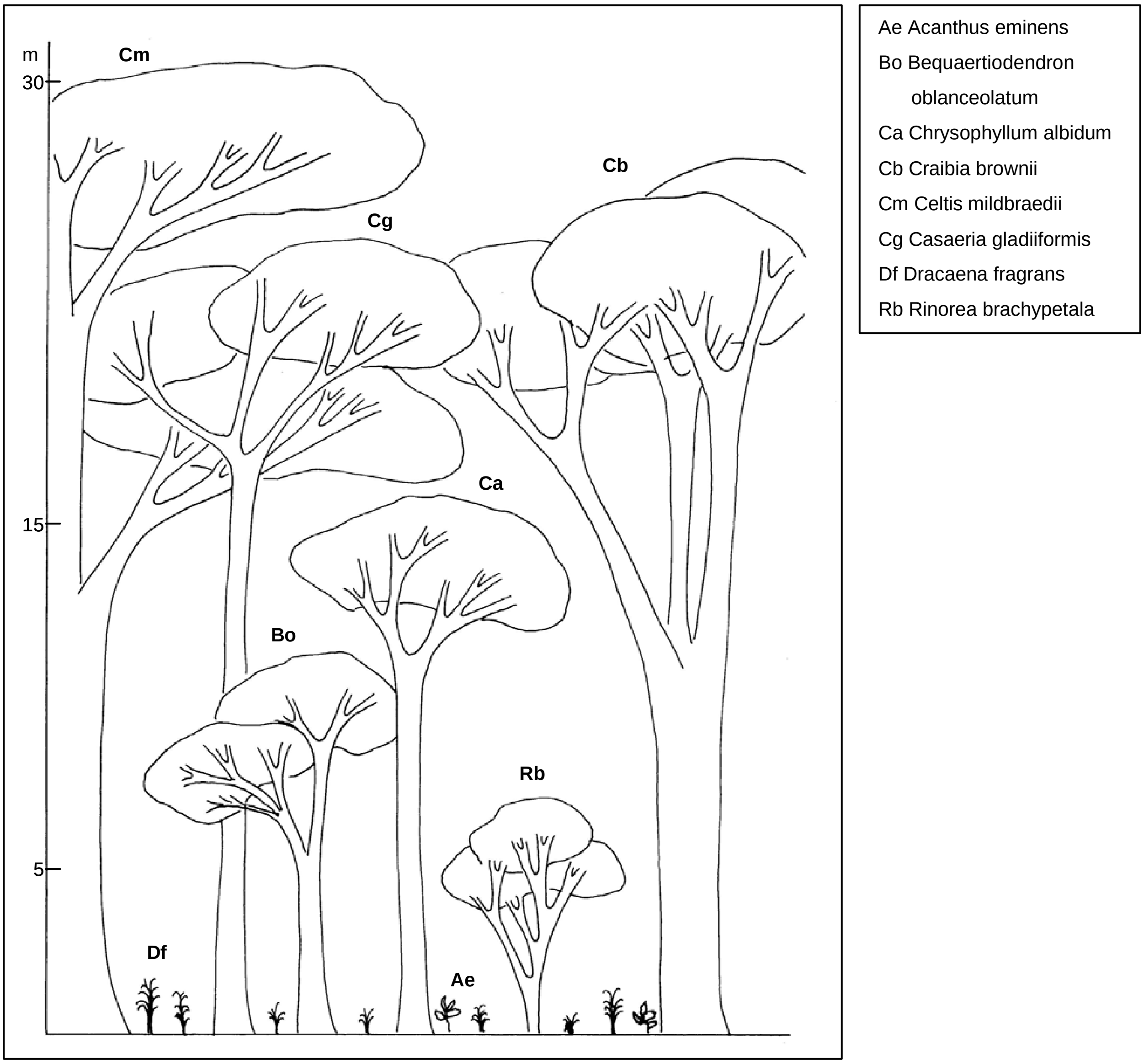


Fig. 50: Profile diagram of *Celtis mildbraedii- Craibia* browni - community in Salazar.

Harungana madagascariensis – Desmodium adscendens Alliance **II**

In study sites in the Buyangu National Reserve near the Campsite and Buyangu Hill as well as in Vihiga on the eastern side of the main forest block, pioneer vegetation was investigated. After clear-felling bushland develops followed by initial young secondary forest stages. The structure of the initial young stages and the species composition will be described in the following. The vegetation is about 10 to 20 years old and the treelayer is up to 12 m high.

Over 60 % of the canopy is closed in the relevés, but only thin crown layers exist. Therefore, a lot of sunlight flushes through the vegetation resulting in a dense shrub- and herblayer. The coverage of the herblayer is very high, numerous seedlings and saplings of pioneer species grow there. There is a thick shrublayer constructed by spiny shrubs and numerous long and thin lianas. Due to the high amount of sunlight it is very dry and hot inside the relevés. Light-demanding species find perfect conditions to grow and are dominant here. Two species are characteristic for the alliance II and are dominant in that initial forest vegetation. A dominant tree is *Harungana madagascariensis* with a reticulate-scaly bark and long, thick leaves. A characteristic feature is the red-orange latex. This tree is not a typical member of bushland. It is known as an abundant tree species of moist forest margins or forest remnants and is a member of the guineo-congolian flora. The second characteristic species is the small creeping herb *Desmodium adscendens*. It is typical for disturbed forest edges and has three leaflets, where the terminal is obovate and sometimes pointed. The fruit is a pod with short hairs which can stick at the skin of animals and thereby achieves dispersion. Companions of the treelayer are *Bridelia micrantha*, *Pseudospondias microcarpa* and *Syzygium guineense*. *B. micrantha* has a grey or blackish bark which is flaking and rough. Trunks and branches are often scattered with woody thorns. Like *H. madagascariensis* it is a typical species of forest margins and occurs less often in bushland. *P. microcarpa* is occassionally frequent as young tree in that kind of vegetation. In Kenya Kakamega Forest is one of the few habitats where it grows. The species has buttressed stems and a flaking, greyish-yellow bark. The fruits are blue-black at long panicles. The wood is bright-white and not durable. Specimens of *Syzygium guineense* are often young trees or shrubs in Kakamega Forest. The bark is grey and flaking in patches and the timber is red, hard and strong. The tree is known as a forest member, but its main occurrence in Kakamega Forest are the young secondary stages. Further abundant shrubs are *Tarenna pavettoides*, *Apodytes dimidiata* and *Psidium guajava*. *T. pavettoides* has elliptic, dark-green and thick leaves, white flowers and black fruits. It is known as species of riverine forest or secondary bushland near forests. The only member of the family Icacinaceae in Kakamega Forest is *A. dimidiata*. It is an evergreen shrub with a smooth, grey bark and asymmetrical, red fruits. It is widespread in Kenya and is known from upland dry forest. *P. guajava* (Guava) has been introduced from tropical America. It is a small evergreen tree widely cultivated in the tropics for its fruits and now almost naturalised in East Africa. The fruit contains delicious pink-white flesh and is eaten by birds, bats or monkeys which disperse the seeds. The wide occurrence of *P. guajava* springs from plantations in clear-felled areas, but nowadays its distribution is mainly performed by animals rather than by humans. Typical herbs of the dense undergrowth are *Piper umbellatum*, *Urena lobata* and *Sanicula elata*. The soft-wooded herb *P. umbellatum* has broad, ovate leaves with a deeply cordated base. It is typical for disturbed forest sites. A characteristic species of disturbed grounds and cultivations in western Kenya is the erect and long-hairy herb *U. lobata*. An erect perennial, small herb with palmately lobed leaves is *S. elata*. It is common on shady forest floors. Orchids like *Habenaria malacophylla*, *Calanthe sylvatica*, *Disperis aphylla* or *Eulophia streptopetala* are occassionally frequent in sunny, warm places. Several lianas are abundant in the young secondary forest. *Embelia schimperi* is a cauliflorous climber with obovate leaves and its roots and dry seeds are used as anthelmintic. It is known in Kenya in upland evergreen forests. A liana with winged rachis at the leaflets is *Paullinia pinnata*. It climbs by coiled tendrils at base of inflorescences. *Smilax anceps* is a climber with prickly stems and alternate leaves with two tendrils per petiole-base and is one of the responsible lianas for the thick shrub- and herblayer. *Jasminum fluminense* has opposite, trifoliolate leaves with flowers in terminal corymbs. It occurs in deciduous bushlands, woodland but also at forest edges and is known as secondary vegetation species. Fern species which are occassionally frequent are *Asplenium* cf. *buettneri*, *Asplenium anisophyllum* var. *microphyllum* and *Pellea viridis*.

The *Harungana madagascariensis – Desmodium adscendens* alliance II consists of two plant communities which will be described in the following.

Maesa lanceolata – subcommunity (3., K)

A characteristic pioneer species in secondary forests and forest margins is the differential species *Maesa lanceolata*. This abundant species occurs often as shrub up to 4 and 6 m and has lenticellate branches with glabrous orange-red resin. The roots and fruits are medicinally used, but are toxic in large doses. Companions of the plant community are *Acanthus pubescens* and *Pavonia urens*. *A. pubescens* is the analogue to the forest species *A. eminens*. *A. pubescens* looks very similar, but the leaves are bright-green without white veins. This shrub species is typical for bushed or wooded grasslands and is highly abundant in forest clearings. *Pavonia urens* is a soft, hairy herb with almost circular and triangular-lobed leaves. It is locally common in forest edges or riverine woodland to highland forests. The treelayer is up to 12 m high and about 15 to 20 years old (fig. 51). A frequent species is *Oncoba spinosa*, a much branched shrub or tree with axillary straight, long spines and great white-pink flowers. It is common in riverine forests or bushland. Climax species of older succession stages can be found in high numbers as seedlings and saplings in the herblayer. Among them are *Antiaris* *toxicaria*, *Diospyros abyssinica*, *Prunus africana*, *Funtumia africana* and *Heinsenia diervilleoides*.

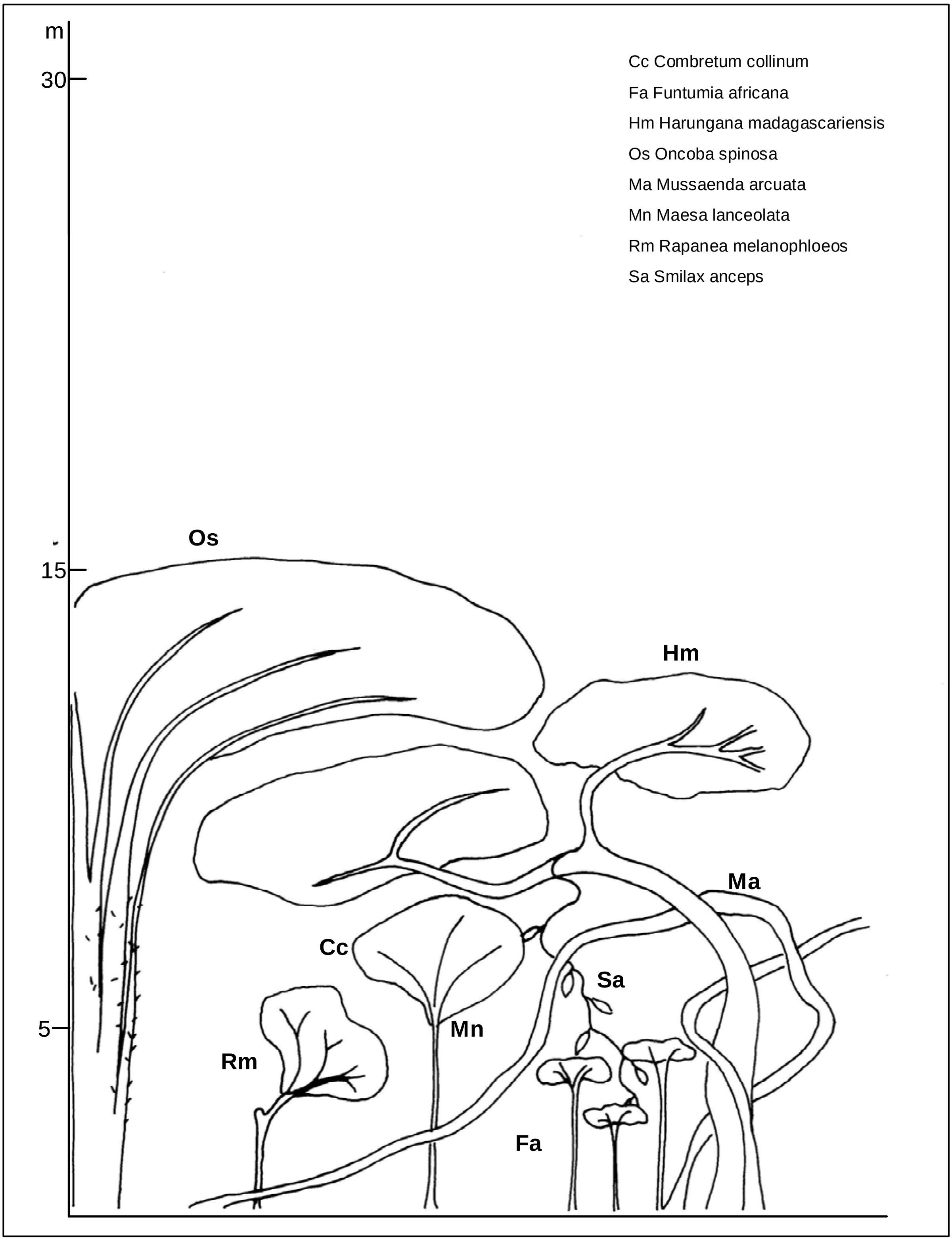


Fig. 51: Profile diagram of *Maesa lanceolata* – subcommunity near Campsite.

Pittosporum viridiflorum – community (4., L)

Relevés with vegetation heights between 4 and 10 m are included in the *Pittosporum viridiflorum* - community. This plant community is the youngest of all investigated succession stages in Kakamega Forest. A dense herblayer occurs and coverage of the canopy is between 60 and 80 percent. *Pittosporum viridflorum* is mostly a shrub in Kakamega Forest. In Kenya it is a widespread species of the guineo-congolian flora and occurs in dry evergreen forest or wooded grassland and also in forest clump remnants. A further differential species of that plant community is the fern *Nephrolepis undulata*. Its common name is annual swordfern. Companions of the two communities of alliance II are the following species. *Combretum collinum* is the character species of the *Combretum* wooded grassland which is typical for the surrounding landscape of Kakamega Forest and occurs in the forest in highly disturbed and young succession stages. Its crown is flat or rounded, the bark is smooth and grey-brown. The conspicuous fruits are reddish brown or purple, often metallic and 4-winged. *Rhamnus prionides* is a shrub of forest edges or secondary bushland. The roots are medicinally used against malaria and rheumatism. Flowers are yellowish-green and grow in fascicles, the fruits are red and 3-lobed. The species belongs to the afromontane flora and is widespread in Kenya. Beside several herbs of the family Acanthaceae, Lamiaceae or Asteraceae the small herb *Justicia flava* is occassionally frequent in the undergrowth. It is a trailing erect perennial herb with bright yellow flowers in subtended by linear to lanceolate bracts. This plant species is common in a variety of open habitats and occurs in Kakamega Forest in more or less disturbed, light places. An abundant, tall liana is *Mussaenda arcuata*. It is common in bushed or wooded grassland, in secondary bushland and forest margins. The flowers are bright yellow with an orange hairy center, the fruit is blue-metallic and edible.

Heavily disturbed and replanted forest sites (N, O, P, R)

Several plantations mainly in the southern forest parts were established in the last 70 years. Great *Eucalyptus saligna* -, *Pinus patula* - and *Cupressus lusitanica* - plantations are still present between the Isecheno area of the main forest blocks and the fragments Yala and Ikuywa. North of Malava *Eucalyptus saligna* was planted, but not only monocultures can be found. In the following section heavily disturbed forest sites with planted trees are described.

Forest sites of Malava, Kaimosi, Ileho and Kibiri can be defined as potential *Deinbollia kilimandscharica – Markhamia* lutea - community with dominating planted tree species.

A special case is the forest of the Kaimosi fragment (column N in appendix 4 and 5). Two main tree species are highly dominating the forest canopy and nearly all individuals have similar heights and therefore ages. One of these trees is the described *Trilepisium madagascariense* whose fruits are eaten by Red-tailed and Colobus monkeys. But the characateristic tree species of this forest area is *Afrosersalisia cerasifera*. It is well known for rain- and riverine forest in the Kakamega area, but could only be recorded in Kaimosi forest. The bole is fluted and the leaves are obovate, at the apex obtuse and glabrous. The red, ovoid fruits are eaten by monkeys, too. During the study time in march 2002 a dense layer of fruits, seeds and seedlings of these two abundant tree species could be observed. Shrubs of *Uvariopsis congensis*, *Deinbollia kilimandscharica*, *Markhamia lutea*, and *Trichilia emetica* are occassionally distributed in the understorey vegetation. These species are typical for the northern forest sites, but also occur in the most southern forest site. It is somehow a mixture of the alliance 1. and 2., because beside the mentioned shrub species characteristic species from the southern forest sites like *Mimulopsis arborescens* and the tree *Strombosia scheffleri* and *Croton megalocarpus* are also frequent there. Figure 52 shows a profile diagram of forest of the Kaimosi fragment.

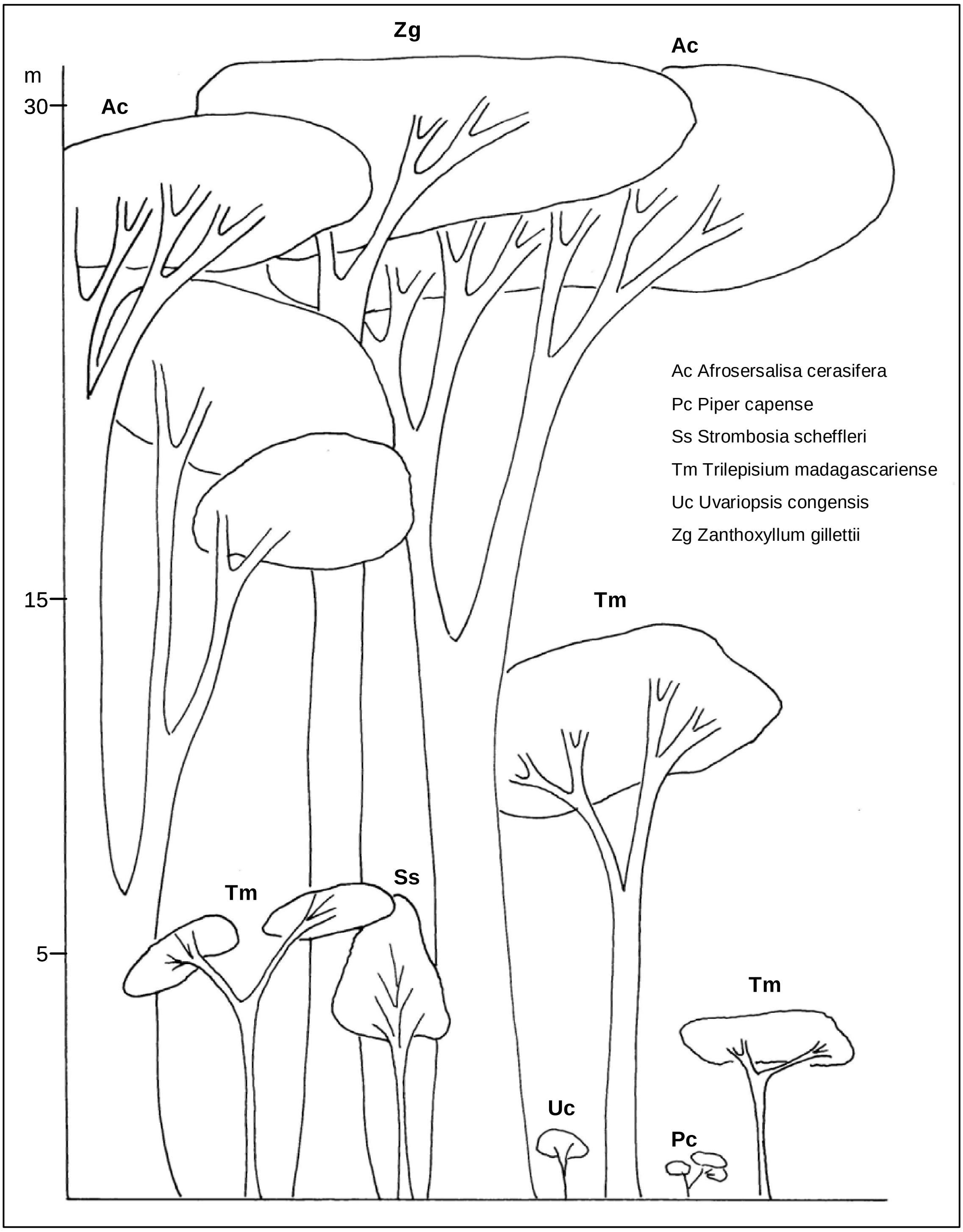


Fig. 52: Profile diagram of forest site of Kaimosi forest.

In Malava forest gaps were replanted with *Khaya anthotheca* and *Zanthoxyllum gillettii* (column O). The african mahagony *Khaya anthotheca* has been introduced from Uganda and is the most common mahagony in Budongo Forest. It is a very large deciduous tree with a long, wavy trunk and with a massive spreading crown. Specimens of this forest tree could be recorded in Malava forest. *Z. gillettii* is a tall, deciduous tree with a smooth, grey trunk covered with spines on bosses. Due to its scented, hard wood is was planted in forest gaps.

The treelayer in the fragment reaches heights about 25 m and builds up a canopy cover of 60 to 80 %. Several companions belonging to alliance 1. like *Rawsonia lucida*, *Strychnos usambarensis*, *Bequaertiodendron oblanceolatum* or *Heinsenia diervilleoides* could be recorded. In the lower shrublayer *Dracaena fragrans* is dominant and several specimens of *Coffea eugenioides* occur. The indicator species for light, less disturbed forest sites *Uvariopsis congensis* is abundant, too. Some tree individuals of *Antiaris toxicaria* are spread over the forest and also small trees of *Diospyros abyssinica*. Because several illegal activities like selective logging or cutting of young trees are performed in Malava, several gaps could be recorded in the forest. Under the disrupted canopy there has been opportunity for spiny shrubs like several tall *Oncoba spinosa* to develop (fig.53).

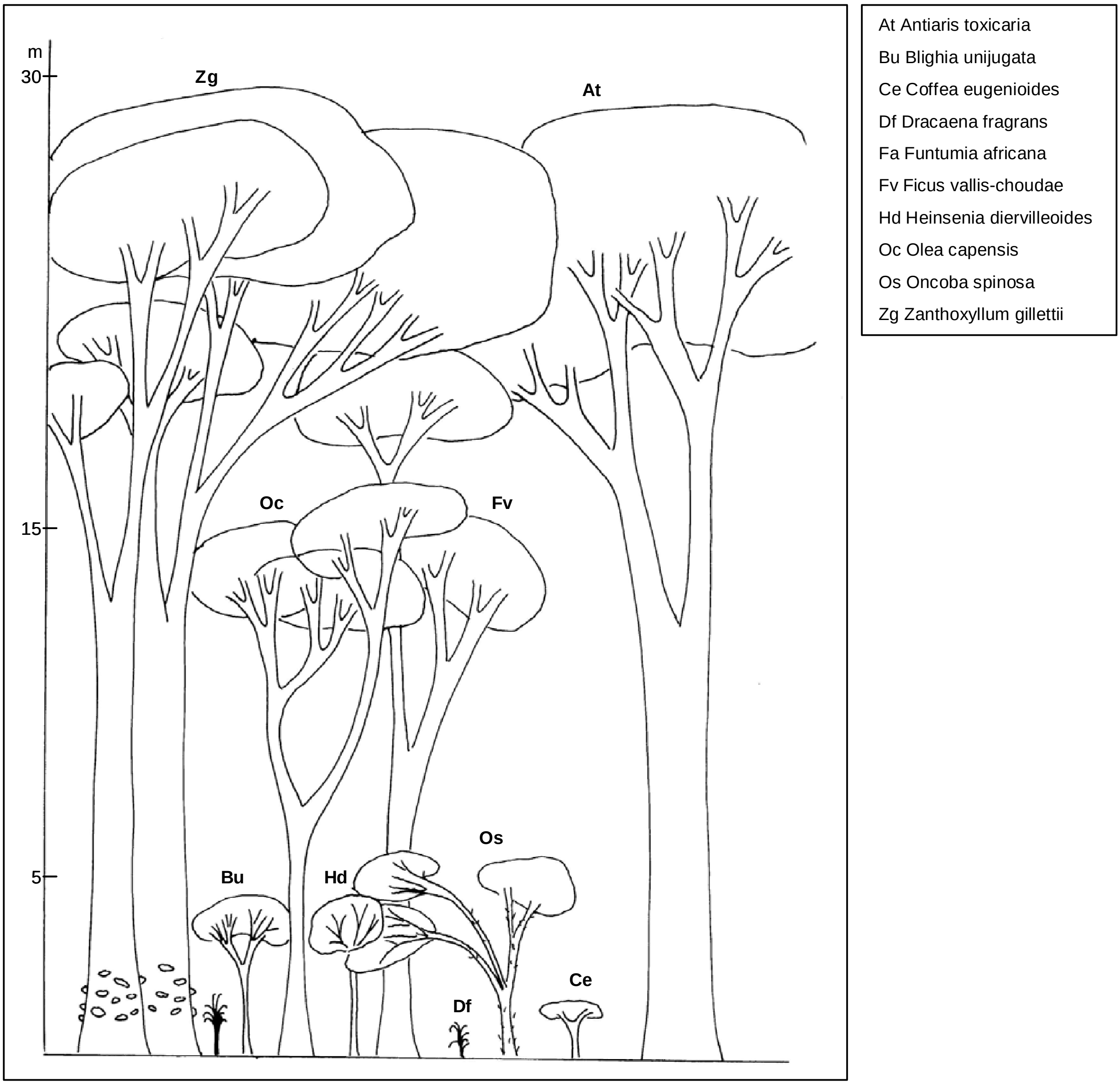


Fig. 53: Profile diagram of Malava forest.

The study site Ileho is an old, broad plantation of *Maesopsis eminii* north of the Ikuywa fragment (column P). *M. eminii* is known in Kenya only in Kakamega Forest where it is widely cultivated. It is a deciduous tree with a grey-silvery bark. The most famous tree individual is the “Mama Mutere” tree in Isecheno. It is said that all seeds of the plantation saplings originated from this adult tree. Between the adult *M. eminii* trees there are species of the pioneer vegetation or early climax stages growing. The first trees which develop in that kind of plantation are *Alangium chinense*, *Harungana madagascariensis*, *Bridelia micrantha*, *Celtis gomphopyhlla* and *Trilepisium madagascariense*. The first three are typical pioneer species which found good conditions in the open, light plantation. But species of older succession stages now develop in the lower tree- and shrublayer like the two later mentioned species. The characteristic species *Deinbollia kilimandscharica* and *Markhamia lutea* as well as several shrubs like *Bequaertiodendron oblanceolatum*, *Antiaris toxicaria*, *Cassipourea ruwensorensis* or *Coffea eugenioides* show, that the plantation can develop into natural forest sites of Kakamega Forest when no human disturbances happen. Even saplings of *Diospyros abyssinica* and *Olea capensis* reflect the possible regeneration into a natural forest stand. But still a lot of pioneer and bushland species like *Albizia gummifera*, *Bersama abyssinica*, *Pittosporum viridiflorum* or *Solanum mauritianum* are very abundant.

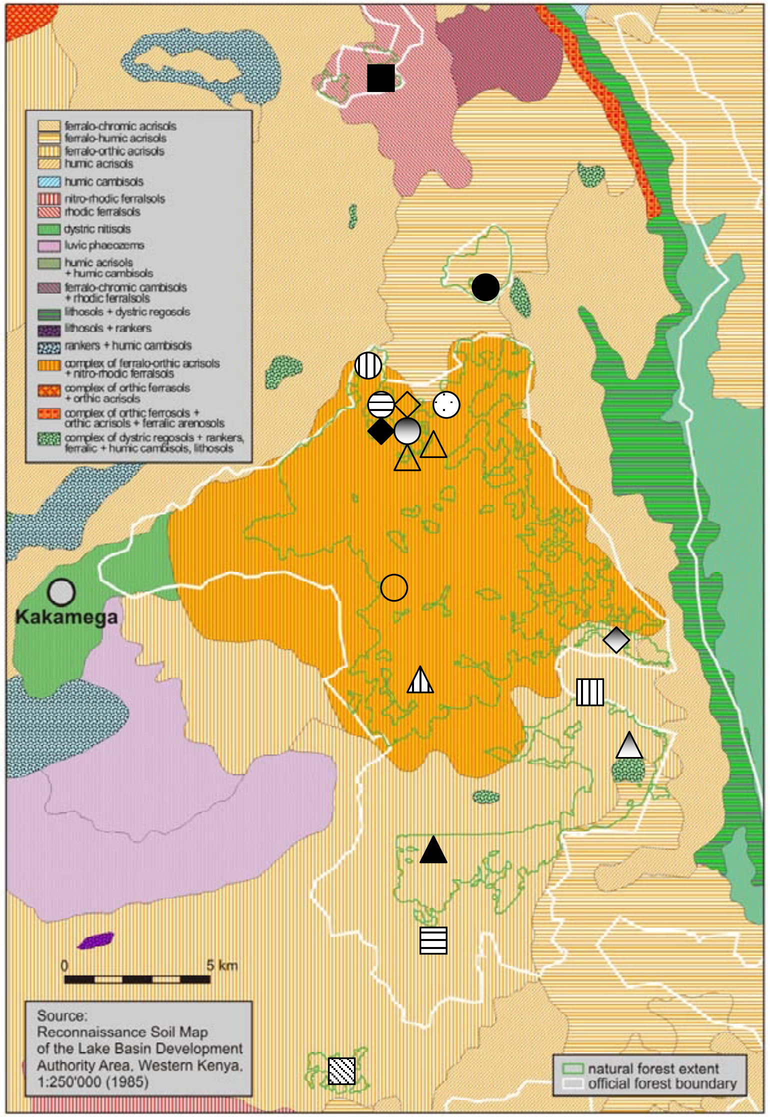
In the Kibiri forest south of Yala a mixture of *Maesopsis eminii*, *Bischoffia javanica*, *Prunus africana*, *Zanthoxyllum gillettii* and *Cordia africana* were planted. *B. javanica* has been introduced from Asia because of its hard, tough wood. This species has a brown-grey, straight bole and elliptic leaves. The plantation is about 20 years old. All trees have nearly similar heights and the shrublayer is full of young saplings. A lot of sunlight reaches the floor due to the open canopy. Interestingly, two new species could be found there in the understorey. A new *Desmodium* species, *D.* sp. A with three ovate leaflets which are paler below and with a pale centre above. The flowers are pink on long stalks. It is known from roadsides and forest edges. A small orchid, *Disperis anthoceros*, is frequently distributed over the forest floor. The white flowers look like small jelly bag caps. Like in the plantation several pioneer and early climax species could be recorded as well as the two characteristic species *Antiaris toxicaria* and *Diospyros abyssinica* of the alliance I. This indicates that the plantations possibly develop into a climax stadium which is natural for Kakamega Forest (column Q).

In Kakamega Forest the following species are represented in every investigated relevé and forest area. They are characteristic for that dry peripheral guineo-congolian transitional rainforest and occur also in the forest plantations. Two species are highly abundant and separate the forest from the surrounding vegetation. *Allophylus abyssinicus* is a small shrub or tree in the forest with a grey, smooth bark and trifoliate leaflets. It occurs in dry as well as in moist forest and is represented as shrub, sapling or seedling in every relevé. In the herblayer *Desmodium repandum* is dominant in shadowed forest sites as well as in the light-flooded young secondary forests. It has three leaflets and ovate to rhombic leaves with a pale centre. The flowers are orange in a terminal raceme and the developing fruit is a hairy pod, which sticks on animals to be dispersed over a long distance.

An abundant companion is the tree species *Funtumia africana*. It is a fast growing species and saplings and young trees could be observed in young forest stages and middle-aged forest sites. It has white latex and large elliptic leaves which are light-green and glabrous. The fusiform fruit is grey-brown and contains hairy seeds which are dispersed by wind. It is a guineo-congolian element and occurs, beside Kakamega Forest, in Taveta and Shimba Hills, which are lowland rainforests. Another species of the guineo-congolian flora is the tree *Blighia unijugata*. It reaches heights of 15 to 20 m in the forest and has a smooth, brown-grey bark. The fruits are red, three-lobed and contain a seed with yellow aril. *B. unijugata* is highly abundant mainly as young tree in the shrublayer in Kakamega Forest. *Teclea nobilis* is a small tree and very dominant in the shrublayer in the forest. The leaves are three-foliolate, dark-green, glabrous and leathery. Since it belongs to the family Rutaceae, the leaves contain small oil cells. Also, in the shrublayer occurs the spiny, much-branched and multistemmed species *Dovyalis macrocalyx*. The branches have straigt axillary, long spines and the flowers are yellow-green which develop in red-yellow fruits with an enlarged, red and hairy calyx. In the lower shrub- and in the herblayer *Piper capense* is distributed throughout Kakamega Forest. It is a woody herb or shrub with aromatic and broadly ovate leaves. The flowers are minute in white spikes and the fruits are green. Its relative *Piper guineense* is also widely distributed in every studied forest site. It is a liana and is restricted in Kenya to Kakamega Forest, but widespread in Western and Central Africa. Its stems are corky-ridged near the base and the leaves are elliptic, leathery and dark-green. The flowers are minute, yellowish and the fruits are red and round. Dominant species of the herblayer are two grasses *Oplismenus hirtellus* and *Pseudochinoleana polystachya*. They are difficult to distinguish without flowers or fruits in the field and were therefore summarized as one species complex. Both species belong to the family Poaceae and have small, lanceolate leaves. *O. hirtellus* - flowers are borne on longitudinal racemes branching out from the culm with purple awns which are sticky when fresh. In contrast, *P. polystachya* has white, round flowers on sessile racemes. Several *Aframomum* species are occassionally abundant especially in more open, light places in the forest, for example *A. mala* with its yellow flowers and rolled bottom petal or *A. zambesiacum* with its pedicellate inflorescence and large blackish-red fruits.

Distribution of the plant communities

Due to the mosaic-structure of the vegetation in Kakamega Forest, the plant communities occur in direct vicinity. For example the area of the Buyangu National Reserve contains plant communities of old succession stages like the *Ficus cyathistipula* – subcommunity in Ghostisland as well as a typical plant community of very young succession stages like the *Pittosporum viridiflorum* – community. Nevertheless, the main part is covered with middle-aged forest with *Uvariopsis congensis* – or cf. *Fernandoa magnifica* – communities. An overview of the distribution of the main plant communities of every studied forest site is shown in figure 54. With help of the underlayed soilmap the distribution of the different plant communities is tried to analyse and understand. The main difference between the northern and southern part of the main forest block is reflected by the two alliances *Deinbollia kilimandscharica – Markhamia lutea* and *Celtis mildbraedii – Craibia brownii*. Another group comprises the forest sites of secondary forest reflected by the *Harungana madagascariensis – Desmodium adscendens* – alliance. The fourth group are the heavily disturbed and afforested sites. The four different symbol shapes indicate the main analysed groups of the forest. Each group has its own symbol on the map. The symbol contents reflects the different plant communities and plantation groups within the four distinguished groups.



Study site	Plant community	Symbol
Kisere	*Trichocladus ellipticus* – subcommunity	●
Ghostisland	*Ficus cyathistipula* – subcommunity	◐
Colobus	*Uvariopsis congensis* – community	⦶
Buyangu Hill	cf. *Fernandoa magnifica* – community	⊖
Shiamololi	Pure *Deinbollia kilimandscharica* – *Markhamia lutea* - community	○
Isiukhu	Degraded *Rapanea melanophloeos* – riverine - community	⊙
Yala	*Suregada procera* - subcommunity	▲
Ikuywa	*Pseuderanthemum ludovicianum* - subcommunity	◭
Isecheno	*Strombosia scheffleri* - community	⟁
Busambuli, Salazar	Pure *Celtis mildbraedii* – *Craibia brownii* community	△
Camp forest	*Deinbollia kilimandscharica* – *Markhamia lutea* transitional - subcommunity	◇
Vihiga	*Maesa lanceolata* - subcommunity	◈
Buyangu Hill - secondary	*Pittosporum viridiflorum* - community	◆
Malava	disturbed *Deinbollia kilimandscharica* – *Markhamia lutea* community	■
Kaimosi	*Afrosersalisia cerasifera* – special case	▨
Ileho	*Maesopsis eminii* - plantation	▥
Kibiri	*Bischoffia javanica* - plantation	▤

Fig. 54: Distribution of the plant communities over Kakamega Forest on the base of the Reconnaissance Soil map and legend, Source E 02, FH Karlsruhe, G. Schaab 2005.

At Kakamega Forest the ferrasolic soil at equatorial tropical rainforests typical for a perhumid climate occurs in different characteristics (Walter & Breckle 2004). In total five different soil types could be distinguished at Kakamega Forest and its adjacent fragments.

The soil map shows, that the main forest block from the Buyangu National Reserve up to the Isecheno area is build up of a complex of ferralo-orthic agrisols and nitro-rhodic ferrasols (fig. 54). In contrast the fragments Yala, Ikuywa and Kaimosi are composed of ferralo-orthic acrisols.

Further different soil types were recorded at Malava and Kisere. There is a rhodic-ferralsol-type at Malava and ferralo-humic acrisols at Kisere.

Measurements of spatial heterogeneity regarding soil properties conducted by subproject E 03 show small-scaled distribution pattern of the different parameters. Soils of Colobus, Salazar and Isecheno have different values in pH and CEC (Dalitz 2004). Results from samples of different soil horizons out of soil pits demonstrate the diverse composition of soil types in Kakamega Forest and the high spatial heterogeneity of the soils. Due to the fact, that a mosaic of different soil types occurs in Kakamega Forest and soil pits were not established in the analysed relevés of our subproject direct comparisons or the analysis of correlation between plant species distribution and soil typ on this lower scale was not possible. The aim was part of the studies of subproject E 03, where a tree species composition was analysed with references to the soil where it occurs.

Therefore, the connection between the analysed plant communities and the soil types are discussed on the base of the five distinguishable, broad soil types visible on the Reconnaissance soil map made available by subproject E 02.

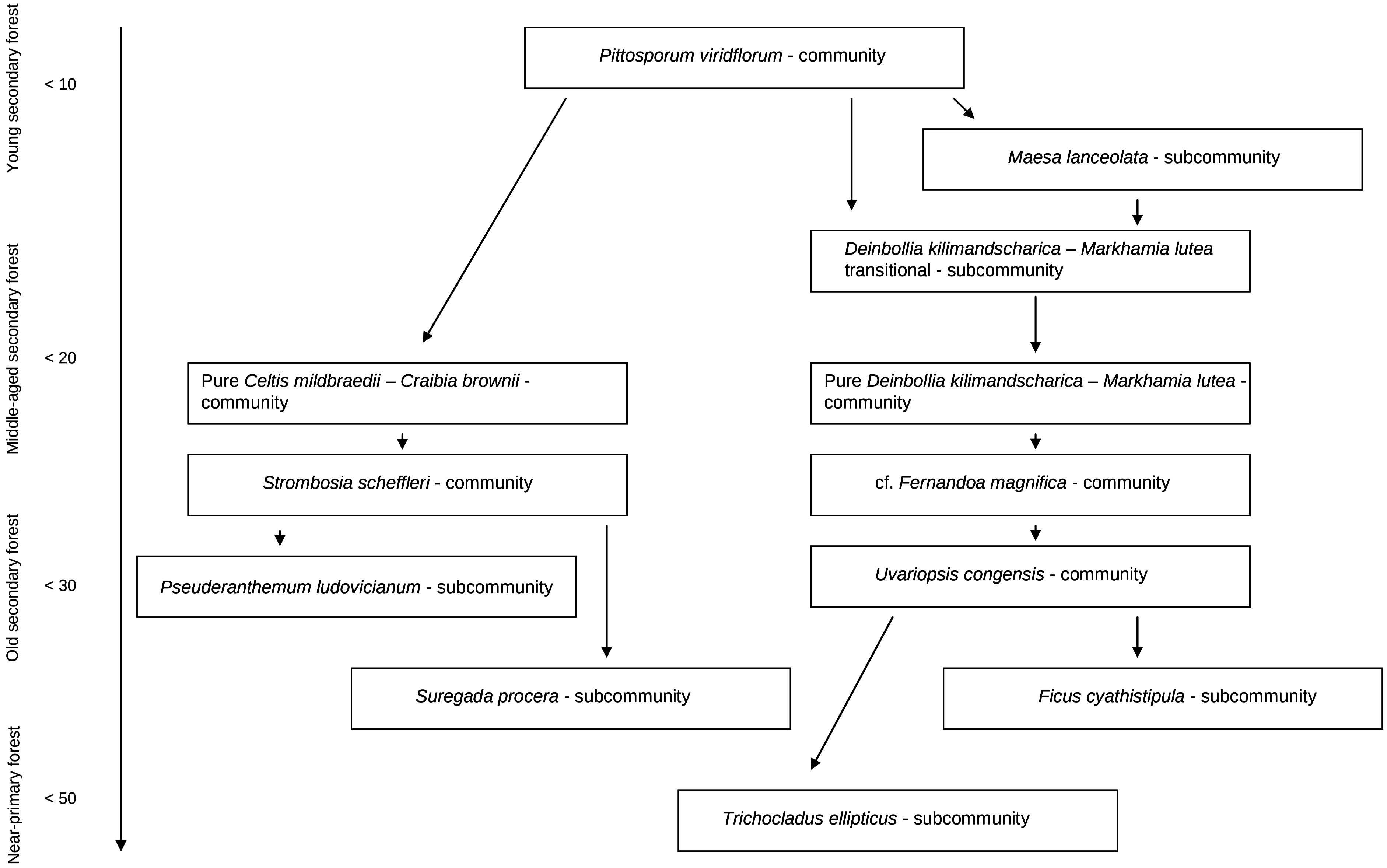
Succession stages

Study sites were chosen to get an overview of the different succession stages of Kakamega Forest. The defined vegetation structure occurring side by side in the forest can be arranged along a time-axis to describe the progression of the different plant communities.

The following table 7 of the different succession stages of the forest is based on the analysed plant communities. Information about the forest structure, the vegetation heights as well as data about the last human disturbances like logging activites were included in the analysis.

The youngest analysed plant community is the *Pittosprum viridoflorum* – community with vegetation heights of about 8 to 10 m followed by the *Maesa lanceolata* – subcommunity which reflects an older stage. After some years the plant composition changes and develops into a *Deinbollia kilimandscharica* – *Markhamia lutea*-transitional – subcommunity. Due to the fact that the analysis separates two alliances of northern and southern forest, two possible ways of development are presented here. The left side of the diagram shows the succession stages of the middle and southern forest sites. From a pure *Celtis mildbraedii* – *Craibia brownii* – community it develops over the *Strombosia scheffleri* – community and *Pseuderanthemum ludovicianum* – subcommunity to the *Suregada procera* – subcommunity. This plant community is the oldest analysed stage in the *Celtis mildbraedii* – *Craibia brownii* – alliance. In the northern forest sites the cf. *Fernandoa magnifica* – community and the *Uvariopsis congensis* – community arise from a pure *Deinbollia kilimandscharica* – *Markhamia lutea* – community. Both plant communities have a similar age and succession stage and develop into the *Ficus cyathistipula* – and *Trichocladus ellipticus* – subcommunity.

Table 7: Succession of different plant communities of Kakamega Forest



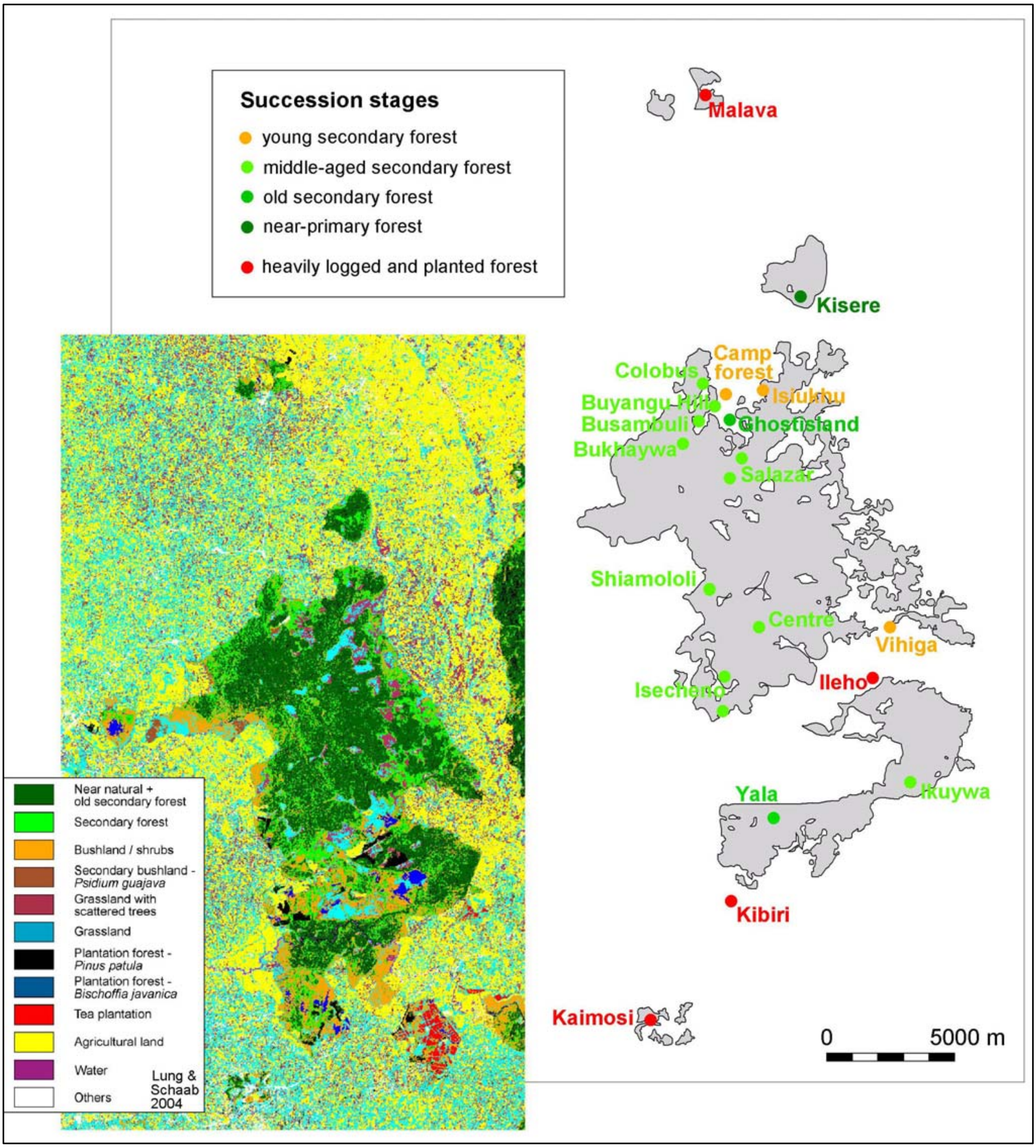


Fig. 55: Landsat ETM+ land classification result of 2001, source E 02, FH Karlsruhe (left site), distribution of the succession stages in Kakamega Forest (right site).

All studied forest sites can be assigned to four defined succession stages. Figure 55 shows the distribution of the different succession stages over Kakamega Forest.

In cooperation with the present study subproject E 02 designed a land cover classification based on a satellite imagery of the year 2001. Their class “near natural and old secondary forest” contains plant communities of near primary and old secondary forest of the defined *Antiaris toxicaria – Diospyros abyssinica* – alliance. A more detailed presentation of the different plant communities was not possible by means of remotely-sensed imagery. The areas of “secondary forest” defined after Lung & Schaab (2004) are the middle-aged forest of *Antiaris toxicaria – Diospyros abyssinica* and older stages of the *Harungana madagascariensis – Desmodium adscendens* – alliances. In their class bushland/shrubs the defined young secondary forest of this study is included. Thus, it is a first overview of the different succession stages of the forest and after the present analysis it can be stated that most of Kakamega Forest consists of middle-aged secondary forest. Only few forest areas are old secondary or even near-primary forests. A large part of the area around Vihiga is young secondary forest as it is also presented in the classification map of land cover in figure 55. Large areas especially between Isecheno and Yala are broad plantations. These plantations are not shown in the right illustration of figure 55, because only boundaries around indigenous forest were drawn, but in Malava and north of Ikuywa plantations or planted areas occur within indigenous forest. Furthermore, the *Maesopsis eminii* and *Eucalpytus saligna* plantations could not be separated on the base of the satellite photos provided by subproject E 02, and are included in the two forest classes of the left illustrations in figure 55. Surprisingly the oldest forest site with the fewest disturbance during the last decades could be found in a fragment, namely in the Kisere fragment north of the main forest.

Concluding, figure 56 and 57 show pictures of the two main alliances of Kakamega Forest to get an impression of the different structure.

Fig. 56: Profile of Kisere forest.

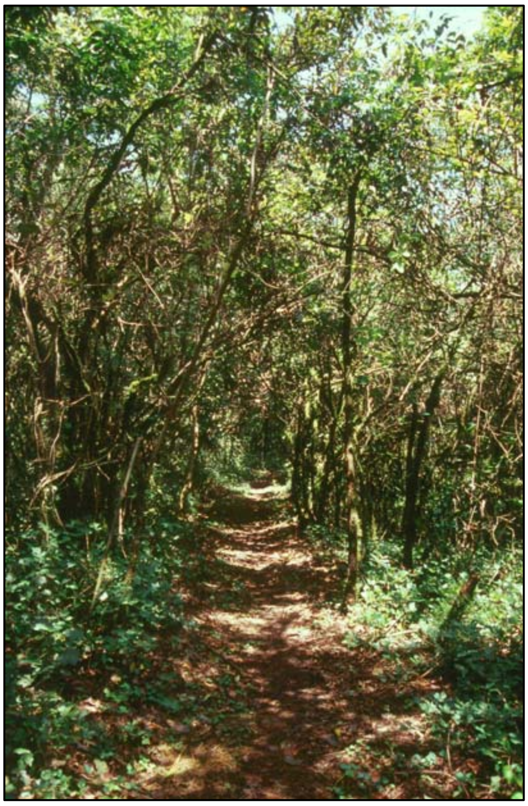


Fig. 57: Profile of Camp forest.

Figure 56 provides a view into the forest of the Kisere fragment. In the foreground *Dracaena fragrans* is visible. The undergrowth is shadowed and the shrub and tree crowns are interlocking. The average tree height is about 35 m. *Strychnos usambarensis*, *Diospyros abyssinica*, *Olea capensis* and *Prunus africana* are the canopy constructing species. In contrast the Camp forest has low tree individuals which reach heights of about 12 m (fig. 57). The broad path through the vegetation reflects the high degree of disturbance. A high amount of sunlight provides good conditions for the undergrowth vegetation, many seedlings and saplings build a dense cover. The young stems belong to species like *Harungana madagascariensis* or *Maesa lanceolata*. Between the young secondary forest in figure 57 and the near primary forest in figure 56 lies a time span of about 40 years of succession.

Indicator species

A selection of indicator species of Kakamega Forest is presented in table 7.

Table 7: Indicator species. Shown are lifeform and level of disturbance (high – low).

lifeform	high	low
lianas	*Stephania abyssinica*	*Tiliacora funifera*
lianas	*Secamone punctulata*	*Culcasia falcifolia*
lianas	*Smilax anceps*	*Hippocratea africana*
herbs	*Aframomum mala*	*Impatiens stuhlmannii*
shrubs	*Acanthus pubescens*	*Acanthus eminens*
trees	*Polyscias fulva*	*Diospyros abyssinica*
trees	*Alangium chinense*	*Strychnos usambarensis*

The occurrence of adult specimens of the three liana species *Stephania abyssinica*, *Secamone punctulata* and *Smilax anceps* in a forest indicates a young succession stage. Over the past years e.g. human disturbances like selective logging or clear-felling happened and the forest site is in regeneration. All these species are typical pioneer species which grow under the light, dry conditions of such forests. The more species could be recorded in a sample the higher was the disturbance in the past. In contrast, the record of liana species like *Tiliacora funifera*, *Culcasia falcifolia* and *Hippocratea africana* indicates older climax stages. The larger the liana specimens are the older is the succession stage, because they are slow growing species. Further species of the two genera *Aframomum* and *Impatiens* are useful indicators for disturbed places. Many *Aframomum* individuals signify open, sunny places with a certain level of drought. Compared to this species group individuals of *Impatiens stuhlmannii* grow in undisturbed forests, ofter near river streams. Only *I. hochstetteri* grows in disturbed, open places like near pathways, but under wetter conditions in shadowed places. The shrub *Acanthus eminens* grows in great numbers in disturbed forest sites e.g. in gaps or along pathways, but is a forest-dependent species. It also occurs in the shrublayer of mature forest sites. In contrast, *A. pubescens*, its relative, is a characteristic species of the bushland and young succession stages and is found in highly disturbed places with a lot of sunlight and open canopy. Although both species grow after disturbance, the level and duration of the disturbance is determining the occurrence of *A. eminens* or *A. pubescens*. Furthermore, the vicinity of bushland with potential individuals of *A. pubescens* enhance the dispersion of this species. Therefore, the more fragmented a forest is, the higher is the possibility to find individuals of that bushland indicator species rather than individuals of the forest-dependent species *A. eminens*.

Polyscias fulva and *Alangium chinense* are typical fast growing gap species which occur in high individual numbers in disturbed places. The trees *Diospyros abyssinica* and *Strychnos usambarensis* are climax species of old, mature forests. The more tall trees of these species can be recorded in a forest, the older is the forest site and the less disturbance it faced in the past.

With the knowledge of these species a rapid assessment of the quality of the studied forest site can be conducted. But not only the occurrence is important but also the numbers of adults or seedlings are indicators for the age and regeneration stage of given forest sites. For a first overview of the quality of a forest the method of recording the mentioned species is enough, but for quantitative statements further data on the population structure should be collected.

5. Population structure

Introduction

Beside a description of the plant communities of Kakamega Forest, we conducted a comparison of the species composition between the different study sites. In particular the population structure of the tree species was analysed. One aim of the present study was to understand the species composition of the 19 studied forest sites due to its developmental history. It was analysed if and in which way the tree structure of Kakamega Forest was influenced by different human activities like selective logging and clear-felling in the past. Due to the large exploitation of the forest inventory several conservation sanctions started in the early 80's. We compared the effectiveness of conservation of two different management regimes, the Kenya Wildlife Service (KWS) and the Forest Department (FD). Since Kakamega Forest is separated in several fragments, we also investigated the influence of fragmentation on the vegetation and the population structure of trees. Additionally the stand structure of different forest sites was compared with each other. Also the horizontal structure of the forest like the progression of mature forest and gaps was analysed.

Methods

Diversity indices

The species diversity of the 19 investigated forest sites was analysed and compared with each other. The most simple method to determine species diversity is to count the number of species in the community (= the species richness) (McIntosh 1967). Species diversity is not only a measure for the number of species, diversity is also expressed in evenness. A community where the relative abundances of the species is more even than a community with the same number of species, but with few dominants and a lot of rare species, is more diverse by a heterogeneity measure. The term heterogeneity is also a measure for diversity and was first applied by Good (1953). But nowadays the term diversity is synonymous to heterogeneity for many ecologists (Hurlbert 1971). Since it is impossible to enumerate all of the species in a natural community (Krebs 1999), several attempts have been undertaken to estimate the community's total richness. None of these methods to estimate the community's total richness were conducted in this study, because the expected species composition and number were covered by the used method and the comparisons between the study sites were emphasised.

Alpha-diversity

The diversity of species in a habitat or collection is the “within-habitat diversity” or α-diversity (Whittaker 1967). Beside the species richness which expresses the number of species in a given community or study site, the Shannon-Wiener function is another measure based on information theory. Here the question is not how many species are present in a habitat, but *how difficult would it be to predict correctly the species of the next individual collected?* (Krebs 1999). With increasing diversity of the habitat it becomes more difficult to predict the species of the next collected individual correctly. Therefore, the more uncertain the prediction becomes the more diverse is the habitat. The uncertainty can be measured by the Shannon-Wiener function:

$$H' = - \Sigma_{\ i} (\log_2 \text{ x } p_i) \qquad p_i = \frac{n_i}{N}$$

H' = Shannon-Wiener index of species diversity

p_i = Proportion of total sample belonging to *i*th species

N = Total number of species

n_i = Individual number of species *i*

A community with only one species has no uncertainty and is $H' = 0$. The value increases with the number of species in the community, observed values in nature are between 1.5 and 3.5 and do not seem to exceed 5.0 (Washington 1984).

Adams & McCune (1979) showed that estimates of H' from field data are usually biased and are only valid for simple random sample from the community which is never the case for data collected in quadrats or transects (Kempton 1979). To overcome this problem the index can be expressed in units of number of species (MacArthur 1965) as:

$$N_1 = e^{H'}$$

where e = 2.71828 (base of natural logs)

H' = Shannon-Wiener function (calculated with base *e* logs)

N_1 = Number of equally common species that would produce the same diversity as H'

N_1 is better understandable to ecologists than H' because units (number of species) are used (Hill 1973). Furthermore Peet (1974) claimed N_1 to be the best heterogeneity measure for the abundance of rare species in a community.

A method to measure evenness (or equitability) is to scale one of the heterogeneity measures relative to its maximal value when each species in the sample is represented by the same number of individuals (Krebs 1999). Evenness (*E)* reaches values between 0 and 1. If $E = 0$ every determined individual belongs to one species. $E = 1$ means that there is an equal distribution of individuals over all species.

$$E = \frac{D}{D_{\max}}$$

E = Evenness
D = Observed index of species diversity
D = Maximum possible index of diversity, given S species and N individuals

Beta-diversity

The species diversity of every studied site was compared with each other. We were interested in the degree of similarity in species composition between different habitats, because this is a base for classification of different communities. Furthermore, decisions can be made in conservation needs how much separate areas differ in their flora and should therefore be conserved (Krebs 1999). Species turnover along a disturbance gradient or along environmental factors can be described with the “between habitat diversity” or β-diversity. The amount of species overlapping between two given habitat samples can be measured by binary similarity coefficients which are based on presence/absence data. A study site, like a tropical rainforest, with a diverse and heterogenous mixture of forest sites with different species compositions, leads to a high β-diversity. The less species two habitat communities have in common, the higher becomes the β-diversity (Magurran 1988). A measure which is independent of sample size and of the number of species in the community (Wolda 1981) is the Sørensen’s coefficient (Sørensen 1948). This coefficient compares the number of species found in two samples and weights matches in species composition heavier than mismatches (Krebs 1999). With increasing similarity in species composition the coefficient’s value increases, $S = 1$ is 100 % similarity.

$$S_S = \frac{a}{2a + b + c}$$

S_S = Sørensen's similariy coefficient

a = Number of species in sample A and sample B (joint occurrences)

b = Number of species in sample B but not in sample A

c = Number of species in sample A but not in sample B

Quantitative vegetation parameters

To get information on the population structure in the different plant communities we recorded the dbh (diameter at breast height, 1.30 m) and the phenology for every tree individual. Trees with large buttresses were measured at height where true stem diameter could be examined. On trees with multiple trunks each trunk was measured separatley and were summed to give the total dbh for one individual. Individuals with dbh of 10 cm and more were defined as trees, below this as saplings. The trees were then separated in different size classes. With this information predictions for the structure of tree species in a given community and the development of the tree populations can be made. The diameter record leads to another important parameter, the basal area (ba) which is the space covered by the tree stems (Mueller-Dombois & Ellenberg 2002).

The formular is: $ba = (\frac{1}{2} d)^2 \times \pi$, where d is the diameter.

The basal area were combined for all species per area by summing the basal areas of individual trees.

Moreover, quantitative analyses of tree stratum in forest communities were conducted on 10 x 10 m quadrats where trees were counted by species in diameter classes consistent with Mueller-Dombois & Ellenberg (2002). Additionally the density or abundance of species can be measured in quadrats, and a commonly used size for the tree layer is 10 x 10 m.

Stand structue

To analyse the stand structure of different forest sites we conducted line-transects. The line-transects were chosen to start where a representative forest structure could be expected. Every 50 m a 5 x 5 m plot was established. The line-transects have different lengths between 500 and 1150 m, because a transect was stopped when hindrances like rivers or streets were encountered. The vegetation heights of these plots were recorded. From the measured heights conclusions can be made about the age and succession stage of these plots along the transect. Thus density and amount of gaps inside the mature forest can be easily recognised. Altogether eight line-transects were carried out, one transect in the northern fragment Kisere and Ikuywa respectively, five in the Buyangu National Reserve and one line-transect in the center of the main forest block.

Statistics

For the descriptive statistics mean values and standard deviation (SD.) are given.

The assumption of normal distribution and homogeneity of the variance of the data was tested using the Kolmogorov-Smirnov test and Levene test, respectively. Differences between groups were tested using Mann-Whitney U-tests for unmatched samples, because data were not distributed normally and could not be transformed. Correlation analyses were done with Pearson correlation test.

The level of significance was determined $\alpha = 0.05$. A value less than $p < 0.05$ is an advice that the differences between the analysed groups or the correlation are significant, a value less than $p < 0.001$ as highly significant. All tests were analysed with SPSS® for Windows 11.0.

Results

The plant species compositions of the relevés of the 19 study sites were analysed and are presented in the following. Population structure analyses of tree species could be done for 18 study sites. For an easier presentation the names of the study sites were shortenend. Table 8 presents the study sites with their abbreviation, their location in the forest and their affiliation to the four defined vegetation groups of the plant communities chapter.

Table 8: 19 study sites. Given are abbreviation and fragmentation, management status and vegetation groups. Colours indicate the location and the management status of the study site: yellow-brown = fragment, plum = main forest; yellow-green = FD, blue-green = KWS; red = planted forest, green = northern forests, yellow = highly disturbed areas, blue = middle and southern forests.

Study site	Abbreviation	Fragmentation	Management	Groups
Malava	Ma	🟧	🟩	🟥
Kisere	Ki	🟧	🟦	🟩
Colobus	Co	🟪	🟦	🟩
Camp forest	Ca	🟪	🟦	🟨
Buyangu Hill	Bh	🟪	🟦	🟩
Buyangu-top	Bt	🟪	🟦	🟩
Buyangu-secondary	Bs	🟪	🟦	🟨
Isiukhu	Isi	🟪	🟦	🟨
Ghostisland	Gh	🟪	🟦	🟩
Salazar	Sa	🟪	🟦	🟦
Busambuli	Bu	🟪	🟦	🟦
Shiamololi	Shi	🟪	🟦	🟦
Vihiga	Vi	🟧	🟩	🟨
Isecheno	Is	🟪	🟩	🟦
Ileho	Ie	🟧	🟩	🟥
Ikuywa	Ik	🟧	🟩	🟦
Yala	Ya	🟧	🟩	🟦
Kibiri	Kb	🟧	🟩	🟥
Kaimosi	Ka	🟧	🟩	🟥

Species richness

The mean numbers of vascular plant species of every studied site was compared with each other (fig. 58). High species numbers were recorded in the more disturbed forest sites. In average 51 species could be found in every studied site. The lowest species numbers were recorded at the forest sites of the Buyangu National Reserve followed by the middle and southern parts. The Malava and Kaimosi fragments have lower species numbers than the *Maesopsis eminii* and *Bischoffia javanica* plantations of Ileho and Kibiri. For the next indices abundance values of all species of the investigated relevées were incorporated in the calculations. For this we used the total coverage in percent of a species in a given study site.

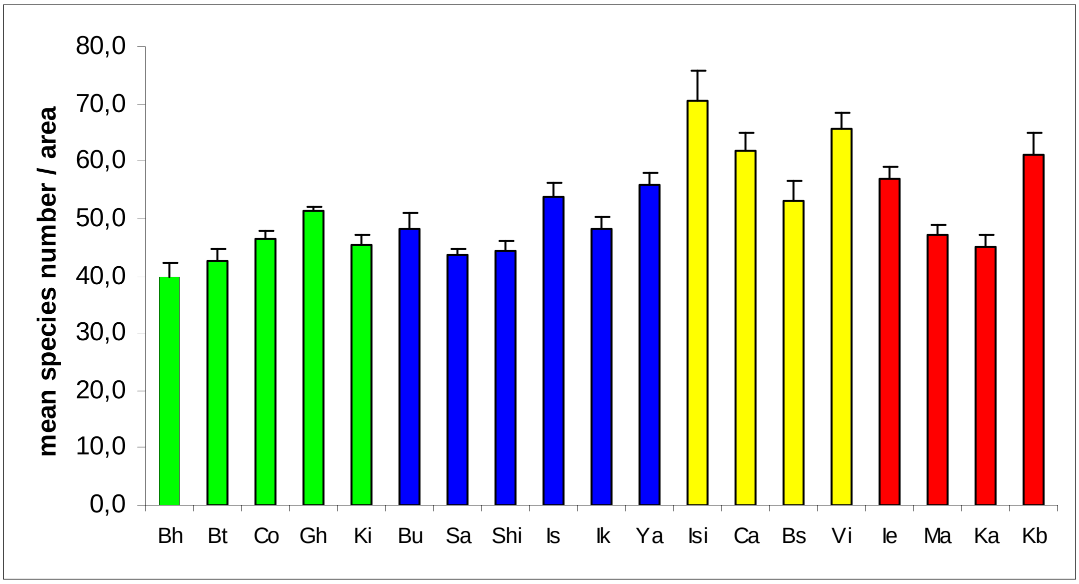


Fig. 58: Plant species numbers per area – green columns: study areas of the northern parts of the forest, blue columns: areas of the middle and southern part, yellow columns: highly disturbed study areas, red columns: areas where planted trees and plantations occur. All given values are mean values + SD.

Shannon - Wiener – diversity

Species "within-habitat diversity" was measured with the Shannon-Wiener function and evenness. Table 9 presents the analysed values for the 19 study sites. High diversity was recorded in the disturbed forest sites. The higher the disturbance and the younger a forest site is, the more diverse is the habitat. Middle-aged forest sites like the southern areas of Isecheno, Ikuywa and Yala have lower diversity than the forest sites which consist of young secondary forest. The planted forest sites have similar values like the southern forest parts. In disturbed forest sites pioneer and climax species occur together with some bushland and grassland species. This mixture of several species of different habitat preferences leads to high diversity values. Undisturbed forest sites of the northern and middle part of the forest have the lowest measured diversity. A rather equal distribution of species in a given area was measured in the planted sites of Ileho, Kibiri and Malava as well as in disturbed forest sites near the Isiukhu river, at the Campsite and in Vihiga. The evenness values are higher than in more undisturbed forests of Yala, Colobus or Kisere. In these forests more dominant species occur beside only a few rare species. The more equal a distribution of species in a given habitat and the higher an evenness value, the more species with similar abundance occur. Thus, the older secondary forest sites have lower evenness values due to the occurrence of some dominant species, like trees in the upper canopy, and a few species in low coverages or abundances in the understorey vegetation.

Table 9: Shannon-Wiener index and Evenness.

area	H s	Eveness
Ileho	3,69	0,80
Malava	3,80	0,80
Kaimosi	3,70	0,75
Kibiri	3,73	0,78
Isecheno	3,84	0,78
Ikuywa	3,63	0,75
Yala	3,49	0,70
Isiukhu	4,40	0,86
Campforest	4,02	0,79
Buyangu-sec.	3,45	0,72
Vihiga	3,76	0,78
Buyangu	3,05	0,66
Buyangu-top	2,98	0,66
Colobus	3,31	0,69
Ghostisland	3,40	0,75
Kisere	3,44	0,72
Busambuli	3,55	0,75
Salazar	3,02	0,67
Shiamololi	3,42	0,75

The Shannon-Wiener index can also be expressed in units of species number. In the following diagram the measured values were applied against a disturbance gradient (fig. 59). The more disturbed a study site, the higher values shows the diversity index. Human disturbances like selective logging or afforestation of cleared forest parts seem to have an influence on the plant species diversity. After disturbance a habitat is more heterogenous because of small, sunny gaps beside dense forest, different microclimate conditions in a near distance, etc. These heterogenous environments offer diverse possibilities for a high amount of different species. Thus, the diversity increases.

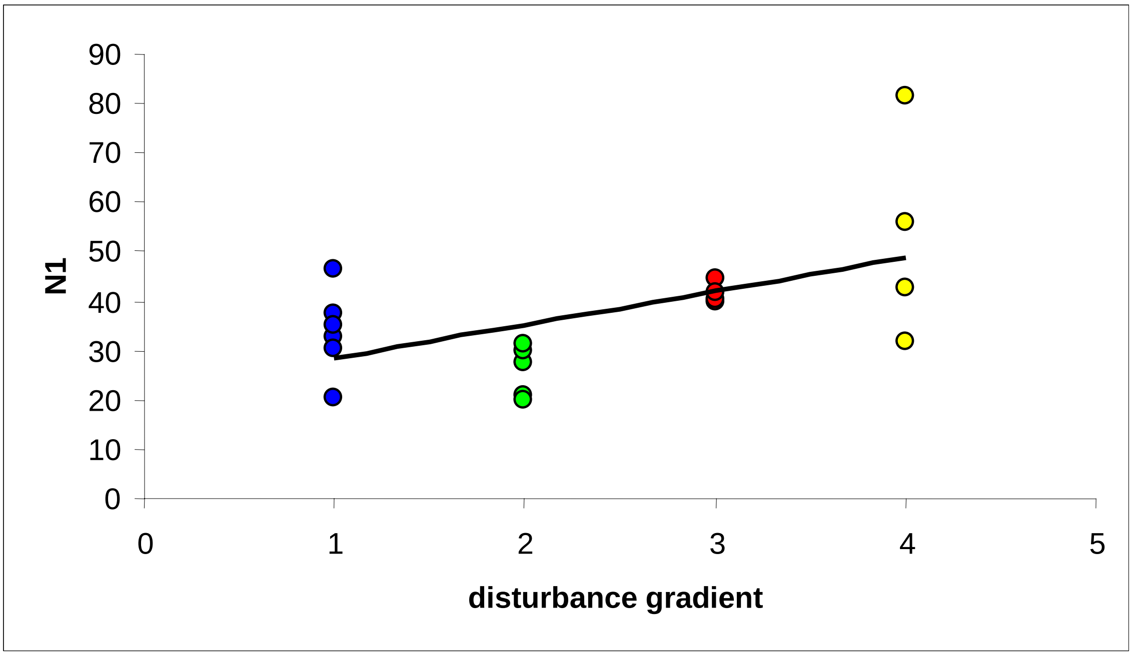
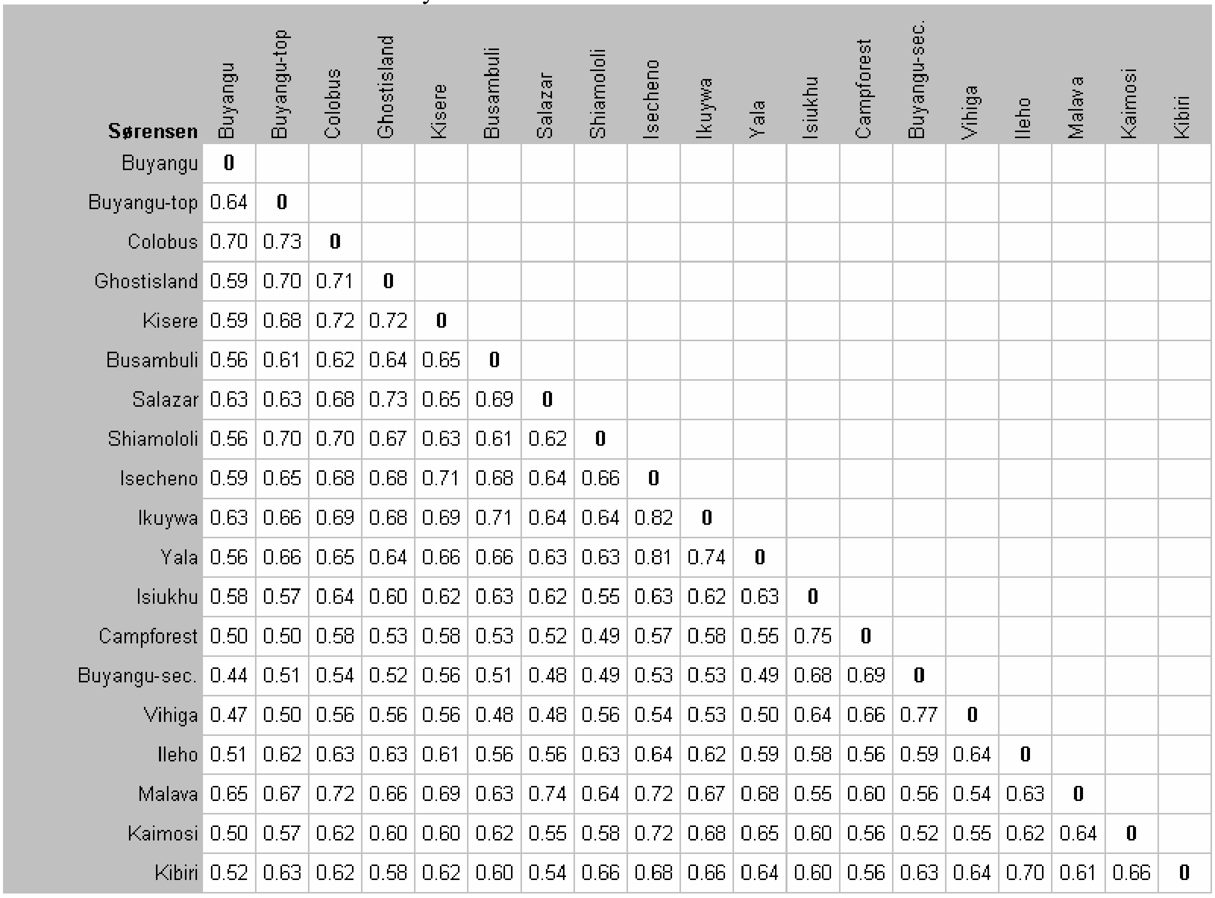


Fig. 59: Shannon-Wiener indices in the 19 study areas correlated with a disturbance gradient. (Pearson, N = 19, $p < 0.05$, $r = 0.550$).

Sørensen – index

The "between-habitat" or β-diversity was calculated between each of the 19 study sites. High similarity in the species composition could be recorded between study sites in direct neighbourhood like Buyangu-top and Colobus (73 %) or Salazar and Busambuli (69 %) or between forest sites of similar age and succession stage like Vihiga and Buyangu secondary (77 %). A high β-diversity could be observed between forest sites of different succession stages e.g. between Camp forest and Buyangu Hill (50 %). The higher the values of the Sørensen-indices the more similar are the investigated forest sites. Accordingly, low values indicate high diversity. If all similarity-indices of species composition between the 19 study sites are regarded it can be seen that most of the indices are below 80 % similarity. This indicates that the forest sites are not of total similarity. Every studied forest site has its unique species composition which is not in fact comparable with other forest sites.

Table 10: Sørensen-indices for 19 study sites.



Sørensen	Buyangu	Buyangu-top	Colobus	Ghostisland	Kisere	Busambuli	Salazar	Shiamololi	Isecheno	Ikuywa	Yala	Isiukhu	Campforest	Buyangu-sec.	Vihiga	Ileho	Malava	Kaimosi	Kibiri
Buyangu	**0**																		
Buyangu-top	0.64	**0**																	
Colobus	0.70	0.73	**0**																
Ghostisland	0.59	0.70	0.71	**0**															
Kisere	0.59	0.68	0.72	0.72	**0**														
Busambuli	0.56	0.61	0.62	0.64	0.65	**0**													
Salazar	0.63	0.63	0.68	0.73	0.65	0.69	**0**												
Shiamololi	0.56	0.70	0.70	0.67	0.63	0.61	0.62	**0**											
Isecheno	0.59	0.65	0.68	0.68	0.71	0.68	0.64	0.66	**0**										
Ikuywa	0.63	0.66	0.69	0.68	0.69	0.71	0.64	0.64	0.82	**0**									
Yala	0.56	0.66	0.65	0.64	0.66	0.66	0.63	0.63	0.81	0.74	**0**								
Isiukhu	0.58	0.57	0.64	0.60	0.62	0.63	0.62	0.55	0.63	0.62	0.63	**0**							
Campforest	0.50	0.50	0.58	0.53	0.58	0.53	0.52	0.49	0.57	0.58	0.55	0.75	**0**						
Buyangu-sec.	0.44	0.51	0.54	0.52	0.56	0.51	0.48	0.49	0.53	0.53	0.49	0.68	0.69	**0**					
Vihiga	0.47	0.50	0.56	0.56	0.56	0.48	0.48	0.56	0.54	0.53	0.50	0.64	0.66	0.77	**0**				
Ileho	0.51	0.62	0.63	0.63	0.61	0.56	0.56	0.63	0.64	0.62	0.59	0.58	0.56	0.59	0.64	**0**			
Malava	0.65	0.67	0.72	0.66	0.69	0.63	0.74	0.64	0.72	0.67	0.68	0.55	0.60	0.56	0.54	0.63	**0**		
Kaimosi	0.50	0.57	0.62	0.60	0.60	0.62	0.55	0.58	0.72	0.68	0.65	0.60	0.56	0.52	0.55	0.62	0.64	**0**	
Kibiri	0.52	0.63	0.62	0.58	0.62	0.60	0.54	0.66	0.68	0.66	0.64	0.60	0.56	0.63	0.64	0.70	0.61	0.66	**0**

Trees

Tree individuals were measured separately in every relevée. In total about 112 tree species were recorded on 2 ha in Kakamega Forest. That number is quite normal for tropical rainforests in Africa (Richards 1996). On the base of the tree species and their abundance the following comparisons were made:

Figure 60 shows the mean individual numbers per plot and area.

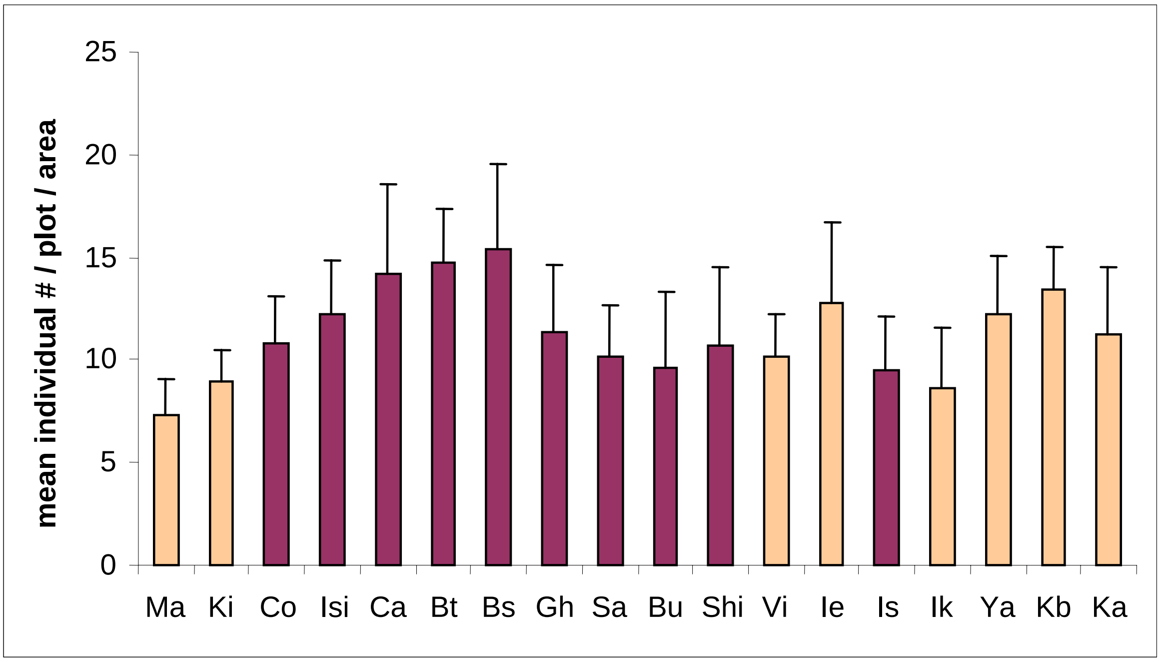


Fig. 60: Mean inidivual numbers of 18 study sites. Given are mean values + SD.

The yellow-brown columns of fig. 60 are tree abundances of the fragments. Although some forest sites are situated in reserves, like the Buyangu National Reserve in the north, they do not consist of higher species numbers. Instead, higher species numbers occur in forest sites with high degree of disturbances like Camp forest, Kaimosi fragment or Buyangu-secondary. But forest sites of old secondary succession stages like Yala have a similar species richness like disturbed forest sites of Isiukhu. High species numbers are therefore not strictly correlated with high degree of disturbance or with draconic conservation strategies. A comparison between tree species numbers of the main forest block and the fragments is shown in fig. 61. This analysis shows a highly significant difference between the mean species number of the main forest block and the fragments. Therefore, fragmentation of the forest seems to have an effect on the species number resulting in lower species numbers.

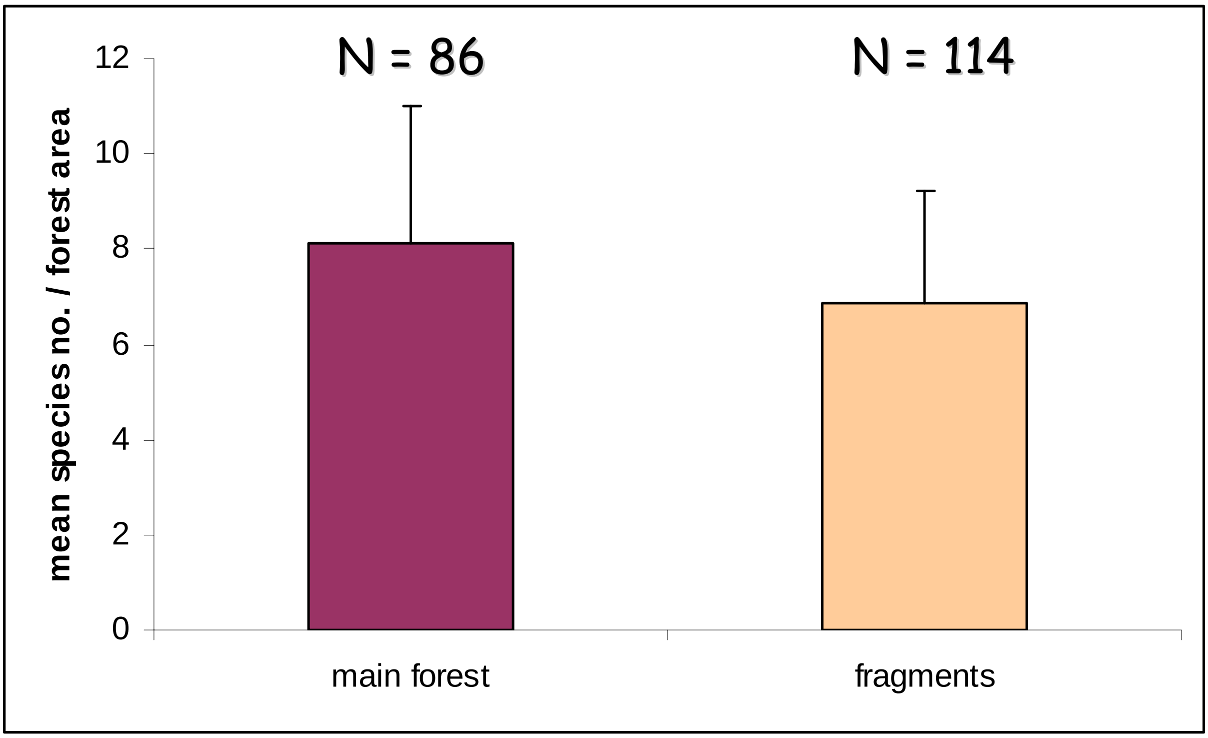


Fig. 61: Mean species number of trees of the main forest block and the fragments. (Mann-Whitney U-test, main forest block, N = 86 relevés, fragments = 114 relevés, U = 3618.00, p = 0.001). Given are mean values + SD.

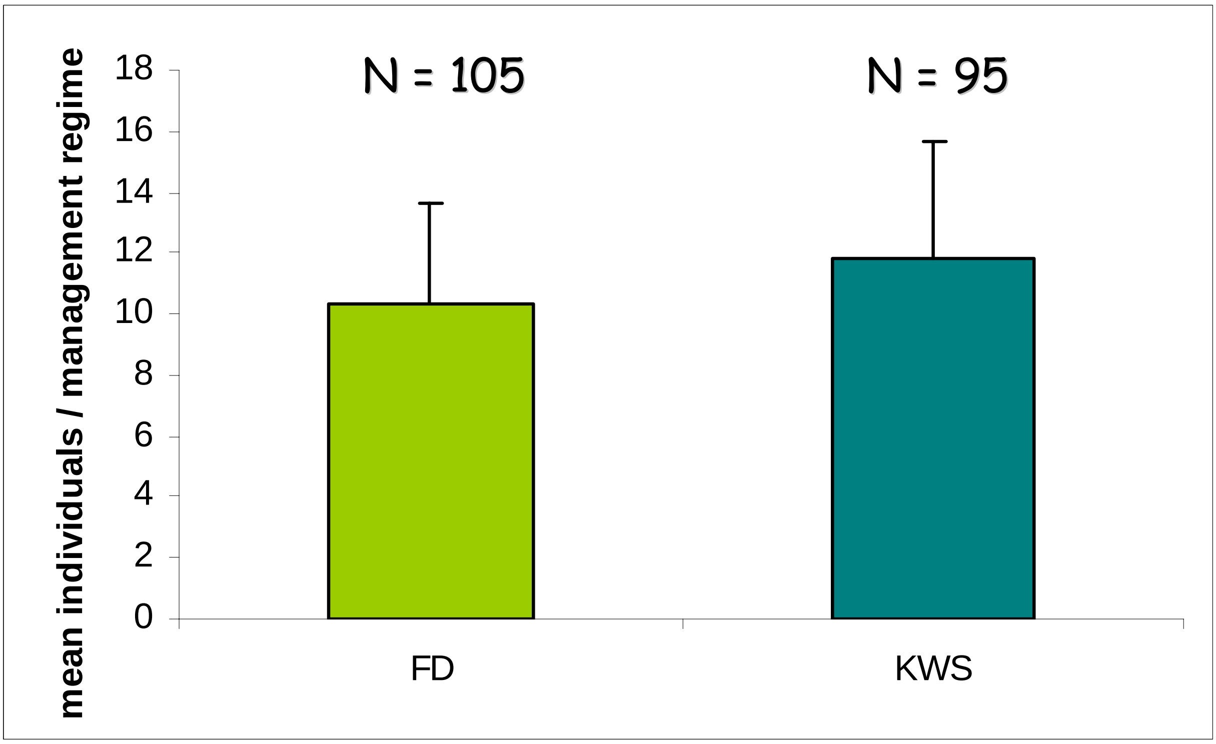


Fig. 62: Mean species number of trees of relevés inside the FD-regime and under the controll of KWS. (Mann-Whitney U-test; FD, N = 105 relevés, KWS, N = 95 relevés; U = 3700.00 p = 0.001). Given are mean values + SD.

Species number is lower in the forest sites under the regime of the FD (Forest Department) than in the study areas of the KWS (Kenya Wildlife Service) (fig. 62). Therefore, the different management strategies seem to have an influence on the species number. A better protection of the forest like it is conducted in the National Reserves of the KWS leads to higher species numbers. However, data must be interpreted carefully, because forest sites of highly disturbed places like the Camp forest in the Buyangu National Reserve with its high species number are included in the analysis. A further comparison was done between forest sites of lower and higher protection. Forest sites of the Nature Reserves of FD were categorised as higher protected areas like the forest sites of KWS. Only forest sites under the control of FD but outside the Reserves were included in the group of low protected forest sites. Figure 61 shows this comparison.

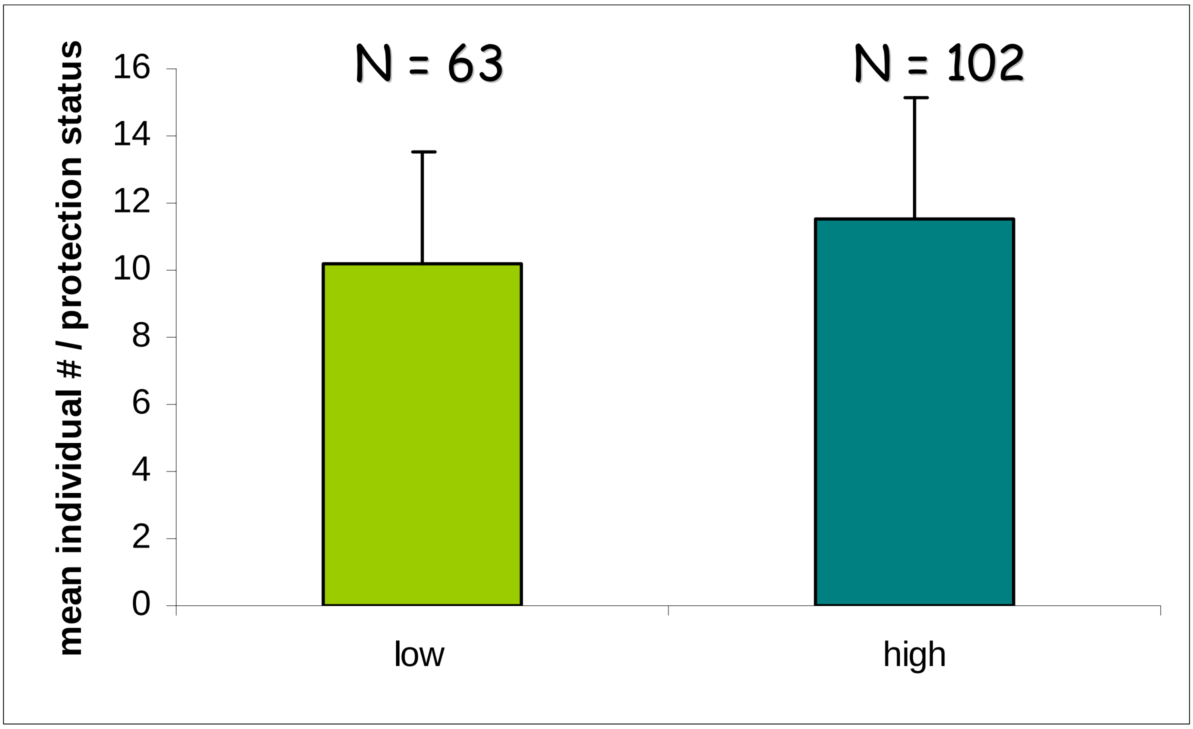


Fig. 63: Mean species number of different protected areas. (Mann-Whitney U-test; Low protection, N = 63 relevés, high protection, N = 102 relevés; U = 3048.00, p = 0.001). Given are mean values + SD.

Forest sites under lower protection contain lower species numbers than forest sites of higher protection. This could be an advice that stricter management rules lead to higher species numbers and therefore to a higher diversity, which is an aim of conservation management.

The diameter at breast height (dbh) was measured for every tree individual in every relevée. Very high dbh could be recorded in fragments as well as in more or less undisturbed forest sites. Also forest sites of older succession stages like Yala and Kisere contain larger tree individuals than forest sites of younger ages like the Camp forest. The measure dbh is a quantitative indicator for ages of forest sites. The more large trees a relevée contains the older the trees are and the more undisturbed is a forest site (fig. 64). In forest sites of older ages (Kisere) or where selective logging took place (Ikuywa) the average tree dbh is higher than in younger stages. The forest site with the biggest tree individuals is Shiamololi. Here the tallest trees with the highest circumferences of Kakamega Forest could be found. This is not a result of a low degree of disturbances, instead the tree species *Aningeria altissima* which was not selectively logged in the past is highly abundant there. The smallest trees and therefore the youngest succession stage could be observed near Buyangu Hill.

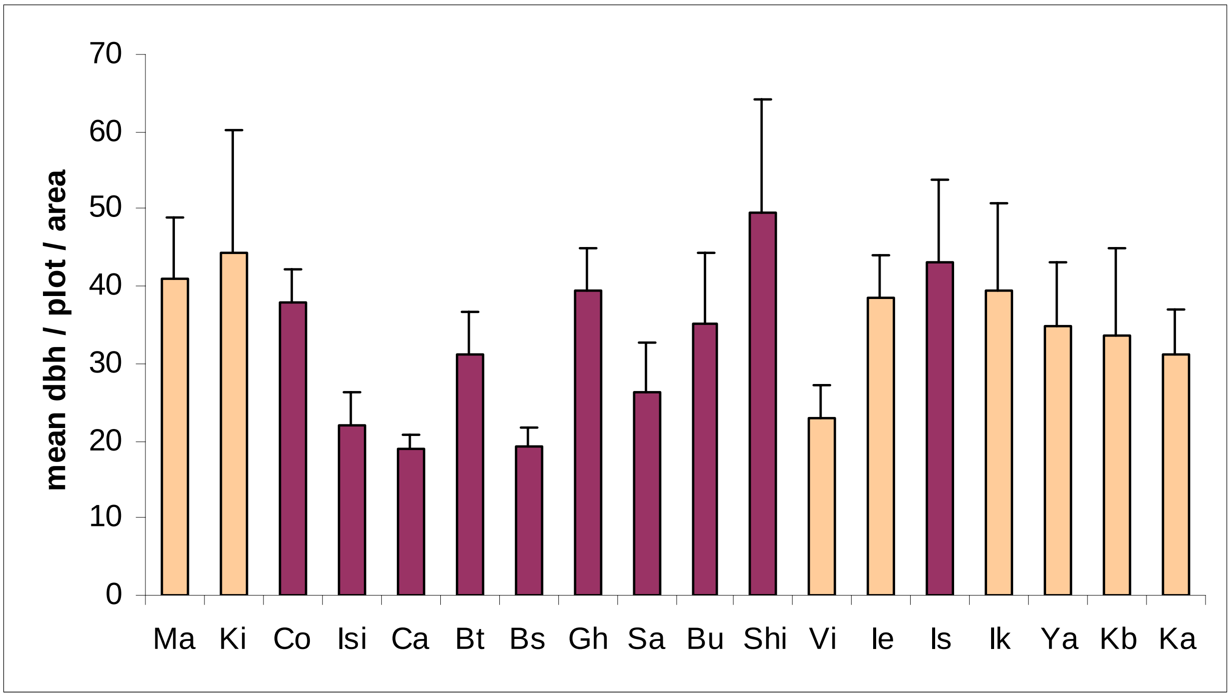


Fig. 64: Mean diameter at breast height (dbh) of tree individuals of the main forest block and its fragments. Given are mean values and +SD.

Figure 65 shows the number of stems per 500 m² of the 18 study sites. The highest abundance of tree individuals could be recorded in the main forest block in disturbed forest sites. Although Yala is defined as old secondary forest a high amount of stems could also be found there. The effect of disturbance on the abundance of tree individuals leads to a similar pattern like in the former analysis of dbh of the different study sites. The higher the degree of disturbance, the more stems could be recorded. The relation between high stem number and low dbh is obviously due to the fact that many small tree individuals can share the same room as few bigger individuals.

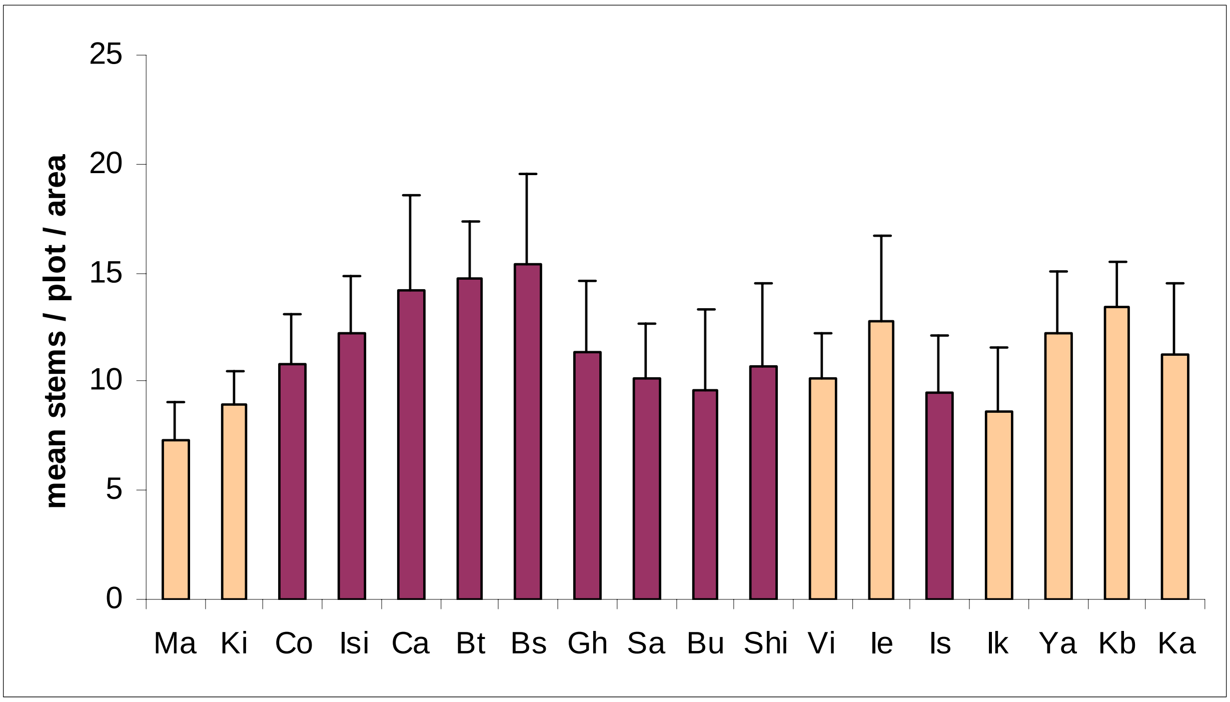


Fig. 65: Stem density (mean stems per plot per area) of 18 study sites. Given are mean values and +SD.

The degree of disturbance has an influence on the tree individuals in the different forest sites. The more disturbance took place in the past, the smaller and younger are the trees in a given area. A high stem density is an evidence for former disturbance whereas few trees with a high dbh are an indicator for more or less undisturbed forest sites. Even in Nature Reserves like in the Buyangu National Reserve human disturbance is still visible, e.g. around the campsite. But further conservation strategies will admit further regeneration of these forest sites. Obviously most parts of Kakamega Forest contain disturbed forest sites and tall, old trees are rare, because they were selectively logged in the past.

The basal area of the trees of every study site was compared with each other (see fig. 66). Lowest basal area can be recorded in the disturbed forest sites, e.g. around the Camp site or near Buyangu Hill. The forest sites of Salazar and the replanted sites of the fragments Kaimosi, Malava as well as Ileho and Kibiri have lower basal areas than forest sites of the middle and southern parts. Except for Shiamololi the forest sites with the lowest degree of disturbance, the forest in the Kisere fragment, has the highest basal area. The higher the basal area the more bigger trees are present in the relevés. Higher basal area is therefore a possible evidence for a low disturbance degree.

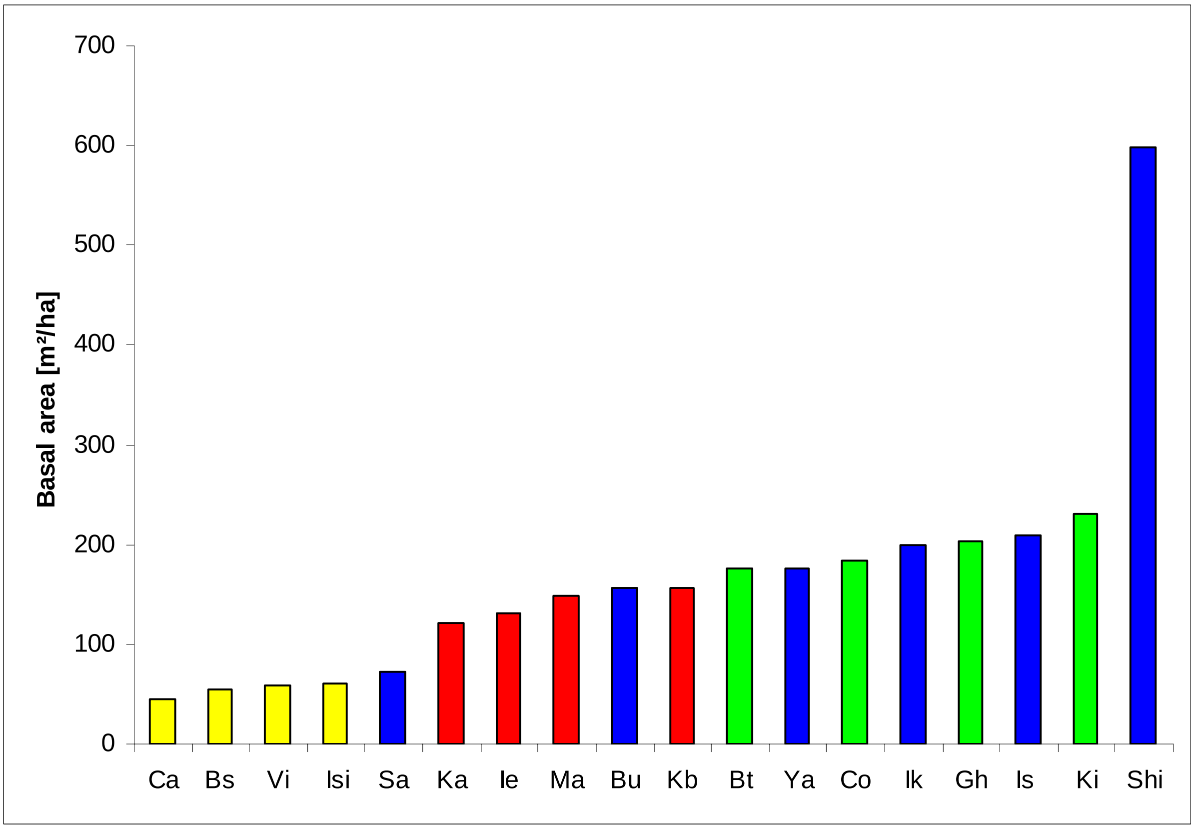


Fig. 66: Basal area (m² per ha) of 18 study sites.

Thus, differences in the degree of disturbance in the past can be analysed with the amount of basal area of a given area. A special case is the forest site in Shiamololi, although highly disturbed (see above) the biggest trees were recorded here.

The measured tree individuals were divided in dbh-size-classes to analyse the population structure. Forest sites were categorised into the four groups: forests of northern parts, middle and southern parts, disturbed and replanted parts like in figure 66.

In every of the four groups there were larger numbers of trees in the smaller dbh size classes with decreasing numbers as the dbh size classes increase (fig. 67 – 70). But closer examination revealed differences in the number of stems in the different size ranges. The northern forest sites have fewer tree stems in the size range between 21 and 40 cm and increasing numbers of stems again in the size range between 41 and 60 cm (fig. 67). Trees with dbh over 85 cm are very rare. Forest sites of the middle and southern area have the highest numbers of stems in the size class between 11 and 16 cm and the size class between 16 and 20 cm. Here the number of stems was higher in the larger size classes than in the same size classes of the northern forest sites (fig. 68).

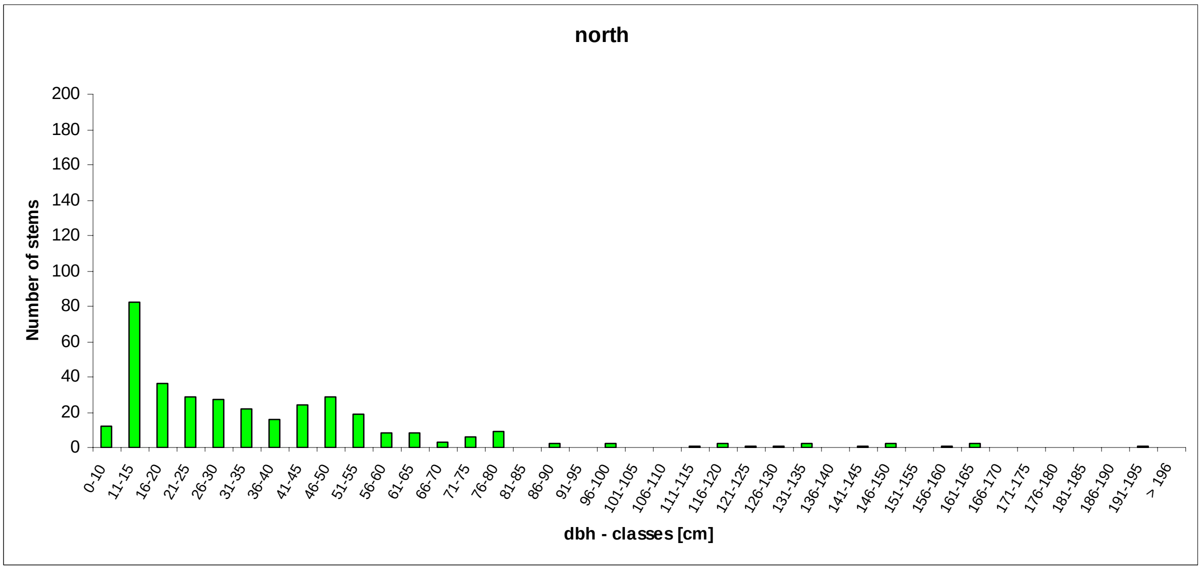


Fig. 67: Size distribution of tree individuals of the northern study sites.

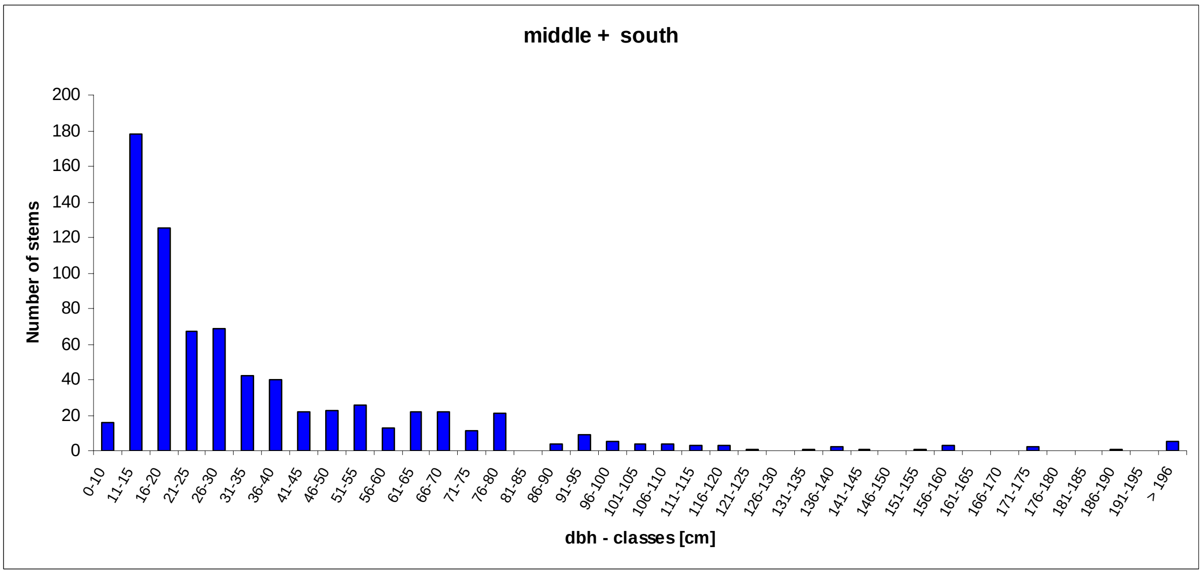


Fig. 68: Size distribution of tree individuals of the middle and southern study sites.

As expected mid-range and large size classes could not be recorded in the disturbed forest sites (fig. 69).The forest sites are in young succession stages and tall, big trees could not delevope in this short time. Trees in the replanted forest sites show wider size distribution than those of the disturbed sites, but larger size classes are also missing (fig. 70). The only forest area with high number of stems in the mid-range dbh size-classes is the northern forest area including the Buyangu National Reserve under the control of the KWS.

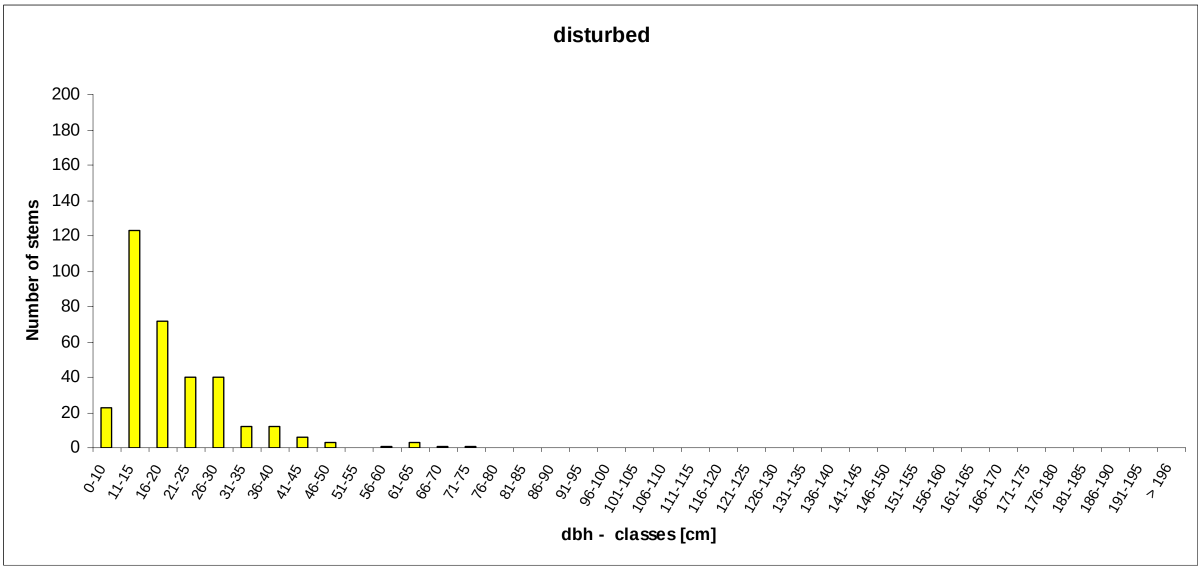


Fig. 69: Size distribution of tree individuals of the heavily disturbed forest sites.

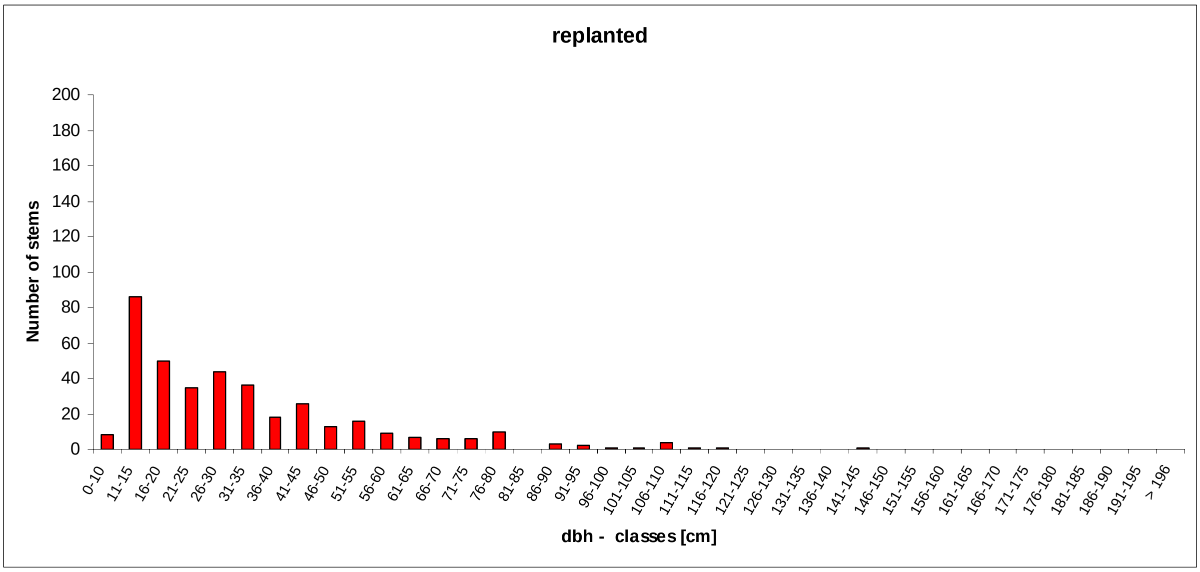


Fig. 70: Size distribution of tree individuals of replanted forest sites.

Horizontal forest structure

The progression of different vegetation heights and gaps was analysed along line-transects in eight forest sites. The next figures show the measured heights of vegetation of the 5 x 5 m plots which were done every 50 m. The highest vegetation could be recorded in the northern fragment Kisere, but the forest is heterogenous. Several gaps and younger succession stages disrupt the mature forest. This is an evidence that the near-primary forest in Kisere is under pressure and human disturbances, maybe through illegal selective logging, take place (fig. 71).

Fig. 71: Vegetation heights along the line-transect in Kisere.

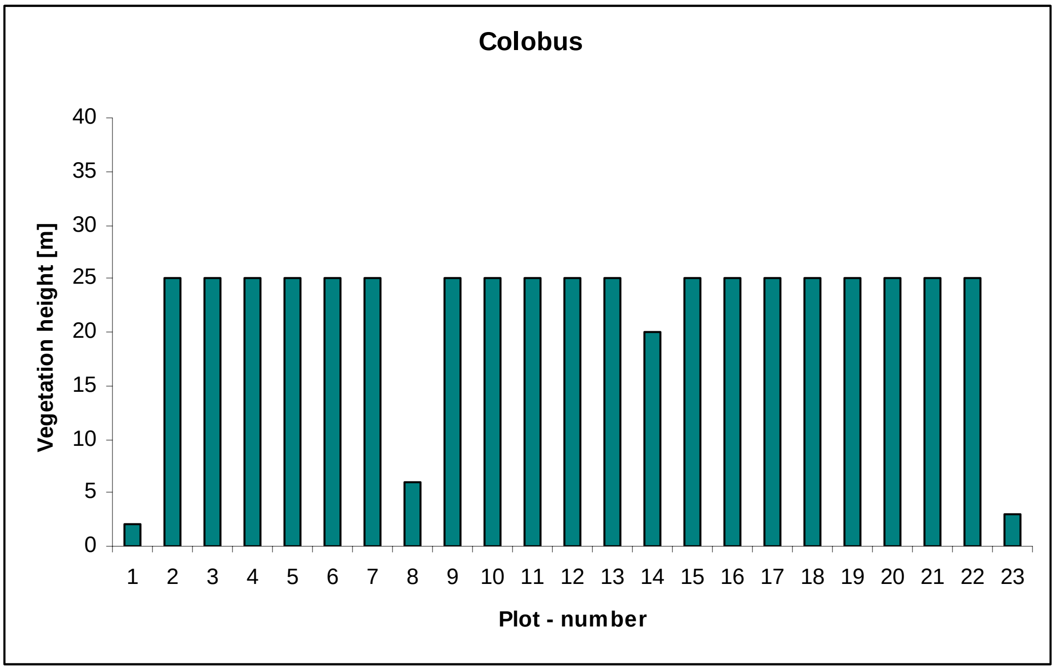


Fig. 72: Vegetation heights along the line-transect in Colobus.

Colobus has a nearly continuous forest structure (fig. 72). The line-transect was done across the whole forest lappet of the northern Buyangu National Reserve here called Colobus area. Low vegetation heights of the end and beginning of the transect are due to the young succesion around and are not gaps inside the forest. Gaps like in Bukhaywa (fig. 75) or Salazar (fig. 76) are rare. The average vegetation height is about 25 m, which is an indicator for middle-aged secondary forest. The vegetation on the slope of Buyangu Hill is very heterogenous (fig. 73). At the beginning of the transect young succession forest occurs. Towards the top of the hill the trees get taller and older and therefore the vegetation is higher. Although the forest is a mosaic of different vegetation heights gaps are missing along the transect.

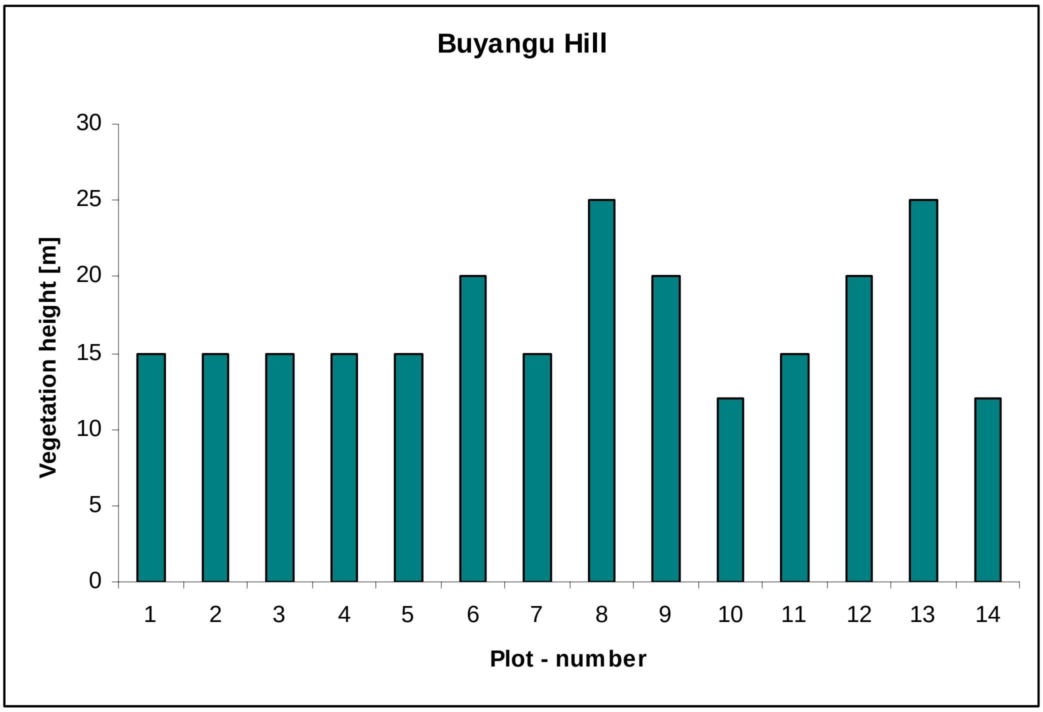


Fig. 73: Vegetation heights along the line-transect in Buyangu Hill.

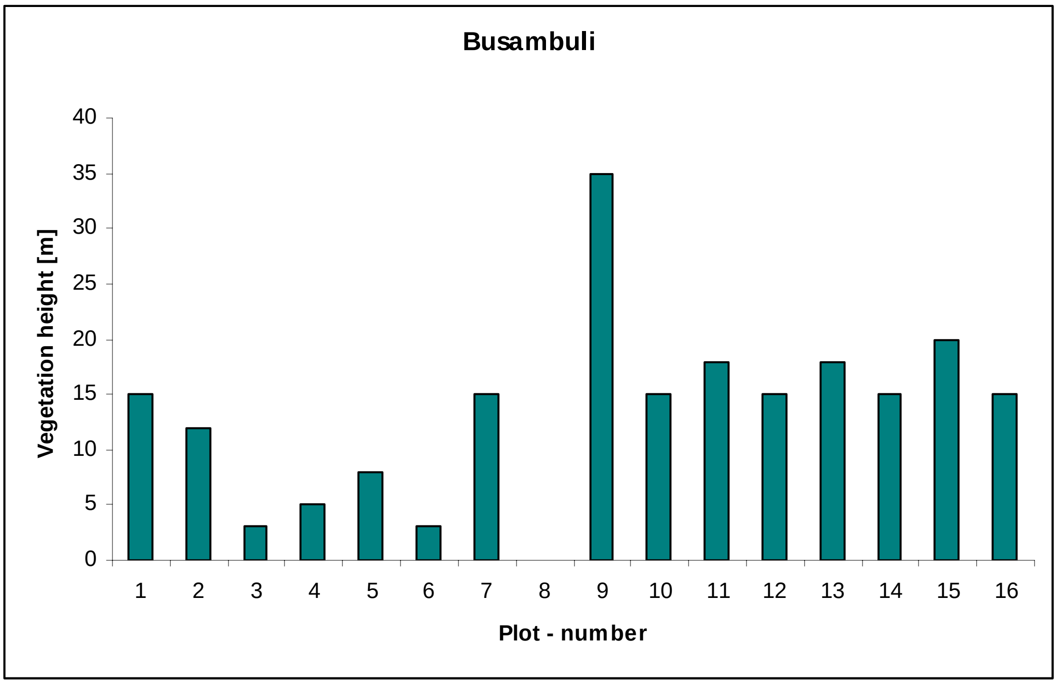


Fig. 74: Vegetation heights along the line-transect in Busambuli.

Along the transect of Busambuli several gaps or very young secondary forest sites can be observed. The overall vegetation height is very low and only few taller trees can be recorded like in plot no. 9 (fig. 74).

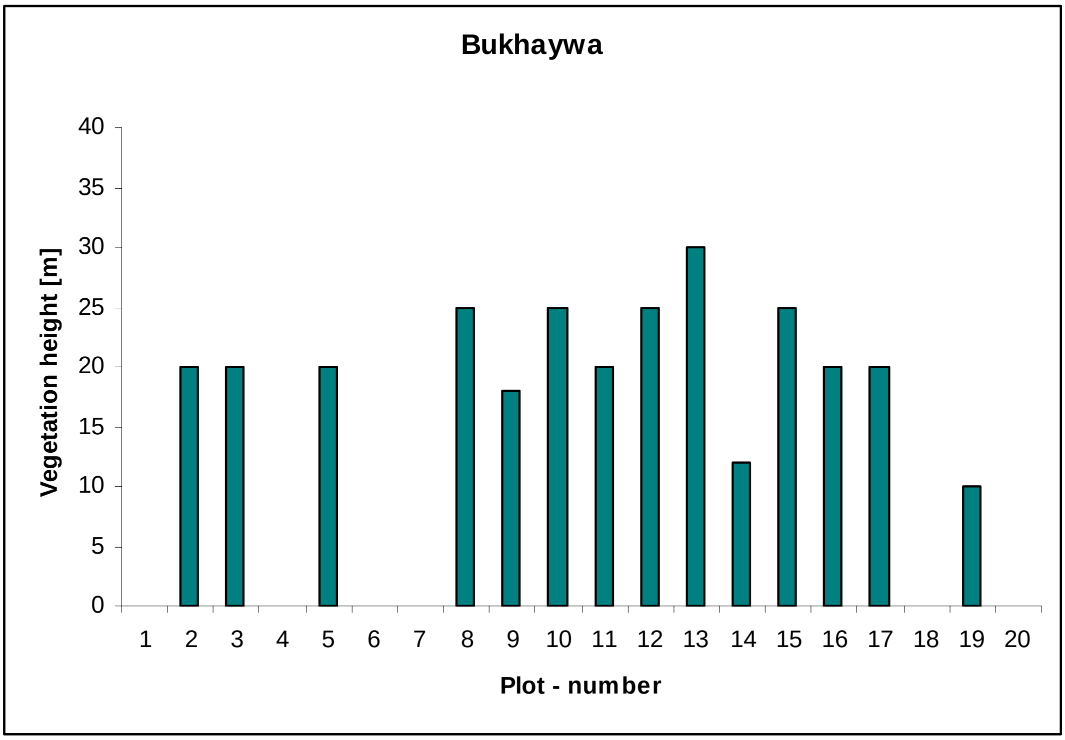


Fig. 75: Vegetation heights along the line-transect in Bukhaywa.

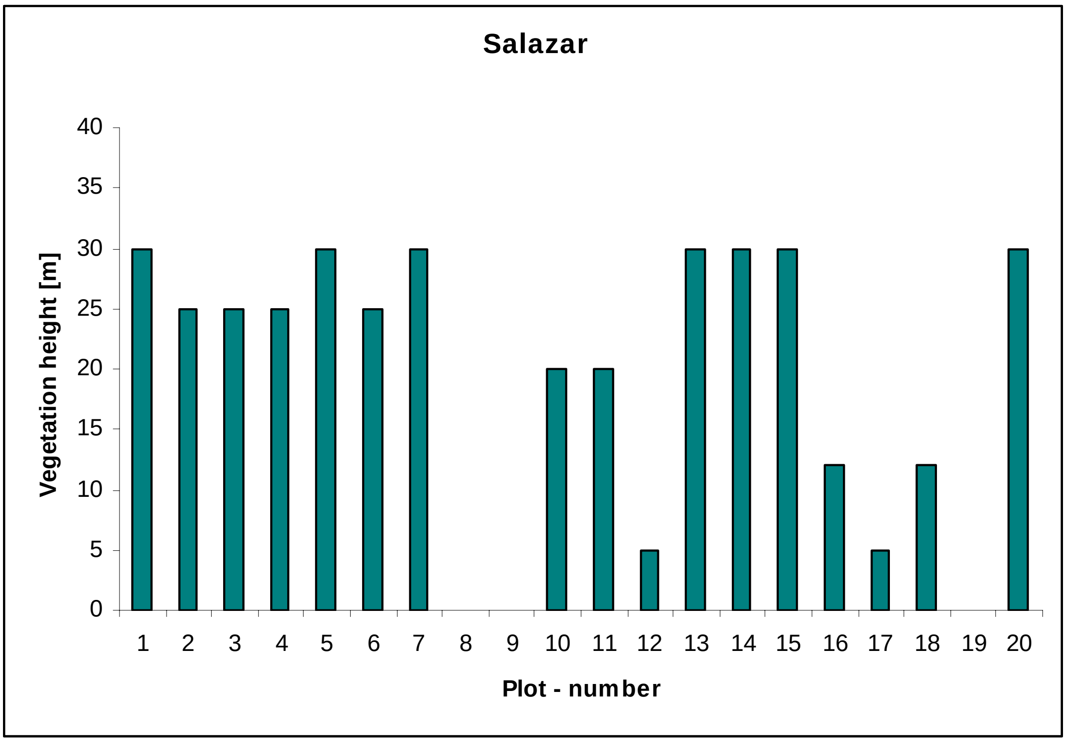


Fig. 76: Vegetation heights along the line-transect in Salazar.

In Bukhaywa a middle-aged secondary forest occurs, but the forest is disrupted by several gaps (fig. 75). The heterogenous forest structure could be a result of selective logging. The occurrence of some gaps inside a mature forest is natural, but such a great amount of holes inside the vegetation is an evidence for human disturbance. The same pattern of gaps beside mature forest can be observed in Salazar (fig. 76). But in the first half of the transect the forest is homogenous which is an indicator for a quite good mature forest.

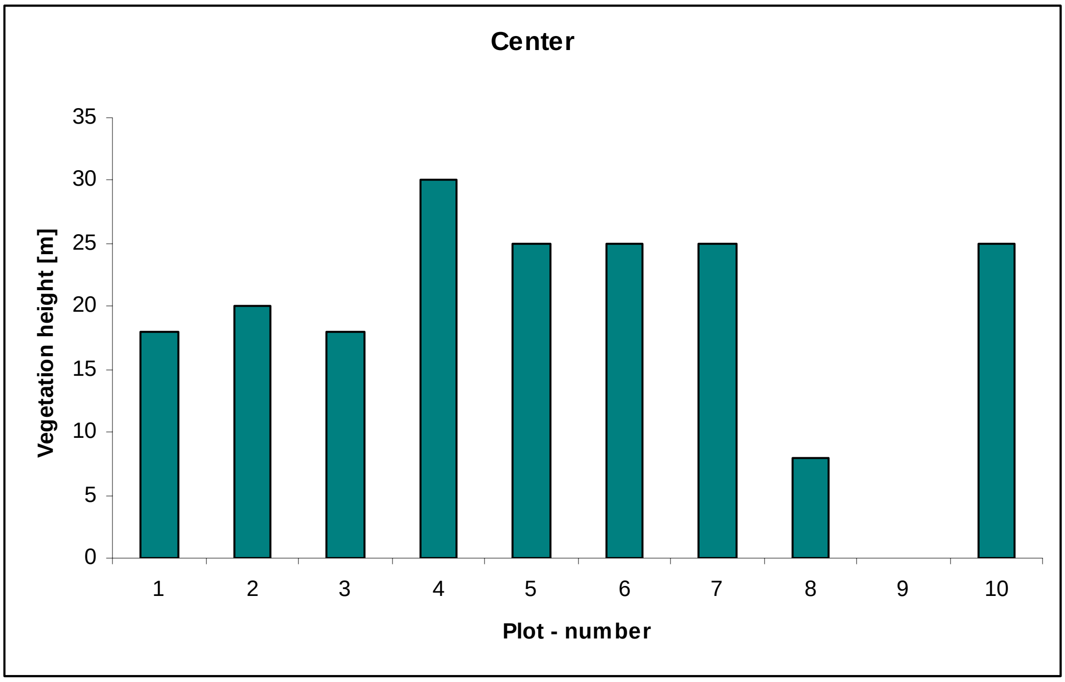


Fig. 77: Vegetation heights along the line-transect in Center.

To analyse the forest structure in the middle of the main forest block, a small transect was laid out in the center (fig. 77). Even in the heart of the forest indicators for human disturbances could be recorded. The overall vegetation is about 20 to 25 m what is typical for middle-aged forest sites. But these quantitative better forest sites alternate with young succession stages and gaps. Due to the distance to the edge of the forest where a high degree of human disturbance is typical, a near-primary forest was expected inside of the main forest block, but obviously activities like selective logging happened also there.

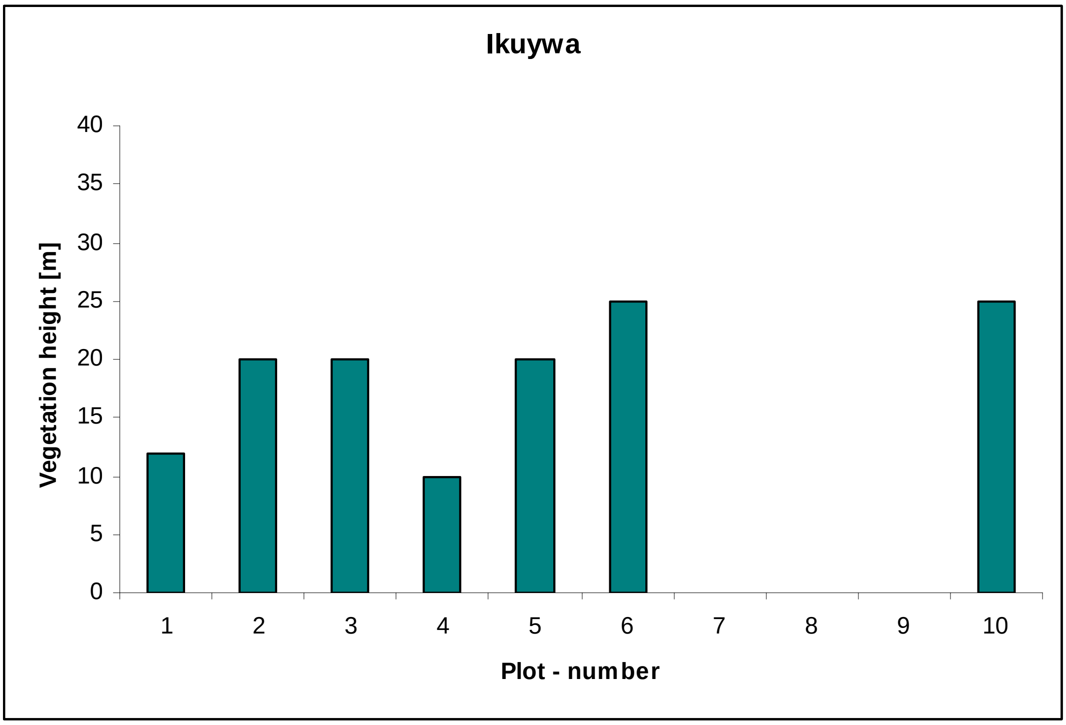


Fig. 78: Vegetation heights along the line-transect in Ikuywa.

In the southern fragment Ikuywa several gaps were recorded along the transects, the vegetation is very low and only few tall trees were measured (fig. 78). This forest area is highly disturbed and a heterogenous pattern of different succession stages can be observed. Therefore, the quality of the forest is not very good.

Except for the forest of Colobus all areas show a mosaic pattern of different succession stages side-by-side. The high amount of gaps or young secondary forest are indications for human disturbances in the past. Along the line-transect the plots were laid out every 50 m, which is a random selection. If the distance between the plots was smaller, e.g. about 20 m, probably more gaps would have been recorded. The more gaps or low vegetation heights along the line-transects were observed the higher the disturbance was in the past. Most of the gaps were originated from selective logging and rarely after a tree-fall. The overview of the eight forest areas shows that Kakamega Forest consists mainly of highly disturbed forest sites.

6. Population densities of three common tree species

Introduction

In North America ecological tree analysis techniques arose from timber survey methods. In this inventory work enumeration by species within diameter classes is often done by transects. The sampling of trees by species in relation to a given strip-width and strip-length allows calculation of the density of species by a unit area (Mueller-Dombois & Ellenberg 2002). Stem density can be determined by measuring the distance between tree individuals or between sampling points and individuals. Therefore, measurement of distances can be used to analyse tree species density (Mueller-Dombois & Ellenberg 2002). The Wisconsin Plant Ecology Laboratory (WPEL) developed the concept of mean distance as a measure of density. Plotless sample techniques were developed based on the idea that the number of trees per area (density) can be calculated from the average distance between the trees. This method of plotless sampling is quicker than the quadrat methods and is applied for analysing the distribution of trees (Hopkins 1954). Several distance methods were proposed in literature and are applied in different vegetation and population studies. For measuring density the distances between random points and closest individuals (point to plant) or the distances between nearest neighbour (plant to plant) can be used (Cottham & Curtis 1956). To investigate the population density of three common tree species in Kakamega Forest we chose the variable-area transect method. After selecting a random point the distance from that point to the *n*th organism (point to plant) was measured.

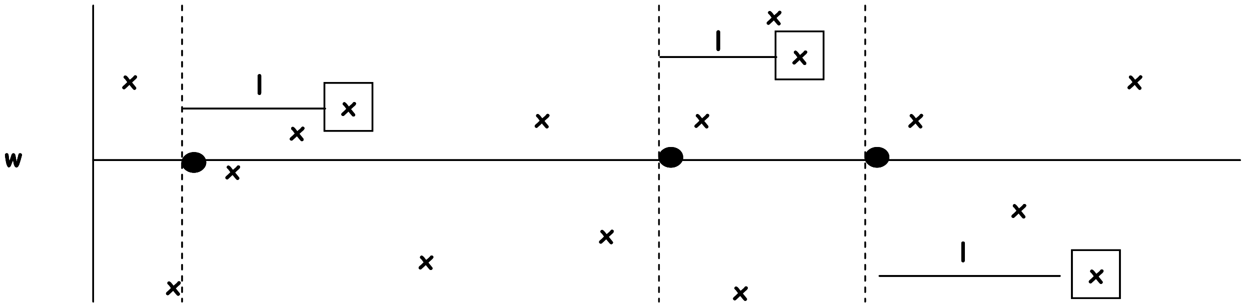
An important question concerns the pattern of individuals in space. Therefore, the spatial distribution of tree species in different areas of Kakamega Forest is of interest. Based on the knowledge of the spatial pattern of a focal tree species, predictions about the population structure in space can be made. The spatial pattern can be random, uniform or clumped. A uniform pattern of a population can imply an undisturbed environment, whereas a clumped distribution can be an evidence of past selective logging of the given tree species.

Methods

The variable-area transect method is a combination of distance and quadrat methods (Krebs 1999) and was first suggested by Parker (1979). It is a plotless sampling method that works well on trees and shrubs. In february and march 2004 one transect for each focal tree species was established in seven study areas of Kakamega main forest block and in some of its fragments. The focal tree species were *Antiaris toxicaria*, a climax species mainly occuring in older succession stages, *Croton megalocarpus*, also a climax species, but abundant in younger forest sites and *Funtumia africana*, a climax species which is one of the first species very abundant in young initial forest stadiums. A total of 20 transects (instead of 21) was done, because in the northern fragment Malava *Croton megalocarpus* was missing inside the forest and was only replanted along the main road which divides the forest in two parts.

At first a starting point for the transect was chosen in a more or less undisturbed forest part of the study area. Then a fixed-width strip was searched in one direction from a random point on the transect line until the 3rd individual of the focal tree species on this strip was found. Along the perpendicular of the transect line the distance *l* from the random point to the third nearest tree individual was measured. The information about the direction of transect, the width, the number of random points and the measured distances were recorded. This procedure was repeated until we sampled 30 to 40 distances *l*. Also additional data about the dbh (diameter at breast height, 1.30 m) and phenology of the third nearest individuals were taken. Only tree individuals older than two years and with a diameter above 5 cm were included. The height of the tree individuals and their ages were estimated by the field assistant Bonny Dumbo, who has a lot of experience with forest tree species. Since the size of woody plants is related to age estimations about the age of the tree can be done by measuring its heights (Krebs 1999, Mueller-Dombois-Ellenberg 2002).

The sketch gives an impression about the method:



● = random point

x = tree individual of species x

☒ = third nearest individual

w = transect width

l = distance from random point to the third nearest individual

Counting the focal species in relation to transect-width and the distances measured allows calculations of the density of each species (Krebs 1999).

The formula was derived by Parker (1979) as follows:

$$D = \frac{3n - 1}{w \sum (li)}$$

where D = Estimate of population density

n = Number of random points

w = Width of transect searched

l_i = Length of transect I searched until the third individual was found

With the knowledge of the density of a population this plotless sampling method could be used to find out if the spatial pattern is random, clumped, or uniform (Krebs 1999).
The provided data can be used for a test of null hypothesis of a uniform spatial pattern. Again Parker (1979) suggested a statistical test by calculating two values for each observation:

$$P_i = \frac{i}{N}$$

$$S_k = \frac{\sum_{i=1}^{k} l_i}{\sum_{i=1}^{n} l_i}$$

where

P_i = Proportion of sample counted up to quadrat i

n = Total numbers of quadrats sampled

S_k = Proportion of total lenghts measured up to quadrat k

l_i = Length to third individual for quadrat number i ($i = 1, 2, 3, 4, \ldots n$)

Under the null hypothesis of uniformity, the two proportions P_i and S_k will rise together. To test the null hypothesis the largest deviation between the two proportions is searched. This maximum deviation (observed value) is referred to the value of table for the Kolmolgorov-Smirnov goodness-of-fit test (Zar 1996, 474 and Table B.9; Sokal and Rohlf 1995, 708). The null hypothesis will be accepted when the observed value is less than the tabled value and rejected when the observed value is higher. The level of significance is $\alpha = 0.05$.

Results

Density

For the three focal tree species estimations about their density in seven forest sites were done. Figure 79 shows the calculated number of stems per ha derived from the formular of Parker (1979). The density of every tree species differs between the seven forest sites.

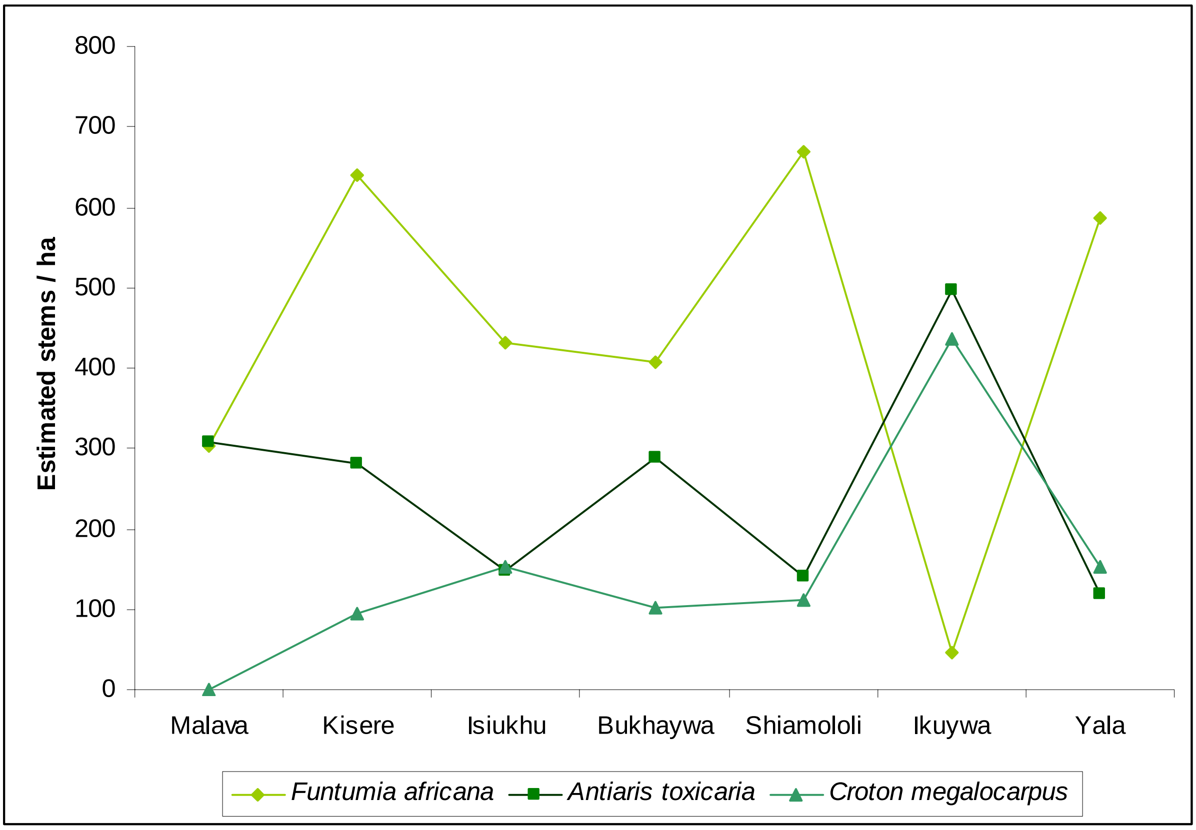


Fig. 79: Estimation of population density derived by the variable-area transect method for seven forest sites.

All studied forest sites differ concerning the density of the analysed tree species. The tree species are not evenly distributed over Kakamega Forest, every studied site has its unique species density. Additionally the number of individuals of the three tree species is not similar in a given forest site. The only exception is Malava where *Funtumia africana* and *Antiaris toxicaria* have a similar density. In this forest no individual of *Croton megalocarpus* was recorded as mentioned above. Apart from Ikuywa the fast growing climax species *F. africana* has the highest number of individuals in every studied forest site. Although the fragments Kisere and Yala were defined as forest of old succession stage with a quite natural species composition, dense covers of *F. africana* were recorded. These high densities of the species in the two forests lead to the assumption that disturbances happened there recently, otherwise this light-demanding indicator species of disturbance would not be that abundant there. Most individuals of *C. megalocarpus* were estimated in Ikuywa and fewer in the northern sites like Kisere or near the Isiukhu river. This pattern agrees with the analysis of the plant communities. The analysis of the plant communities shows that *C. megalocarpus* is characteristic for the southern sites. *A. toxicaria* is a tree species distributed over and characteristic for the whole forest. The different densities in the studied forest sites could be a result of past logging activities.

Additionally, parameters of the height and the age of the trees were recorded. Figure 79 shows the estimated densities for individuals of every age and height. But we were also interested in the population structure of the focal tree species. The more younger trees were recorded along the variable-area transect the more disturbed the forest sites are. Thus, the high density of *F. africana* can be a result of past human disturbance. The following diagramms show the estimated heights and ages of the focal species in the studied forest sites.

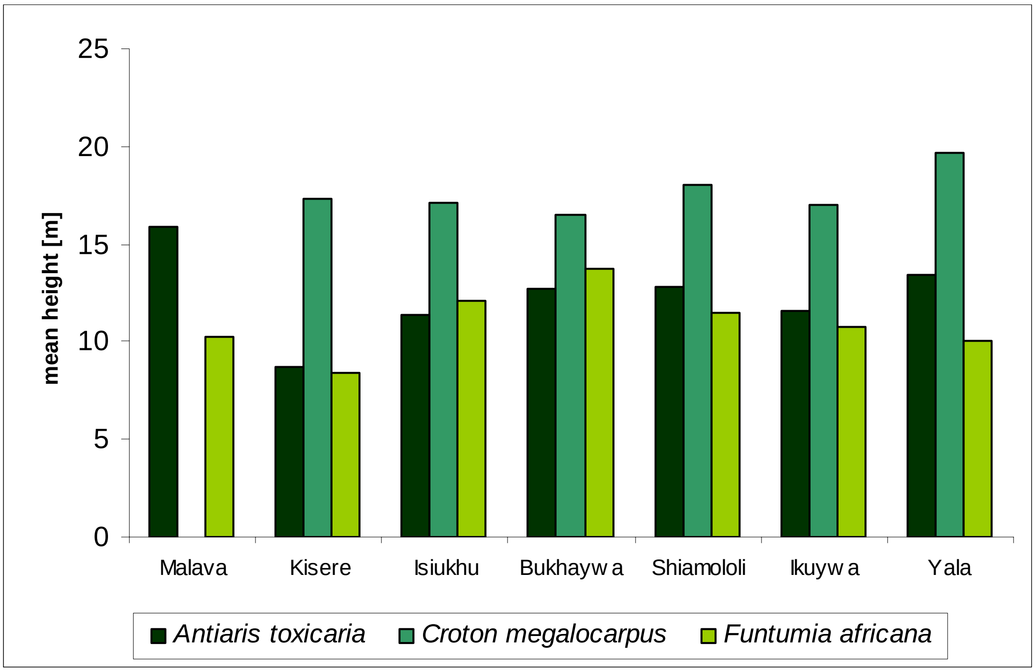


Fig. 80: Average estimated heights of the three focal tree species in the seven studied forest sites.

In average the recorded trees along the variable-area transects are between 8 and 18 m high (fig. 80). The tallest and oldest tree individuals of *F. africana* were recorded near the Isiukhu river and in Bukhaywa, in contrast to Kisere and Yala where in average small and young individuals occur. The occurrence of old and tall trees of *F. africana* is an evidence for past disturbance whereas young, small trees are evident for current disturbances.

In every studied area the tallest individuals are of the tree species *C. megalocarpus*. These individuals have an almost similar height and therefore an almost similar age in every studied forest site (fig. 81).

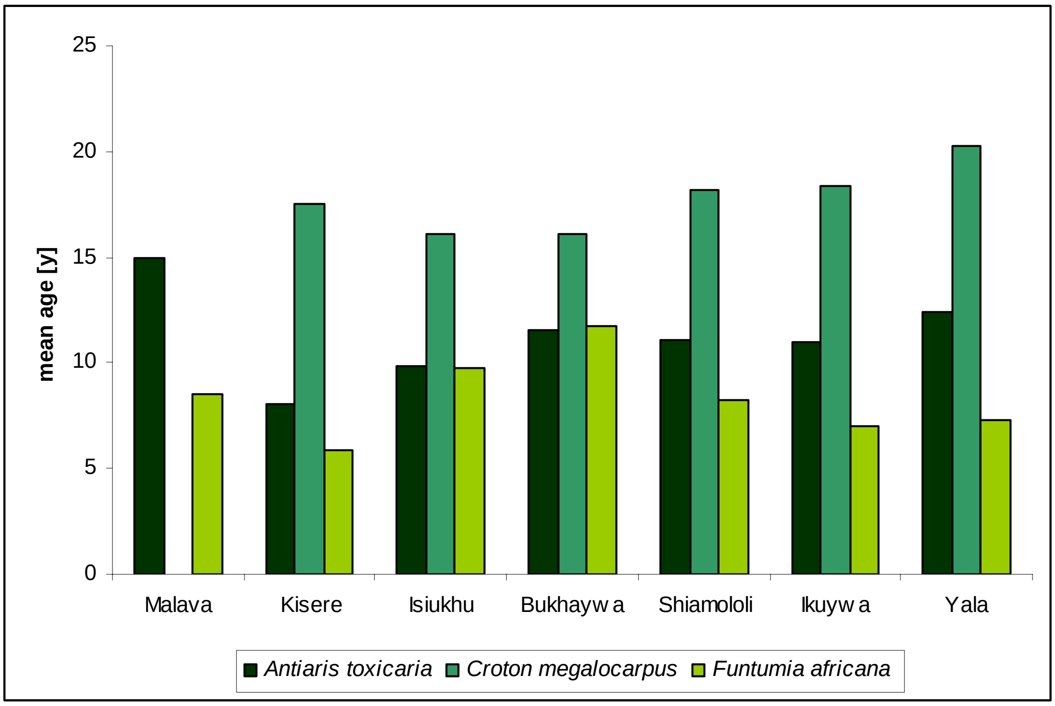


Fig. 81: Average estimated ages of the three focal tree species in seven forest sites.

Because of the similar height and age the population structure of the species is comparable between the studied sites. But comparing the density of *C. megalocarpus* between the studied sites (fig. 79) reveals differences in the population structure. Lower densities of *C. megalocarpus* in the northern forest sites than in Ikuywa e.g. could be a result of selective logging of tree individuals or could be caused by soil properties or tree species competitions.

Tall tree individuals of *A. toxicaria* were recorded in Malava, Shiamololi and Yala. In Malava a lower density of this species was recorded than in the other two forests. Like near the Isiukhu river, the lowest densities of the species were measured in Malava. Therefore, low density of species is not correlated with height. It is expected that a lot of tall trees occurring in a given area have higher distances between them than a high number of young trees. Many small trees can grow in a denser pattern than many tall ones. Therefore, more space in Malava between trees of *A. toxicaria* with a similar age than in Shiamololi and Yala leads to the assumption that logging activities of that tree species occurred there. A high abundance of that common tree species in a forest site is an indicator for middle-aged forests like in Ikuywa or Bukhaywa. The youngest trees of *A. toxicaria* were recorded in Kisere. This forest site was found to be the only near primary forest in Kakamega. The absence of old trees of *A. toxicaria* and the high abundance of old and tall trees in the other studied forest sites leads to the conclusion that this tree species is an indicator for middle-aged forest. Most of Kakamega Forest is classified as middle-aged forest and only Kisere as near primary forest. The absence of old individuals of *A. toxicaria* in Kisere is therefore an additional evidence that near primary forest in Kakamega Forest is rare and most parts are disturbed.

Spatial pattern

The proposed null hypothesis is that the three focal tree species are distributed uniformly over the investigated forest sites. An example for a uniform pattern is shown in figure 82.

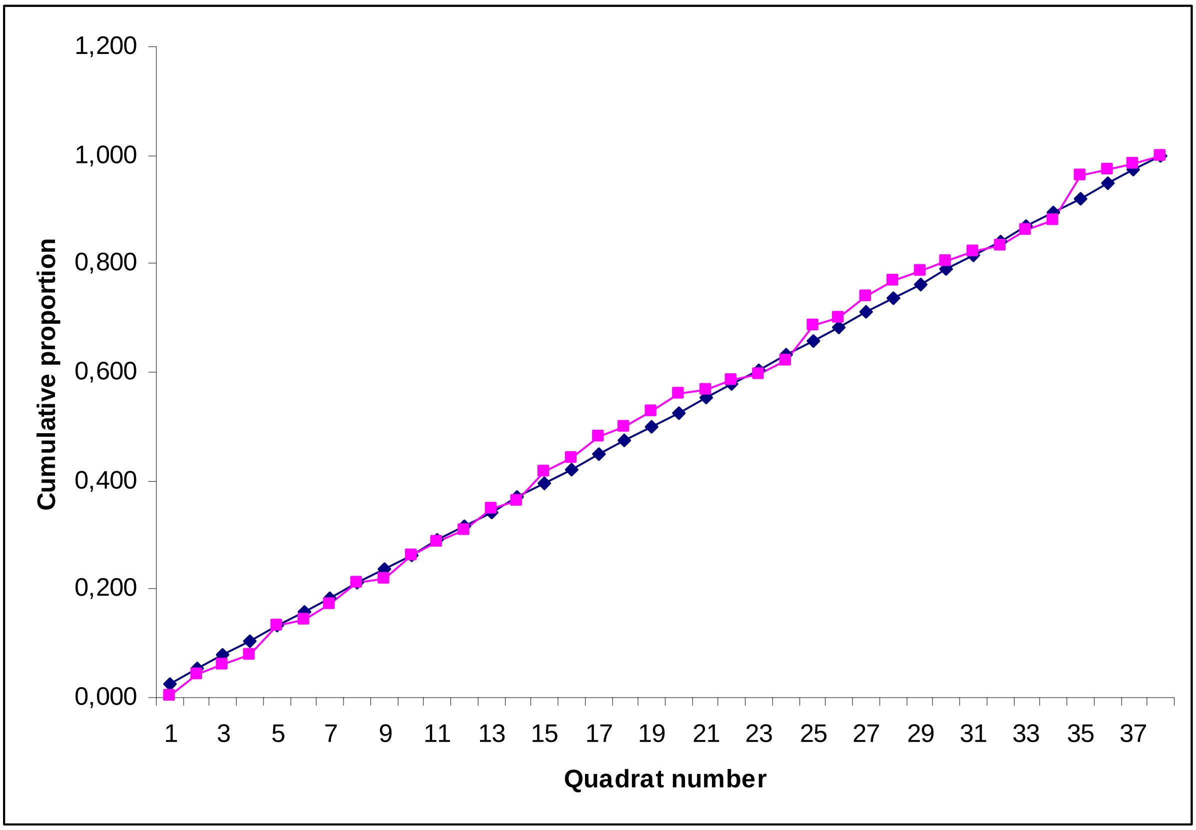


Fig. 82: Test of the null hypothesis of a uniform pattern for the variable-area transect method. Two cumulative distributions are plotted for the sampled data of *Funtumia africana* in the study site Yala. The blue line gives the cumulative proportion of quadrats searched and is a straight line. The data points are the cumulative proportion of the total quadrat lenghts searched up to each quadrat number (pink line). The maximum deviation between these two distributions is the Kolmogorov-Smirnov statistic D tabled in Zar (1996, Table B.9).

The cumulative proportion of quadrat searched is a uniform distribution (fig. 82). The observed cumulative quadrat lengths of the data of *Funtumia africana* along the transect in Yala is a uniform distribution as well, since both lines (blue and pink) are very close to each other. Therefore, the maximum deviation between these two distributions is very small, $d_{\text{observed}} = - 0.043$. The observed value is less than the tabled value of the Table B.9 in Zar (1996) $D_{\text{tabled}} = 0.21544$, therefore the null hypothesis of a uniform pattern is accepted.

An example of a clumped, thus not uniform, distribution is shown in figure 83. The maximum deviation is more than the tabled value: $d_{\text{observed}} = - 0.0337 > D_{\text{tabled}} = 0.23788$. Therefore, the null hypothesis of a uniform distribution of *Croton megalocarpus* along the transect in Bukhaywa is rejected. Whether the spatial pattern of the tree species is clumped or random can be seen at the raw data on the observation along the transect. Short measured distances between a random point and the third nearest individual alternating with long distances are an evidence for a dense distribution of the tree species and therefore a clumped spatial pattern (fig. 83).

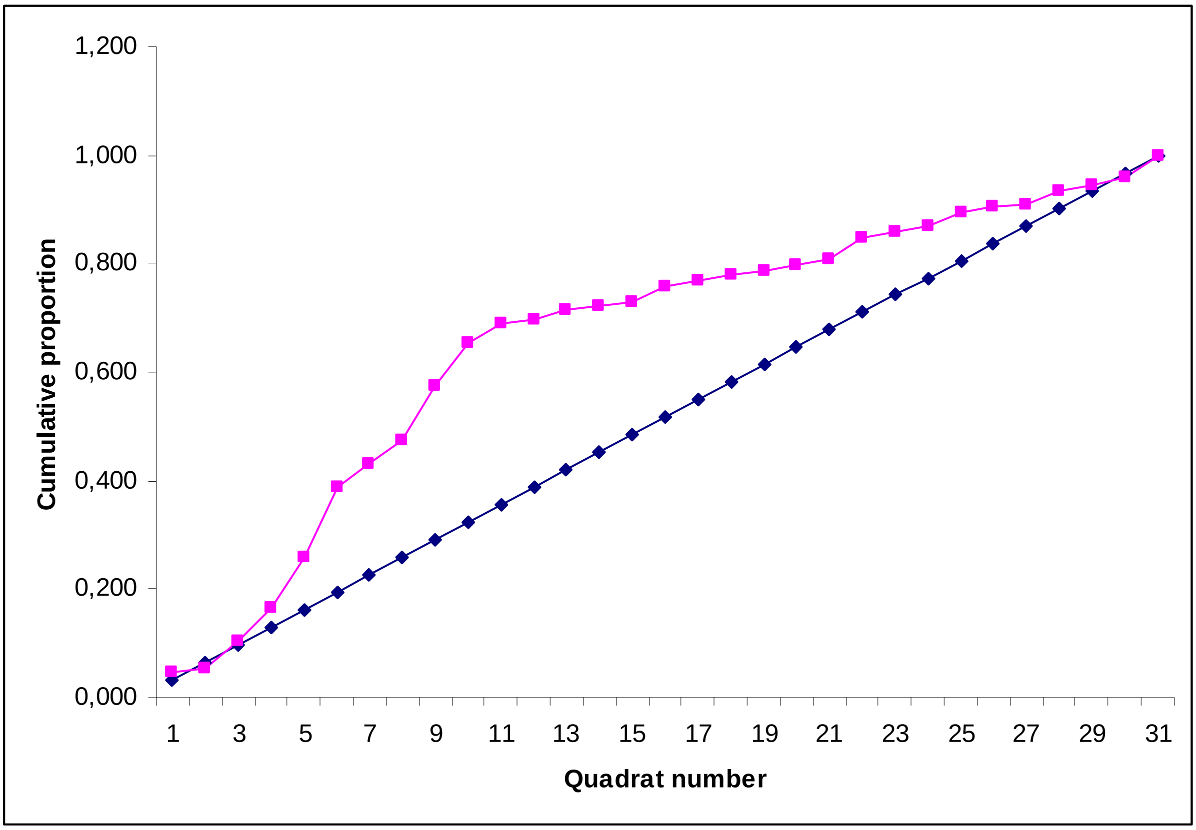


Fig. 83: Test of the null hypothesis of a uniform pattern for the variable-area transect method. Two cumulative distributions are plotted for the sampled data of *Croton megalocarpus* in the study site Bukhaywa. The blue line gives the cumulative proportion of quadrats searched and is a straight line. The data points are the cumulative proportion of the total quadrat lenghts searched up to each quadrat number (pink line). The maximum deviation between these two distributions is the Kolmogorov-Smirnov statistic *D* tabled in Zar (1996, Table B.9).

A clumped pattern of trees in a studied area can be an evidence for past selective logging. Table 11 gives an overview of the Parker's test for random spatial pattern with the variable-area transect data of the three common tree species.

Table 11: Results of the Parker's test for random spatial pattern with variable-area transect data. Given are d_{maximum} = Maximum deviation, n = Quadrat numbers searched, D = Critical value for the Kolmogorov-Smirnov Goodness of Fit Test for Continuous Distribution, H_o = Null hypothesis.

Species	d_{maximum}	Area	n	D	H_o
Funtumia africana	- 0.21020	Malava	40	0.21012	rejected
Funtumia africana	0.28139	Kisere	40	0.21012	rejected
Funtumia africana	0.23576	Isiukhu	40	0.21012	rejected
Funtumia africana	0.09360	Bukhaywa	38	0.21544	accepted
Funtumia africana	0.16620	Shiamololi	40	0.21012	accepted
Funtumia africana	- 0.09769	Ikuywa	30	0.24170	accepted
Funtumia africana	- 0.04336	Yala	38	0.21544	accepted
Antiaris toxicaria	- 0.09258	Malava	37	0.21826	accepted
Antiaris toxicaria	0.13254	Kisere	38	0.21544	accepted
Antiaris toxicaria	0.06990	Isiukhu	34	0.22743	accepted
Antiaris toxicaria	0.07126	Bukhaywa	31	0.23788	accepted
Antiaris toxicaria	0.11337	Shiamololi	40	0.21012	accepted
Antiaris toxicaria	0.19923	Ikuywa	40	0.21012	accepted
Antiaris toxicaria	- 0.07127	Yala	33	0.23076	accepted
Croton megalocarpus	0.16896	Kisere	32	0.23424	accepted
Croton megalocarpus	0.16597	Isiukhu	32	0.23424	accepted
Croton megalocarpus	- 0.33651	Bukhaywa	31	0.23788	rejected
Croton megalocarpus	0.13977	Shiamololi	40	0.21012	accepted
Croton megalocarpus	- 0.11319	Ikuywa	33	0.23076	accepted
Croton megalocarpus	- 0.10341	Yala	30	0.24170	accepted

Almost all tested null hypotheses of a uniform pattern of the three focal tree species in the studied forest sites are accepted. Therefore, the distribution patterns of the tree individuals are not random or clumped. Exceptions can be found in Malava, Kisere and Isiukhu for *Funtumia africana*. The raw data of the measured distances between a random point and a third nearest tree individual of *F. africana* in these three forest sites show that clumped patterns occur. A clumped pattern of tree individuals in a forest site can be a result of past selective logging. In the arising gaps the fast growing, light-demanding tree species *F. africana* can establish. It also occurs in the forest sites with closed canopyies, but there in a less dense pattern. Thus, an alternating pattern of many individuals at one site and few at another site develops. Such a clumped distribution of *Antiaris toxicaria* could not be recorded and only one case for *Croton megalocarpus*. In Bukhaywa, where a clumped pattern for that tree species occurs recent and past selective logging happens, therefore a uniform distribution of the species over that forest site is disrupted by human activities.

7. Discussion

Some remarks on the applied methods

When sampling a forest community the size and the shape of a quadrat is to consider, because these two variables influence the possible measurement bias. A rectangular quadrat has more edge than a square resulting in increasing edge effects, because ecologists tend to count species on the edge rather than to ignore them. Long, thin quadrats are often preferred because they cross more heterogenous vegetation. Rectangular plots are used when any observed contour, soil or vegetation banding should be crossed (Bormann 1953). Usually organisms are rather distributed patchily than uniformely within the overall sampling zone (Krebs 1999). Since preferably homogenous vegetation units should be sampled and an edge effect should be avoided, we choose the square size. The sample size 10 x 10 m has been used frequently in mature forest sites (Krebs 1999) with low tree species diversity which is true for Kakamega Forest in contrast to South-American tropical rainforests (Richards 1996). In addition multiple small quadrats have a higher precision (= lowest S.E.) than bigger, fewer quadrats, if an equal total area is being sampled (Krebs 1999). Another advantage of smaller quadrat size is that they can be easily replicated and an area can be sampled quite quickly (Lwanga et al. 1999).

To analyse the vegetation of this tropical rainforest of Kakamega the floristic-physiognomic approach of Braun-Blanquet was used (Braun-Blanquet 1964, Mueller-Dombois & Ellenberg 2002). For the establishment of a relevé for the phytosociological analysis a subjective choice was deciding. Homogeneity in terms of physiognomy and species composition is one of the prerequisite for this analysis, therefore we choose size relevé of 10 x 10 m. The required size of a relevé depends on the number of species occurring in a studied vegetation unit (or plant community). In community sampling as many species as possible should be represented.

In practice a so-called “minimum area” is determined. The “minimum area” is defined as the smallest area on which the species composition of the community is adequately represented (Dierschke 1994, Mueller-Dombois & Ellenberg 2002). After determining that “minimum area” the relevé size can be defined, which in the majority of cases is bigger than the analysed “minimum area”. But determination of the “minimum area” by the common nested plot technique failed due to the small-scaled mosaic structure of different vegetation units in Kakamega Forest. Similar experiences were made by Schmidt (1991) in the Shimba Hills, Kenya. Moreover, the “minimum area – concept” is still discussed in vegetation science (Barkman 1989) and in practice experience of the studied vegetation is more crucial factor than a theoretical “minimum area” (Dierschke 1994). A “minimum area” is determined by a species/area curve. The minimum sample size is achieved at the point where the increasing curve becomes almost horizontal and most of the species would be sampled. An objective definition of that point in a graphic illustration is difficult (see Dierschke 1994). Therefore, for the analysis of the species composition and structure of trees the plot size used in the KIFCON – project (Mutangah et al. 1994) was adopted. A bigger relevé size would have not fulfilled the requirements of a homogenous vegetation segment in Kakamega Forest. Another work in the tropics shows the same problem that the "minimum area" could not be reached at the end of a relevé, because of the homogeneity constraints (Senterre et al. 2004). Furthermore, a determination of a "mimimum area" is only possible in a not only relatively homogenous but also not fragmentary community (Mueller-Dombois & Ellenberg 2002). Fragmentary means that there is a lack of species usually occurring in a given community, by habitat fragmentation or by selective destruction of certain species e.g. through selective logging. It was already known that tree species were selective logged in Kakamega Forest and are missing in several forest sites. Therefore, instead of one large relevé in each study site several small relevés were established subjectively to cover all possible species of that typical vegetation segment occurring there. This method allows a quick and accurate assemblage of species in a forest site of interest. One must choose a relevé size that is praticable and manageable even if it contains only a fraction of the number of species in a given community, but several of these small relevés together reflect a nearly complete species composition (Mueller-Dombois & Ellenberg 2002).

In species-rich tropical rainforests a determination of a "minimum area" is often impossible and therefore phytosociological methods deliver no representative data (Homeier 2004, Richards 1996, Walter & Breckle 2004). Species/area curves of tropical rainforests show that even a relevé size of 1 ha does not contain the typcial species assemblages (Gentry 1988, Richards 1996, Wattenberg & Breckle 1995). But analysis of phytosociological data based on the method of Braun-Blanquet (1964) modified by Mueller-Dombois & Ellenberg (2002) was previously successfully used by several authors for the classification of East African vegetation (see list page 47 and Schmidt 1991, Bussmann 2002). Therefore, for this study we used the phytosociological analysis and provide the first description of plant communities of Kakamega Forest.

In the last decades multivariate analyses of forests have been applied in many parts of the world (Bray & Curtis 1957, Greig-Smith et al. 1966, Austin & Greig-Smith 1968, Webb et al. 1970, Williams et al. 1973, Swaine & Hall 1988). These methods are useful for large data sets from areas where only vague ecological information of the plant species are available. Due to the lack of knowledge of the ecology of most of the plant species and because of a large data set with multivariate information we used these methods for the analysis of the vegetation of Kakamega Forest.

For the population structure tree species with dbh (diameter at breast height) over 10 cm were defined as trees. This measuring unit is a common standard for tree data collection (Gentry 1982). Below 10 cm dbh the tree individuals were regarded as saplings and were not incorporated into the study about the tree population structure of the forest. The dbh was measured at 1.30 m above the ground what is as well a common standard in tree population analyses (Scully 2001). Excluding tree individuals below 10 cm dbh could produce less acurate representation of forest tree species (Lieberman & Lieberman 1987, Condit 1995). However, the main focus was on the distribution of elder, established tree species and therefore saplings should be excluded.

The presence of buttresses resulted in overestimated basal areas, therefore the methodology should be interpreted with caution. However, tree individuals with buttresses were rare in Kakamega Forest and the effect is therefore negligible (Scully 2001).

For the analysis of the plant communities of Kakamega Forest it was necessary to detect the characteristic species composition. In most cases single differential species were responsible for the separation of different communities. Plant species with similar or common sociological behaviour were used for a floristical arrangement. The defined plant communities were not ranked in a hierarchical system like it was done in the study of Mt. Kenya (Bussmann 1994, Bussmann & Beck 1995). To arrange the plant communities in such a system would mean to classify them. Since this is a first description of the plant communities and further investigations on correlations between soil or climate and plant species composition should be done, a classification was not attempted. Nevertheless, a preliminary succession description based on the results of the phytosociological analyses was conducted. But further investigations are needed if the occurrence of a differential species is nutrient related or has edaphic and microclimate reasons.

Comparison with other East African vegetation studies

Comparisons with other vegetation studies of forests in East Africa were done. Most of them were conducted in East African mountains which are not virtually comparable to the Guineo-

Congolian transitional Kakamega Forest. The *Olea capensis* - *Diospyros abyssinica* community of Wesche (2002) which was described between 2100 m to 2400 m on the dry exposures of Mt. Elgon (Kenyan side) is similar to the expected near-primary vegetation of Kakamega. The most conspicuous tree species *Diospyros abyssinica* and *Olea capensis* of this plant community are also potential species for climax stades in Kakamega Forest. Two members of the plant communtiy of Mt. Elgon, the tree species *Trichocladus ellipticus* and the shrub *Acanthus eminens* are also typical members of more or less undisturbed forest sites in Kakamega Forest. Therefore, the analysed *Trichocladus ellipticus* – subcommunity of Kakamega Forest resembles the *Olea capensis* – *Diospyros abyssinica* community of Mt. Elgon. Although this plant community occurs on higher altitudinal level at Mt. Elgon the soil is clayey like in Kisere where the *Trichocladus ellipticus* – subcommunity occurs and the topsoil pH was around 6 (Mutangah 1996).

In the Aberdare Mountains occurs the *Cassipourea malosana* – *Olea capensis* community on altitudes of 2100 m to 2300 m (Schmitt 1991). This plant community is comparable to the near-primary forest plant community in Kakamega Forest, but several characteristic species are missing like *Juniperus procera*, a typical member of the East African mountains in higher altitudes. Nevertheless, tree species like *Trichocladus ellipticus*, *Diospyros abyssinica* or *Olea capensis* are abundant in the Aberdare's *Cassipourea malosana* – *Olea capensis* – community which is similar to the species composition of Kisere. Additionally Schmitt (1991) described a *Trichocladus ellipticus* – subcommunity, too, but with different ground covering species which are typical for the higher altitude like *Stipa dregeana* instead of *Oplismenus hirtellus* in Kakamega Forest. Also a dominant tree species of the Aberdare's subcommunity *Podocarpus falcatus* is missing in Kakamega Forest. The compared plant communities of Mt. Elgon and Aberdare Mountains contain more afromontane elements than Kakamega Forest which has much more species of the Guineo-Congolian lowland forests.

Schmidt (1991) provides a vegetation analysis of the Shimba Hills in Kenya. None of the described plant communities of the Shimba Hills fit to one of Kakamega Forest, except of the *Olyra* – *Rawsonia* community group, although some species are common in both forests. Species of the tropical evergreen seasonal lowland forest as described in Schmidt (1991) which can be found in Kakamega Forest, too, are the abundant, creeping herb *Geophila repens* or the tree *Antiaris toxicaria*. *Fernandoa magnifica* is also characteristic like *Trichilia emetica* or *Rawsonia lucida*. *T. emetica* and *R. lucida* are also very abundant in Kakamega Forest.

Bussmann (2002) describes a plant community *Lovoetum swynnertonii* ass. nov. for the Nyambeni Hills and Imenti in Kenya. He concludes that the distinct links of the species to the Guineo-Congolian rainforest which are characteristic for this alliance like *Rytigynia neglecta*, *Uvaria scheffleri*, *Adiantum hispidulum* and tall trees like *Chrysophyllum gorungosanum* or *Premna maxima* show clearly that the forests in Nyambeni and Imenti are a far outpost of these forest systems. This contradicts the statement of Kokwaro (1988) that the Kakamega Forest in Kenya is the easternmost relic of the Guineo-Congolian rainforest. The present study defines that a forest only belongs to the lowland rainforest systems of the Congo basin, if a high amount of Guineo-Congolian plant species is recorded. As opposed to, the companions of the *Lovoetum swynnertonii* ass. nov. described by Bussmann (2002) are all afromontane elements like the trees *Syzygium guineense*, *Albizia gummifera*, *Heinsenia diervilleoides* or *Strombosia scheffleri*. The proportion of Guineo-Congolian plant species is too low to define the forests of the Nyambeni Hills and Imenti as far outpost of these forest systems. Therefore, we concluded that Kakamega Forest is the easternmost relic as postulated by Kokwaro (1988).

Interestingly, the plant species composition of Kakamega Forest is closer related to the forest vegetation of the Nyika Plateau (Dowsett-Lemaire 1985) in Malawi-Zambia (altitude about 1970 m) than to the Nyungwe upland forest (about 1950 m) in Rwanda (Bouxin 1977). Further relevants of Kakamega Forest in East and Central Africa with a similar plant species composition are the Mabira and Budongo Forests in Uganda.

The comparison shows that Kakamega Forest due to its development history and its logging-history has a unique plant community composition.

Comparison with further vegetation analyses of Kakamega Forest

Mutangah (1996) distinguished five broad vegetation types of Kakamega Forest which are comparable to the described alliances of our study. While Mutangah et al. (1994) analysed only the species composition and distribution of tree species in Kakamega Forest Mutangah's work (1996) was a first survey of all lifeforms. The vegetation was analysed using line transects of 1000 m length in less heterogenous forest sites. The stands or vegetation units were analysed with the Normal Information Statistic (NIS) (Mutangah 1996). Only the presence/absence data of the species along the line transects were included in the analysis, whereas in our study the coverage of a species in a vegetation layer was also incorporated. Like in our study the characteristic species for the defined vegetation units are mainly tree species. For the northern Buyangu National Reserve a *Diospyros abyssinica – Croton megalocarpus – Blighia unijugata* Forest is defined by Mutangah (1996). In contrast, the tree species *Diospyros abyssinica* and *Blighia unijugata* were found to be widespread over the forest investigated in this study, whereas in the survey of 1996 the species were considered to be characteristic for the northern region. *Antiaris toxicaria* was observed by Mutangah (1996) and by us to occur in almost every study site. *Croton megalocarpus* was mainly found in the middle and southern region of the forest in the BIOTA-study and is not a characteristic species for the Buyangu region as stated in the survey of 1996. Instead this tree is typical for the middle and southern region including the Salazar and Busambuli area. Accordance consists for the Yala region between the two compared studies. In both cases the tree species *Croton megalocarpus* and *Craibia brownii* are characteristic species for this forest region. The defined alliance for the southern and middle part of Kakamega Forest in our study is the *Celtis mildbraedii – Craibia brownii* - alliance, but *Croton megalocarpus* is an abundant member, too. This alliance and the southern vegetation type of Mutangah are comparable, but for the middle region around Salazar and Busambuli as well as for the Isecheno and the fragment Ikuywa he defined another type of vegetation. The characteristic tree species of these vegetation types are different from our analysed tree species composition. In the northern region we defined the *Deinbollia kilimandscharica – Markhamia lutea* – alliance. Both tree species are not characteristic in Mutangah's survey for this region. Instead *Markhamia lutea* is common in the middle tree canopy layer in Isecheno and as shrub typical for the Buyangu and for the eastern region north of Vihiga. *Deinbollia kilimandscharica* is a typical shrub for the Yala region according to Mutangah. The distribution pattern of this tree species differs between both surveys. Additionally, Vihiga and parts of the center of the forest belong to the *Diospyros abyssinica – Funtumia africana* vegetation type in the survey of 1996. However, in our study both tree species are commonly distributed over whole Kakamega Forest and are no differential species for these regions. *Celtis africana* which is representative for Isecheno, parts of the Center and for Ikuywa in 1996 is widespread in the established relevés in our study. Again, a consensus does not exist in these analyses between the two studies. For Ikuywa *Manilkara butugi* is characteristic and abundant in the survey of Mutangah, but after analysing the investigated relevés in our study this tree species is also common in the northern region and occassionally common in all other forest sites. Therefore, it is not a good differential species nor a typical species for Ikuywa.

A classification of the shrublayer in Mutangah's work shows that *Dracaena fragrans* and *Pseuderanthemum ludovicianum* are typical for the Buyangu Hill area and north of Vihiga, but in our study *Dracaena fragrans* is highly common in every part of Kakamega Forest and *Pseuderanthemum ludovicianum* is typical for the Salazar/Busambuli area as well as for Isecheno, Yala and Ikuywa resulting in the *Pseuderanthemum ludovicianum* – subcommunity. Nevertheless, Mutangah mentioned that *P. ludovicianum* is also a member of the species composition in Yala and *D. fragrans* also occurs in other parts of the forest.

Most of the species associations classified by Mutangah (1996) had a wide distribution in the forest. Only five distinct communities or vegetation types were evident in his analysis. This is also true for our study. Most of the characteristic species of our defined plant communities were not restricted to one area of the forest, resulting in several subcommunities. Only few species like *Ficus cyathistipula* or *Trichocladus ellipticus* were restricted to the northern part of Kakamega Forest. Despite of the two alliances *Deinbollia kilimandscharica – Markhamia lutea* and *Celtis mildbraedii – Craibia brownii* which separate the forest in a northern and southern half no further broad divisions in e.g. eastern or western forest regions can be made.

In our study, species which indicate different plant communities were mostly trees or shrubs. Information about ecological distribution for shrubs and herbs or lianas were only evident for the very young succession stages which are either bushland or preliminary phases of forest and the mature forest. Vegetation analyses of East African forests on altitudes comparable to that of Kakamega Forest also found tree or shrub species to be separating species between plant communities (Bussmann 2002, Wesche 2002, Schmidt 1991, Schmitt 1991). Different observations were made in Central Europe or in North America where herbs were the main differential species (Dierschke 1994, Ellenberg 1996, Mueller-Dombois & Ellenberg 2002).

A comparison of the distribution of the plant communities in our study with the vegetation types of Mutangah (1996) shows that our analysis is more detailed on a smaller scale. Mutangah (1996) created a broad vegetation zonation in his vegetation map. Instead of e.g. one vegetation unit, the *Diospyros abyssinica – Croton megalocarpus – Blighia unijugata* Forest in the northern Buyangu National Reserve, we defined several plant communities and two alliances for this region. The alliance of the more or less undisturbed forest, *Antiaris toxicaria – Diospyros abyssinica* – alliance, and the *Harungana madagascariensis – Desmodium adscendens* – alliance of the highly disturbed forest sites. Due to the small scaled vegetation structure of Kakamega Forest with several glades covered with grass- or bushland we avoid to create a vegetation map with clear vegetation zones. Instead, we show the distribution of the plant communities on the base of the Reconnaissance soil map. The distribution demonstrates the mosaic-structure of Kakamega Forest which is due to the high amount of human disturbance in the last decades.

The surrounding environment of the forest, beside human settlements and agricultural country, is bush- and woodland. The succession of the bushland and the savannah like *Combretum*-woodland to a secondary forest in Kakamega was described by Schultka (1975). The *Combretum* woodland is supposed to be a secondary plant community that appears in areas that have been cleared of forest and turned into farmland or pasture (Schultka 1975, Kokwaro 1988). In the present study analyses of very young secondary study sites lead to a similar conclusion. Underneath *Combretum collinum*, *Harungana madagascariensis*, *Maesa lanceolata* and further pioneers, species seedlings and saplings of climax stages like *Funtumia africana*, *Olea capensis* and *Prunus africana* could be recorded.

Comparison of the studied sites within Kakamega Forest

Northern half

Unlike the Isecheno, Ikuywa and Yala area the forest in the Buyangu National Reserve was much more exploited. The area from the Isiuhku river up to Buyangu Hill and from Colobus in the north to Salazar in the south were clear-felled more than 100 years ago (Mitchell 2004). That area is now covered with bushland, initial forest stages (Camp forest and Buyangu secondary) and large *Psidium guajava* fields. Official records show that *Olea capensis*, *Cordia africana*, *Prunus africana* and *Croton megalocarpus* as well as *C. sylvaticus* were cut. At Buyangu Hill in the mid-1970's *Antiaris toxicaria*, *Celtis mildbraedii* and less quantities of *Croton megalocarpus*, *Trichilia emetica* and *Aningeria altissima* were selectively logged (Mitchell 2004).

In Colobus the largest *O. capensis* and many *A. altissima* trees were said to grow there, making this forest site eminently interesting for timber companies. Both species were cut by several sawmill companies. Until today tall individuals of *O. capensis* could be recorded here. But tall *A. altissima* trees are nowadays only known from Shiamololi. The high abundance and the presence of large individuals of *Aningeria altissima* in Shiamololi is due to their often irregular and fluted stem form. These individuals are difficult to mill and were not useable for further processing (Mitchell 2004).

Species which are characteristic for the southern and middle part of the forest today, in particular *Celtis midlbraedii* and *Croton megalocarpus*, were also abundant in the northern part of the forest. This leads to the conclusion that the past human disturbance is responsible for the present distribution pattern, especially of tall tree individuals.

The same mentioned species were cut around the Salazar and Busambuli region. *O. capensis* and *P. africana* were cut as well as *Croton megalocarpus*, *Celtis mildbraedii* and *Antiaris toxicaria*.

Near Bukhaywa the mills cut *Antiaris toxicaria*, *Ficus vallis-choudae* and *Trilepisium madagascariense*.

Malava nowadays is a plantation of indigenous and exotic tree species. The natural species composition is not maintained today. About 60 years ago the FD started with group planting in the exploited forest sites of Malava. Indigenous species like *Cordia africana*, *Prunus africana* and *O. capensis* were planted beside exotic species like *Khaya anthotheca* and *Bischoffia javanica*. This species composition was found again in the analyses. Vice versa the result of the analyses of the relevés in Malava indicate that the forest was heavily logged and replanted.

In the last decades human disturbance in Kisere forest was comparably low, except for pit-sawing. No official exploitation is recorded in the FD archives (Mitchell 2004). Unlike Kakamega Forest the stand volumes and stand frequency per hectare has not changed significantly between a 1966 and a 1974 inventory (Tsingalia 1988). *O. capensis* was logged by pit-sawyers resulting in lower individual numbers. However, because of the management of the KWS in this forest, rather tall specimens of that species could be recorded compared to other forest sites in Kakamega Forest. Unfortunately, in this solely near-primary forest increasing human disturbance levels are observed (Bleher et al. 2005).

Southern half

Before the exploitation of the forest started in 1933, the Kakamega Forest inventory was known as heterogeneous in the tree species composition (Mitchell 2004). For example in the region between Ikuywa and Yala, now nearly destroyed after clear-felling, *Celtis mildbraedii* was very abundant and *Olea capensis* was very limited in its individual numbers. South of Isecheno *C. mildbraedii* was less significant while the area between Isecheno and Yala as well as Ikuywa were some of the richest areas for *Olea capensis* in the forest (Mitchell 2004). These areas were completely clear-felled, because of this valuable timber tree. Interestingly the forest within the Yala Nature Reserve was only noticable for the occurrence of *Croton megalocarpus*.

The phytoscociological analysis shows that the southern half of Kakamega Forest, including the study sites Isecheno, Yala and Ikuywa, is characterised by the occurrence of *Celtis mildbraedii* and *Croton megalocarpus*. Although these species were selectively logged in high numbers the stand structure of the trees in the upper canopy has not changed much. They are still the characteristic species in these regions. Although the human disturbances in terms of selective logging or clear-felling took place, the tree species composition is not only influenced by the past or recent logging history. Abiotic factors like soil, climate or topographic are suggested to play a role in development of the species composition, too (Mitchell 2004).

The Isecheno area was logged about 1940 to 1943, thus the exploitation stopped earlier than in the Buyangu area. Logging in Isecheno concerned the same tree species as in the northern area, except for *Diospyros abyssinica* which was selectively logged in Isecheno but not in Colobus. Additionally, large numbers of *Maesopsis eminii* were cut, while "Mama Mutere" was spared to serve as seed-mother (Mitchell 2004). Group planting of this species was done in the following years. Both information indicate that *M. eminii* was always a characteristic tree rather for the southern than for the northern region.

The second part of the investigated Isecheno area north of the Kalunya Glade is described as "untouched" forest with no commercial exploitation (Mitchell 2004). However, the species composition was different from other regions, as no *Prunus africana* and *Olea capensis* could be recorded here. Therefore, the forest site was not of interest for sawmill companies. Despite of that, analyses of the established relevés north of the Kalunya Glade in the Center of the forest show a low stem density and a forest with several gaps occurring there. A high abundance of middle-aged individuals of *Funtumia africana* indicates past and recent disturbances. Therefore, the forest is not representative for a mature Kakamega Forest.

Ikuywa was commercially logged from the mid-1940's to the mid-1980's. In the early years *Prunus africana*, *Aningeria altissima* and *Cordia africana* were cut in high numbers, later some specimens of *Olea capensis*, *Funtumia africana* and *Antiaris toxicaria* followed. In the 1980's *Croton megalocarpus* was also selectively logged. The most interesting species for the sawmill companies were *O. capensis*, *P. africana* and *C. megalocarpus*. That *O. capensis* and *C. megalocarpus* were logged in lower numbers compared to other forest sites, could be due to a different stand structure in Ikuywa. Nowadays, the species composition of Ikuywa consists of *Celtis mildbraedii*, *Craibia brownii* and *C. megalocarpus*. In the mid-1930's a similar species composition was recorded for the Ikuywa region, which implicates that despite of the logging activities the main tree species can still be found here.

The relevés of Yala lay within the Yala Nature Reserve. This area was labelled as "poor" forest with mainly *C. megalocarpus* by the foresters. The forester's judgement of "good" and "poor" forest was based on the presence of particular timber species (Mitchell 2004). No large-scale logging but illegal pit-sawing of a few species took place in Yala. The four main pit-sawing trees across Kakamega Forest *O. capensis*, *P. africana*, *Funtumia africana* and *Cordia africana* were also cut in the Yala Nature Reserve.

Kaimosi is owned by the Kaimosi Mission for 100 years and was never under the control of the FD (Mitchell 2004). Locals reported that plants like *Trilepisium madagascariense*, *Afrosersalisia cerasifera* and *Maesopsis eminii* are rare today. But these species except of *M. eminii* are the most characteristic species in the present study. Therefore, the species composition in the past may have been similar to the present and both abundant species are rarer today due to forest size reduction. From the mid-1960's until today selective logging of *Olea capensis*, *Trichilia emetica*, *Celtis mildbraedii* and *Croton megalocarpus* took place with and often without permission. Some of these species are rare now or could not be recorded in any relevé like *C. mildbraedii*. Therefore, before the logging activities happened the forest possibly belonged to the *Celtis mildbraedii – Craibia brownii* – alliance, but the species composition is unique compared to other forest sites because of the abundant occurrence of *A. cerasifera*.

The Kibiri area was known for its high diversity and great number of timber species in the year 1935 (Mitchell 2004). Forests on either side of the Yala Nature Reserve were noted as good in its tree species composition including valuable species like *Olea capensis*, *Cordia africana* and *Zanthoxylum gillettii*.

Today Kibiri is a mixed plantation of indigenous and exotic tree species. The former species-rich and valuable zone was completely destroyed by clear-felling. The natural tree species composition is today merely historical.

Correlation with climate

The species composition and the plant community distribution of Kakamega Forest are compared to the microclimate occurring in the north and the south of the forest. Personal observations during the study period indicate that in the southern parts especially in Isecheno and Yala there is much more precipitation and the climate is much more humid compared to the northern Buyangu area. The meteorological data for Isecheno and Kakamega recorded for a period of 12 years (1986-1997) support these experiences (Dietzsch 2004). Over the 12 years period a higher mean monthly rainfall was recorded at the Isecheno Forest Station than at the Kakamega Weather Station. The climate of Lake Victoria, with its own circulation system of air masses, may influence the climate in the southern region of Kakamega Forest more than in the northern part resulting in higher rainfall in Isecheno or Yala. Most of the plant species recorded in Kakamega Forest are widely distributed in every studied area. Only the abundance of single species like *Diospyros abyssinica* is different between the studied sites (see appendix 4). But this distribution pattern has probably other reasons like selective logging activities in the past than different microclimates. Tree species responsible for the separation of plant communities like *Trichocladus ellipticus* occur only at particular places in the forest. This distribution pattern is perhaps more related to edaphic than to climate causes, because this species has a wide range of habitat requirements of dry or moist to riverine forests. These climate conditions could be found at several places inside of the forest.

Microclimate measurements by Gemini Data Loggers show no great differences in the average temperature between the study sites (table 1). However, the maximum temperature measured at Buyangu Hill was higher than in Isecheno and Yala, supporting the suggestion that the microclimate in the north is hotter than in the south. In addition, the humidity measurements show a difference between north and south. The humidity in Buyangu was much less than in Isecheno and Yala resulting in a drier microclimate. Perhaps the differences in the microclimate contribute to the slightly different species composition between north and south. Nevertheless, great differences in species distribution and occurrence caused by different microclimates in such nearby habitats like in Kakamega Forest could be rather observed in mosses or lichens communities (Fischer 2000 b).

Correlation with soil

The two main different soil types of the Buyangu National Reserve up to Isecheno and of the Yala, Ikuywa and Kaimosi region can not be correlated with the plant communities. Even on the level of the alliances 1. and 2. no characteristic soil types are connected with the plant species composition of these two different groups. The fragments Kisere and Malava, which belong to the *Deinbollia kilimandscharica – Markhamia lutea* – alliance have different soils. Malava consists of nitro-rhodic ferrasols, which is a special case among all studied forest sites, but it neither has a unique plant species composition nor a characteristic plant community. Kisere's plant community is equivalent to a near-primary species composition, but its soil is not unique for the forest. It is similar to that in the southern part of Ikuywa. Therefore the species composition of Malava and Kisere may be a result of human disturbance in the past rather than being influenced by soil types. Salazar, Busambuli or Shiamololi have a different species composition than Isecheno, despite of a similar soil occuring there. Thus, plant communities of two different defined alliances occur on the same soil type. The southern fragment Kaimosi has a unique composition of plant species, which can be described as a mixture of alliance 1. and 2., but has a similar soil like Ikuywa and Yala. The species compositions of Yala and Ikuywa are more similar to Isecheno than to Kaimosi, therefore the soil types cannot play the major role for the species composition.

For some plant species the soil seems to be an influencing factor concerning their distribution within Kakamega Forest. The tree species *Trichocladus ellipticus* occurs only in the Kisere fragment on a ferralo-humic acrisol which is rare in the forest. On the same soil type in Ikuywa no investigations were done, therefore the occurrence of this species cannot be excluded there. Scattered distribution within the Kakamega Forest of some species like *Suregada procera* or *Ficus cyathistipula* cannot be explained by a scattered distribution of a special soil type. The soils on which these two species grow is widely distributed in the forest. Therefore, the different ages of the forest sites and the amount of disturbance in the past are likely to be an explanation for the occurrence of the different plant communities and their distribution over the forest.

Succession and regeneration

The abundant tree species *Antiaris toxicaria* and *Funtumia africana* were classified as climax species in early succession stages. Thus, these species are common in almost every part of Kakamega Forest suggesting that large parts of the forest are middle-aged secondary forest. Mutangah (1996) came to the same conclusion in his survey, that most of the forest is secondary and a true primary forest could not be recorded. In the ten years between the study of Mutangah, conducted in the years 1992-1994 and the BIOTA-study in the years 2001-2004, the forest did not change much concerning the overall main succession stage. A comparison of the tree species composition in the forest sites of Isecheno between the years 1981 and 1999 indicates that the tree community has been structurally stable over this period and that the forest is still maturing towards a climax forest (Fashing et al. 2004). However, the amount of pioneer species declined in that 18-year study. Human impact can retard forest regeneration. The tree species composition compared to the previous vegetation surveys shows no great differences. In a 18-years study in Isecheno the nine densest species remained. This small change is explained by durable and consistent human impact (Fashing et al. 2004). Regeneration towards a natural tree species composition is probably only possible without any kind of human impact (Tsingalia 1988, Mutangah 1996, Fashing et al. 2004).

But this 18 year-period is not long enough for a forest to recover completely from selective logging as it was shown for the Budongo Forest in Uganda. There, even 60-80 years might not be enough time for forest regeneration towards a true primary forest (Plumptre 1996, Chapman & Chapman 2004). We come to the same conclusion in our study. Kakamega Forest regenerates towards a climax stage, but several climax tree species of the late succession stage are missing. Regeneration of *Diospyros abyssinica* or *Strychnos usambarensis*, two climax tree species that are expected to be characteristic members of a primary forest in Kakamega Forest, is evident by abundant seedlings and saplings. But species like the valuable timber tree *Entandrophragma angolense* occurring in Kenya only in that area were known as a common species in the forest from early descriptions (Kokwaro 1988). Now it occurs only in the southern region near the Yala River as assessed in 2004 (Bonny Dumbo, pers. comm.). The same observation was made by Kokwaro (1988), therefore we conclude that this tree species did not recover over the forest during the last 16 years although seedlings and saplings could be recorded. The largest trees of the forest, *Olea capensis* and *Prunus africana*, beside *Aningeria altissima* in Shiamololi, are predicted to be the characteristic primary forest species in Kakamega Forest, but are now replaced by trees like *Croton megalocarpus* or *Funtumia africana* (Mutangah 1996, Fashing 2004).

Analyses of growth rates of different tree species done by subproject E 03 in Kakamega Forest show that *Funtumia africana* is a fast growing species (Uster 2005, in prep.). The high abundance of this species in almost every studied forest site is evidence for Kakamega Forest to be regenerating secondary forest after previous and recent disturbances. The rareness of tall trees of the species *Diospyros abyssinica* and *Strychnos usambarensis* is explained by their growth rates. They are low growing trees and need a long time for regeneration after disturbance. The classification of these species on the ecological list in early climax species (*F. africana*) or late climax species (*D. abyssinica* and *S. usambarensis*) is supported by the tree growth rates measured during the study of subproject E 03.

On the basis of the analysed plant communities and with the information about the age of the different forest sites a first preliminary description of the succession of Kakamega Forest was possible. The age of the forest sites could be detected by the species composition and with the data of the logging history (Mitchell 2004). The species succession within the *Harungana madagascariensis – Desmodium adscendens* – alliance was analysed and described by Schultka (1975). Our results are consitent with those of Schultka (1975) that the trees

Harungana madagascariensis, *Bridelia micrantha*, *Maesa lanceolata* and the shrub *Acanthus pubescens* are important pioneer species. Under their canopy develop the early climax species like *Funtumia africana*, *Blighia unijugata* or *Teclea nobilis*. These forest sites are the first stage of the succession of Kakamega Forest. In the northern and southern regions the succession is similar due to the forest structure, but different plant communities are involved. The composition of the common species in both forest regions is very similar but the differential species vary in each case.

In Kakamega Forest a small-scaled mosaic-structure of different regeneration phases occurs as described by Aubréville in his Mosaic or Cyclical theory of regeneration (see Richards 1996). The idea of a stable plant community of unvarying floristic composition is therefore not evident for Kakamega Forest. Nevertheless, in contrast to a cyclical idea of regeneration most of the plant communities of the forest have undergone disturbance in the past and the changes are part of a normal process of development towards a stable climax.

Due to several gaps they promote the development of seedlings and saplings and therefore contribute to forest regeneration. The first invaders of gaps are herbs and lianas of the families Acanthaceae (*Justicia* spec., *Isoglossa* spec.), Amaranthaceae (*Achyranthes aspera*, *Sericostachys scandens*), Lamiaceae (*Achyrospermum parviflorum*), Asteraceae (*Melanthera scandens*, *Microglossa* spec.), Curcurbitaceae (*Cucumis* spec., *Coccinia* spec., *Momordica* spec.), Dioscoreaceae (*Dioscorea* spec.) and Solanaceae (*Solanum mauritianum*, *Solanum terminale*). Beside pioneer species which form the initial stage of forest regeneration also a sufficient number of adult trees of climax species should be remaining for further forest regeneration (Mutangah 1996).

The greater the disturbance of a climax forest gets the longer it will take to recover. Climax species are slow in recolonising land that has been totally cleared unless seed trees remain (Whitmore 2001). In Kakamega Forest adult seed trees remain in adequate numbers to suggest possible regneration towards a primary rainforest except for *Entandophragma angolense* and *Tabernaemonata ventricosa*.

Several plantations of exotic tree species occur in and around Kakamega Forest. Exotic tree species may not cater for the requirements of wildlife and may have undesirable environmental effects (Lwanga 2003). Analyses of diversity of understorey arthropods in the *Eucalyptus*-afforested fragment Malava demonstrate the decline of the insect species compared to indigenous forest sites (Deshmukh 1982). Artificial restoration of clear-felled land by exotic tree plantations is a promising method to allow natural succession under tree plantations without further human disturbances (Chapman & Chapman 1996, Fimbel & Fimbel 1996, Lwanga 2003). Beneath the indigenous and exotic tree plantations similar species assemblages to natural mature forest could be observed indicating that natural succession towards a natural forest within plantations is possible, if only human disturbance is excluded.

Indicator species

To monitor biodiversity of a habitat in repeating periods is very time-consuming and needs a lot of manpower. Instead, to assess the status of biodiversity over time measurable indicator species can be selected (Noss 1990). To sustain biodiversity ecologists and forest resource managers need measures to judge the success and failure of management regimes (Lindenmayer et al. 2000).

Suitable indicator species allow a rapid assessment of the structure and quality of a forest. Vascular plant species can indicate different important aspects to evaluate the state of a forest. Not only the occurrence but also the abundance of an indicator species is important to know. A high abundance of young individuals of *Funtumia africana* or *Craibia brownii* indicates past disturbance (Mutangah 1996). Tall specimens of *Polyscias fulva* are mainly growing in gaps or along disturbed forest edges and are therefore an additionally indicator species for disturbance. In this case for natural and anthropogenic disturbance, because gaps arise from treefall of older climax tree species or due to selective logging of single trees. Also, the missing of certain species indicates the lower quality of forests. The rareness of species like *Olea capensis* and *Prunus africana* in Kakamega Forest indicates heavy exploitation of the forest climax species.

Beside the indicator species presented in table 7 *Desmodium repandum* and *Dorstenia brownii* need to be emphasised here. *D. brownii* occurs in shadowed and undisturbed forest sites and is therefore related to the disturbance gradient. Nevertheless, the species can also be found in the groundlayer of exotic plantations if they are in older stages and provide dense canopies. *D. repandum* is found in dense cover in every studied forest site and also occurs in young succession stages. Therefore, it is not an indicator for undisturbed forest sites as suggested by Mutangah (1996).

This study presents different species of different life forms for Rapid Biodiversity Assessements (RBA) for future investigations on stand structure, regeneration and status quo of Kakamega Forest. Rapid assessment of protected areas and their management effectiveness enables policy makers to detect management problems and is needed to control the conservation success (Ervin 2003 a, b).

Nevertheless, the relationship between potential indicator species and total biodiversity is not well understood (Lindenmayer et al. 2000). Therefore, attention should be paid to the analysed indicator species, since they do not reflect the total biodiversity of the forest. But the abundance of tall trees of *Diospyros abyssinica* can reflect a primary forest vegetation, because this tree is a characteristic member of old climax stages in Kakamega Forest.

Isolated populations

The surrounding fragments are isolated populations from the main forest block. It was of interest whether the biodiversity declines with increasing distance to the main forest and therefore resulting in lower stability. In Kakamega Forest the fragments have different species assemblages from each other and from the main forest block. This phenomenon is not only due to fragmentation processes or isolation from the forest but due to human disturbance. Quite contrary to the expectation that forest fragments lack in species richness, the Kisere fragment belongs to the forest's best quality sites (regarding primary versus secondary forests). The species assemblages of the forest sites and fragments are related to the past and recent human disturbance within the forest. In a study about effects of fragmentation on the diversity of leaf beetle communities no decline in species richness is visible. Obviously the fragments are large enough to maintain most of the forest beetle species (Freund 2005).

Disturbance and biodiversity

The pattern of plant species distribution is influenced by two main factors. The plant species as well as the study sites are scattered along a disturbance gradient and a north-south gradient. A similar result is presented by the distribution and species composition of trees larger than 5 cm DBH in 20 x 20 m plots (Uster 2005, in prep.). This means that different sampling methods of plant species on the one hand measured by their coverage in relevés (present study) and on the other hand by individual counting in plots (Uster 2005, in prep.) produced a similar distribution pattern. The different vegetation of the forest is mainly caused by the human disturbance history. But a north-south gradient is the second determining factor of the species distrubiton. This north-south gradient is probably caused by environmental conditions like shifting precipitation and average temperature as well as through different soil properties. Habitat fragmentation belongs to the term human disturbance as well. Comparison of tree species numbers between the main forest block and the surrounding fragments show a lower amount of species in the fragments than in the main forest. However, these results must be treated carefully. Certainly an effect of habitat fragmentation on the species inventory in the fragments should be expected, but fragments in good quality, like the Kisere fragment, are included in the analysis as well as the species poor Kaimosi fragment. Additionally, different succession stages within the fragments and the main forest block were incorporated in the analysis. Nevertheless, fragments of smaller sizes compared to the main forest block assemblage a lower plant species number. Attention should be paid to the result that lower tree species numbers were recorded in the FD sites compared to those of the KWS. Not only the stricter rules in conservation of the forests controlled by the KWS but also other factors like climate, soil properties and disturbance history should be taken into consideration. However, Bleher et al. (2005) detected that logging activities appear to has been reduced in the KWS's National Reserve over the last 20 years, since that institution took over the control from the FD. The forest sites under the management of the FD still face the same human impact like 20 years ago.

Diversity of plant communities and floristic composition are influenced by several factors like alitude, soil fertility, precipitation, spatial and temporal heterogeneity and vegetation history (Gentry 1988). All these factors influence the vegetation of Kakamega Forest reflected by the north-south gradient, but the main reason for the species composition and forest structure is the past and recent human impact.

Highest species richness could be measured at the more disturbed forest sites like the secondary forest near the Camp site or in the southern area of Vihiga. The Shannon-Wiener indices and eveness values compared between more and less disturbed forest sites support this observation. The highest Shannon-Wiener indices were measured in disturbed sites as well as in plantations. Forest sites which are considered to be near-primary like in Kisere or Yala have lower α-diversity. A correlation between species diversity and disturbance shows increasing species richness with increasing disturbances. Disturbance promotes diversity in habitats if not exceeding a certain threshold (Scully 2001). The theory that moderate disturbances promote species diversity, because a heterogenous habitat is created, is supported by several authors and by the present study (Gentry 1982, Collins et al. 1995, Hiura 1995, Laurance et al. 2001). The high diversity of trees in tropical rainforests is maintained by severe natural and human disturbances. It is a nonequilibrium state which, if not disturbed further,will progress towards a low-diversity equilibrium community which will be sustained by niche diversification or by a compensatory mortality that favours inferior competitors (Connell 1978).

Although species diversity increases with disturbance, higher species richness is not automatically correlated with habitat quality. More plant species in the disturbed forest sites are due to a more heterogenous habitat environment with different abiotic conditions. Plant species of the open bushland as well as early climax species from the forest sites are mixed up in this disturbed zones. Additionally, left climax tree individuals raise the species richness, but not the habitat quality. A forest is most species-rich when disturbance is at an intermediate intensity, because it contains both pioneer and climax species (Whitmore 2001).

The question is which species should be conserved. If a high number of forest-dependent plant species is preferred disturbance should be excluded. The case of bryophytes and lichens of Kakamega Forest is a good example for different impacts of disturbance. The more disturbed and therefore open and light a forest is, the more lichens could be recorded on the stems and branches. But due to the lighter, warmer microclimate bryophytes decline (Fischer 2004). If forest-dependent bryophyte species should be conserved disturbance events should be avoided, because mosses need humid, shadowed conditions. A decline of primary forest species in correlation with disturbance is also recorded (Chittibabu 2000, Barthlott et al. 2001). The theory of highest species diversity with intermediate disturbance is studied and discussed by several authors. Nevertheless, at a small-scale, in gaps inside the forest species richness is promoted, because forest-dependent tree species regenerate within the gaps and new species get the chance to develop. But in the disturbed forest sites species richness of forest-dependent species is low in Kakamega Forest, because of the broad and long-term human disturbances in the past.

Disturbance should be separated into natural and human disturbances. Natural disturbances include tree fall, which creates gaps, wind, fire or herbivory. For the development of structure and function of forest ecosystems natural disturbance is fundamental as an extensive literature supports (Attiwill 1994). High species diversity in tropical rainforests is often explained by the occurrence of a high amount of natural disturbance (Wright et al. 1997). The hypothesis predicts that natural disturbance is a major force promoting tree species diversity. But long-term human disturbances reduce species diversity and habitat stability (Folster 1994). The theory that maximum diversity occurs at intermediate size, frequency, and intensity of disturbance should be proved for Kakamega Forest regarding disturbance-life-history interactions and short- and long-term effects of disturbance on species diversity (Roberts & Gilliams 1995).

But further investigations are needed to understand how disturbance (natural and human) influences species diversity (Sheil & Burslem 2003).

The analysed characteristic species for the plant communities of Kakamega Forest reflect quite different succession stages due to human disturbance rather than to edaphic, climatic or topographic factors.

Habitat stability

A high biodiversity in a studied forest site is not a clear evidence for a high quality of the forest, if quality is equate with plant species composition equal to primary rainforest. Many species in a habitat often occur as a result of disturbance. The question if a high biodiversity is correlated with stability in a habitat is therefore not easy to answer. Not only the occurrence of many species is a measure for stability, also the ecological range of the plant species is of importance. A lot of pioneer species which are not forest-dependent are not a good measure for forest quality. Instead, abundant occurrence of seedlings and saplings of climax species which are indicators for regeneration of a forest site can maintain habitat stability.

Therefore, not only the amount of plant species should be measured to evaluate forest quality, also the occurrence of species which maintain forest health (early climax species, which prepare the environmental conditions for the late climax species), species which characterise forest habitats (e.g. indicator species for humid, shadowed forests), species which indicate forest degeneration (amount of pioneer species or the stand structure of overexploited trees) and plants of anthropogenic value (species of ethnobotanical importance) should be taken into consideration.

Biotic interactions

The long-term maintenance of plant communities is highly connected to pollination processes. In tropical rainforests most of the plant species are pollinated by animals or more precisely by insects. Human disturbance and fragmentation of continuous forests can lead to the disruption of the mutualistic pollinator-plant relationship. In fragmented plant populations this pollinator service is therefore often reduced. Studies on three plant species in Kakamega Forest showed that the frequency of the animal visits in fragments is even higher than in the continuous forest (Kraemer 2004). The measured pollination success has therefore other, different reasons (Bergsdorf 2005). Perhaps due to the edge effects in fragments the visitation frequency on the forest plants is not restricted. To answer the question whether the important pollinators of the main plant species of the forest still exist in the fragments and whether they are sufficiently abundant to be successful pollinators and to maintain the plant communities needs further investigations.

Most of the tropical plant species also rely on animals for dispersal of their seeds. Seed dispersal is also important for forest regeneration and is essential for the long-term maintenance of tree populations and plant communities in tropical forests (Bleher & Böhning-Gaese 2004). The frugivore communitiy of Kakamega Forest, among them birds and primates, was affected by habitat fragmentation. Significantly fewer frugivorous species and individuals were recorded in the fragments than in the main forest (Farwig 2005).

Biotic interactions seem to have different influences on the biodiversity of fragmented habitats in Kakamega Forest. A decline in pollination and seed dispersals in fragments can lead to changes in the species composition and therefore have consequences for the dynamics and stability of forest ecosystems. But further data and understanding of the highly complex interactions and processes are needed for future management decisions.

Within the BIOTA-project effects of degradation and fragmentation on the genetic population structure of phytophagous beetles were studied (Patt 2005). The genetic differentiation in populations of a weevil between northern and southern forest sites might be reflected by the shifting vegetation. Hence, the vegetation structure and plant species composition might be responsible for the distribution pattern of the animals living inside the forest. Management strategies should therefore be designed dependent on what kind of plants and animals should be conserved.

Stand structure

Altogether about 112 tree species could be recorded in Kakamega Forest. Other studies on tropical rainforests in Africa found 100 to 150 tree species per ha (Richards 1996, Swaine & Hall 1988, Gentry 1988). This is slightly more than our results in Kakamega Forest, once again indicating the species poverty of this forest. Moreover, in neotropical rainforests tree species numbers of over 280 can be recorded (Gentry 1988, De Oliveira & Mori 1999) and species numbers between 200 and 220 per ha in Asia (Richards 1996).

The dbh size-class distribution of the trees of the four distinguished vegetation groups has an 'inverse J'-curve indicating that a continuous recruitment is taking place (Swaine et al. 1987, Hornberg et al.1995, Fashing et al. 2004). Therefore, the forest sites are structurally stable (De Oliveira & Mori 1999). Low stem numbers in smaller size-classes indicate poor recruitment in a given forest site and that regeneration does not proceed (Fashing et al. 2004). Thus, regarding the 'inverse J'-curves of the studied forest sites regeneration takes place everywhere in the forest. High stem density in smaller size-classes could be observed in the middle and southern forest sites compared to the northern forest site within the Buyangu National Reserve. Therefore, regeneration is higher in the middle and southern part (Scully 2001).

Three different views on how the spatial structure of natural forest stands can develop are: (1) Competitive interference of neighbouring trees (density-dependent mortality) produces spatial patterns that change from clumped or random in pioneer stands to more or less regular in old-growth stands. (2) Small-scaled clumped patterns occur due to heterogeneity. (3) Given the hypothesis that trees are randomly dispersed in natural stands, numerous studies indicate that spatial patterns of mature trees do not differ significantly from random (Szwagrzyk et al. 1993, Mutangah 1996). Most of the trees along the variable-area transects show uniform patterns indicating that the spatial structure is typical for oldgrowth stands. Clumped patterns occur where logging activities took place. Fine-scale spatial patterns (with distances among trees not exceeding 15 m) were usually between random or regular (Szwagrzyk et al. 1993). This observation was done during the present study supporting the hypothesis that in fine-scale spatial patterns the tree distribution is regular, more precisely is uniform. Distances exceeding 15 m were measured when a clumped pattern was estimated.

Patterns in vegetation are created and maintained by their environment, e.g. interrelations between plants, soil heterogeneity, but also by animals in terms of dispersal or herbivory, fire, disturbance or historical causes (Greig-Smith 1979).

High similarity in the species composition occurs in forest sites of the northern half between studied sites of similar age and succession stage. The younger and the more disturbed a studied forest site is, the lower the similarity in the diversity compared to an older forest site is. Although Kisere forest is about 2 km away from the Camp forest or Colobus it has high similarity with Colobus, because of a similar age compared to the Camp forest which is a very young secondary forest. Thus, high overlapping in species compositions between studied forest sites are not a result of low geographical distances but rather a matter of similar stand structure development.

High β-diversity could be measured between forest sites of low distances in the southern half like between Yala and Ikuywa. Not only geographical distance influences the species similarity but also the succession stage of the forest sites. For example high similarity in species composition was also measured between Isecheno and Kisere about 8 km away. Similar observations were done for young secondary forests of Vihiga in the south or Buyangu in the north. Here higher values could be recorded than to forests in direct neighbourhood like between Vihiga and Ikuywa. Due to different levels of succession both forests are different in the species assemblage.

The more stems per unit were recorded the lower was the dbh of the trees and their basal area. Dbh of trees is a measure for the age of the individuals. The more younger individuals a forest site contains, the younger is the succession stage. But due to the different logging history of the forest sites, some exceptions could be observed. Kisere and Yala were classified as old mature forests, but Yala contains more stems and a lower basal area compared to Kisere. An explanation could be that recent disturbance takes place in Kisere and a lot of young stems are cut for poles construction, therefore lower numbers of them were recorded. Additionally Kisere holds the biggest trees, except for Shiamololi, and therefore the highest basal area of all studied sites which results in lower space for new, young trees to develop. The recorded basal area of studied sites is an approved measure for the age and quality of those forest sites. But attention has to be paid, because older plantations have similar basal areas like natural forest stand with past disturbance.

A quite easy and timesaving method to estimate the forest quality is to record the vegetation height along transects in different forest sites. Although Colobus was “only” a middle-aged forest compared to a near-primary forest of Kisere it shows a quite low numbers of gaps inside the stand structure compared to Kisere. This might be a result of the better protection through the rangers of the KWS close to the Colobus forest. In Busambuli and Salazar high levels of selective logging took place through a great sawmill company resulting in a still disrupted forest canopy with a lot of gaps. Illegal, recent logging activities could not be recorded in these areas and the gaps might be a result of the past disturbances. In Bukhaywa several gaps occur and in nearly each gap cut stems of tall individuals could be recorded (personal observations). Although it is part of the Buyangu National Reserve solid, recent disturbances come to pass.

The species composition of the studied forest sites reflects the logging history of Kakamega Forest. Areas which underwent high disturbances through clear-felling and pit-sawing were heavily reduced and changed in their stand structure. In contrast, areas like the reserves in the northern fragment Kisere and in the southern fragment Yala never experienced large-scale logging and were the only forest sites that could be characterised as old secondary or near-primary forests.

Remarkable trees

Interestingly the now most abundant tree species *Antiaris toxicaria* and *Funtumia africana* were cut in later decades than e.g. *Olea capensis* or *Prunus africana* in each area. Perhaps, the valuable, favoured tree species were less abundant after selective logging and new trees were chosen for the timber industry. Therefore, both species became more abundant due to the new possibilites to grow there. On the other hand these species possibly could have been always abundant there, but were of lower interest, until *O. capensis* and *P. africana* were over-exploitated.

Records of foresters' enumeration, before the forest were logged, report that today's very abundant tree species *Funtumia africana* was always a major species in Kakamega Forest. There were high numbers of *F. africana* north of the Isecheno-Ikuywa road and west of Vihiga. In the Annual Report of 1959 ecological reasons for the distribution patterns of certain species were denounced (Mitchell 2004). Beside *O. capensis* and *P. africana Zanthoxylum gillettii* and *C. africana* became rare in the forest due to the logging activities. They were among the most logged tree species in the past. Now tall trees of *Z. gillettii* are rare in the forest, apart from the plantations. It was planted e.g. in Malava in high numbers to regenerate its stock.

C. africana is occassionally scattered over the forest, but is now missing in the northern Buyangu Hill area. *Olea capensis* was considered to grow in the northern half of the forest in high individual numbers. The Vihiga area was known to be rich in that tree species, too and the northern Malava fragment was reported to be the best place for logging of *O. capensis* (Mitchell 2004). Due to the commercial activities all of these forest sites, as well as whole Kakamega Forest, are poor in this valuable timber tree nowadays, which is expected to be one of the primary tree species of the forest (Mutangah 1996).

9. References

Adams, J.E. & McCune, E.D. (1979), Application of the generalized jacknife to Shannon's measure of information used as an index of diversity, In: Ecology Diversity in Theory and Practice, Grassle, J.F., Patil, G.P., Smith, W. & Taillie, C. (eds.), 117-131, International Cooperative Publishing House, Fairland, Maryland

Agnew, A.D.Q. & Agnew, S. (1994), Upland Kenya wild flowers, East Africa Natural History Society, Nairobi

Analo, C.I. (2003), Adventure of Kakamega Forest, BIOTA East Africa, E12, Bonn

Attiwill, P.M. (1994), The disturbance of forest ecosystems - The ecological basis for conservative management, Forest ecology and management 63 (2-3): 247-300

Austin, M.P. & Greig-Smith, P. (1968), The application of quantitative methods to vegetation survey. II. Some methodological problems of data from rain forest, Journal of Ecology 56: 827-844

Barkman, J.J., Doing, H. & Segal, S. (1976), Kritische Bemerkungen und Vorschläge zur quantitativen Vegetationsanalyse, Acta Botanica Neerlandica 13: 394-419

Barkman, J.J. (1989) A critical-evaluation of minimum area concepts, Vegetatio 85 (1-2): 89 - 104

Barthlott, W., Schmidt-Neuerburg, V., Nieder, J. & Engwald, S. (2001), Diversity and abundance of vascular epiphytes: a comparison of secondary vegetation and primary montane rain forests in the Venezuelan Andes, Plant Ecology 152 (2): 145-156

Bazzaz, F.A. (1998), Tropical forests in a future climate: Changes in biological diversity and impact on the global carbon cycle, Climatic change 39 (2-3): 317-336

Beck, E., Scheibe, R. & Senser, M. (1983), The vegetation of the Shira Plateau and the western slopes of Kibo (Mt. Kilimanjaro, Tanzania), Phytocoenologia 11: 1-30

Beck, E., Rehder, H., Schulze, E.D. & Kokwaro, J.O. (1987), Alpine plant communities of Mt. Elgon – An altitudinal transect along the Koitoboss Route, J. E. Afr. Nat. His. Soc. & Nat. Mus. 76: 1-12

Beck, E., Rehder, H. & Kokwaro, J.O. (1990), Classification and mapping of the vegetation of the alpine zone of Mt. Kenya (Kenya), Geogr. Bern. Afr. Stud. Ser. A8, Mt. Kenya Area: 41-46

Beentje, H.J. (1990), The forests of Kenya, Mitt. Inst. Allg. Bot. Hamburg 23a, 265-286

Beentje, H.J. (1994), Kenya trees, shrubs and lianas, National Museum of Kenya, Nairobi

Bennun, L. & Njoroge, P. (1999) Important Bird Areas in Kenya, The East Africa Natural History, Nairobi

Bergsdorf, T. (2005), Forest fragmentation and plant-pollinator interactions in Western Kenya, Ph.D. thesis (in prep.), University of Bonn, Germany

Blackett, H.L. (1994), Forest Inventory Report No. 3: Kakamega. Kenya Indigenous Forest Conservation Programme (KIFCON), Nairobi, Kenya

Bleher, B. & Böhning-Gaese, K. (2004), Effect of fragmentation on seed dispersal, regeneration and dynamics of Kakamega Forest, Kenya, in: BIOTA East Africa, Final report phase I: 2001 - 2004

Bleher, B., Uster, D. & Bergsdorf, T. (2005), Assesment of threat status and management effectiveness in Kakamega Forest, Kenya, Biodiversity and Conservation 00: 1-19, in press.

Bonnefille, R., Roeland, J.C. & Guiot, J. (1990) Temperature and rainfall estimates for the past 40,000 years in equatorial Africa, Nature 346 : 347-349

Braun-Blanquet, J. (1964), Pflanzensoziologie, Grundzüge der Vegetationskunde, Berlin

Bray, J.R. & Curtis, T. (1957), An Ordination of the upland forest communities of Southern Wisconsin, Ecological Monographs 27 (4): 325-349

Bruelheide, H. (1995) Die Grünlandgesellschaften des Harzes und ihre Standortsbedingungen. Mit einem Beitrag zum Gliederungsprinzip auf der Basis von statistisch ermittelten Artengruppen. Dissertationes Botanicae 244: 1-338.

Bruelheide, H. (2000) A new measure of fidelity and its application to defining species groups, Journal of Vegetation Science, Vol. 11: 167-178

Brooks, T.M., Pimm, S.L. & Oyugi, J.O. (1999), Time lage between deforestation and bird extinction in tropical forest fragments, Conservation Biology 13 (5): 1140-1150

Brown, L.H. (1981), The conservation of forest islands in areas of high human density, African Journal of Ecology 19: 27-32

Bussmann, R.W. (1994) The forests of Mount Kenya (Kenya) – Vegetation, Ecology, Destruction and Management of a tropical mountain forest ecosystem, Ph.D. thesis, Universität Bayreuth, Germany

Bussmann, R.W. & Beck, E. (1995) The forests of Mt. Kenya (Kenya), a phytosociological synopsis, Phytocoenologia 25 (4): 467-560, Berlin-Stuttgart

Bussmann, R.W. (2002) Islands in the desert – forest vegetation of Kenya's smaller mountains and highland areas, Journal of East African Natural History, Vol. 91: 27-79

Bormann, F.H. (1953), The statistical effiency of sample plot size and shape in forest ecology, Ecology 34 (3): 474-487

Bouxin, G. (1977), Structure de la strate arborescente dans un site de la forêt de montagne du Rwanda (Afrique Centrale), Vegetatio 33 (2-3) : 65-78

Chapman, C.A. & Chapman, L.J. (1996), Exotic tree plantations and the regeneration of natural forests in Kibale National Park, Uganda, Biological Conservation 76: 253-257

Chapman, C.A. & Chapman, L.J. (2004), Unfavorable successional pathways and the conservation value of logged tropical forest, Biodiversity and Conservation 13 (11): 2089-2105

Chapman, C.A., Chapman, L.J., Struhsaker, T.T. et al. (2005), A long-term evaluation of fruiting phenology: importance of climate change, Journal of Tropical Ecology 21 (1): 31-45

Chittibabu, C.V. & Parthasarathy, N. (2000), Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India, Biodiversity and Conservation 9 (11): 1493-1519

Clark, D.A. (2004), Sources or sinks? The responses of tropical forests to current and future climate and atmospheric compositions, Philosophical transactions of the Royal Society of London, Series B-Biological Sciences 359 (1443): 477-491

Collar, N.J. & Stuart, S.N. (1988) Key forests for threathened birds in Africa, International Council for Bird Preservation, Monograph No. 3, IUCN, Cambridge, U.K.

Collinge, S.K. (2003), Ecological consequences of habitat fragmentation: Implications for landscape architecture and planning, Landscape and Urban Planning 36 (1): 59-77

Collins, S.L., Glenn, S.M. & Gibson, D.J. (1995), Experimental-analysis of intermediate disturbance and initial floristic composition – Decoupling cause and effect, Ecology 76 (2): 486-492

Condit, R. (1995), Research in large, long-term tropical forest plots, Trends in Ecology & Evolution (TREE) 10 (1): 18-22

Connell, J.H. (1978), Diversity in Tropical Rain Forests and Coral Reefs, Science 199 (24): 1302-1310

Cords, M.C. (1987) Demography of Blue Monkeys in the Kakamega Forest, Kenya, International Journal of Primatology, Vol. 8: 546

Cottham, G. & Curtis, J.T. (1956) The use of distance measures in phytosociological sampling, Ecology Vol. 37, No. 3: 451-460

Dalitz, H. (2004), Regeneration of tropical-montane tree species – Spatio-temporal dynamcis of positive feedback processes, in: BIOTA East Africa, Final report phase I: 2001 – 2004

De Oliveira, A.A. & Mori, S.A. (1999), A central Amazonian terra firme forest, I. High tree species richness on poor soils, Biodiversity and Conservation 8: 1219-1244

Deshmukh, I.K. (1982), Diversity of understory arthropods in an indigenous forest and an exotic *Eucalyptus* plantation in western Kenya, Kenya Journal of Science and Technology 3: 3-7

Diamond, A.W. (1981), Reserves as oceanic islands: lessons for conserving some East African montane forests, African Journal of Ecology 19: 21-25

Diamond, T. (1979), Kakamega: Is there a way to stop the rot?, Swara 2 (1): 25-26

Dierschke, H. (1994) Pflanzensoziologie, Ulmer Verlag, Stuttgart

Dietzsch, A. (2004), Effects of interspecific pollen transfer on seed set in two East African *Acanthus* species (Acanthaceae), Ms. thesis, University of Bonn

Dharani, N. (2002), Field guide to common trees & shrubs of East Africa, Struik Publishers, Cape Town, South Africa

Dowestt-Lemaire, F. (1985), The forest vegetation of the Nyika Plateau (Malawi-Zambia): ecological and phenological studies, Bull. Jard. Bot. Nat. Belg. 55: 301-392

Ellenberg, H. (1996), Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer und historischer Sicht, 5. Auflage, Ulmer, Stuttgart, pp. 1095

Ervin, J. (2003 a), Rapid assessment of protected area management effectivness in four countries, Bioscience 53 (9): 833-841

Ervin, J. (2003 b), Protected area assessments in perspective, Bioscience 53 (9): 819-822

Faden, R.B. (1994), New species of *Commelina* (Commelinaceae) from the Flora of Tropical East Africa, Novon 4: 224-235

Fahrig, L. (2003), Effects of habitat fragmentation on biodiversity, Annual Review of Ecology, Evolution, and Systematics 34: 487-515

Farwig, N. (2005), Influence of forest fragmentation and disturbance on seed dispersal, seed predation, and genetic structure of *Prunus africana* in Kakamega Forest, Ph.D. thesis (in prep.), University of Mainz, Germany

Fashing, P.J., Forrestel, A., Scully, C. & Cords, M. (2004), Long-term tree population dynamics and their implications for the conservation of the Kakamega Forest, Kenya, Biodiversity and Conservation 13: 753-771

Fashing, P.J. & Gathua, J.M. (2004), Spatial variability in the vegetation structure and composition of an East African rain forest, African Journal of Ecology 42 (3): 189-197

Fashing, P.J. (2004), Mortality trends in the African Cherry (*Prunus africana* and the implications for Colobus monkey (*Colobus guereza*) in Kakamega Forest, Kenya, Biological Conservation 120 (4): 449-459

Fimbel, R.A. & Fimbel, C.C. (1996), The role of exotic conifer plantations in rehabiliting degraded tropical forest lands: a case study from the Kibale National Park, Uganda, Forest Ecology and Management 81: 215-226

Fischer, E. & Hinkel, H. (1992), Natur Ruandas, Ministerium des Inneren und für Sport, Rheinland-Pfalz, Mainz

Fischer, E. (1996), Die Vegetation des Parc National Kahuzi-Biéga/Zaire, Erdwissenschaftliche Forschung 35: 1-240

Fischer, E. (2000 a), Flora and vegetation of the Afromontane region in Central and East Africa, in: Isolated Vertebrate Communities in the Tropics, ed. Rheinwald, G., Proceedings of the 4th International Symposium, Bonn, Bonner Zoologische Monographien 46

Fischer, E. (2000 b), Influence of anthropogenic and natural fragmentation on diversity of flora and vegetation in upland and montane rainforests of East-Africa, in: BIOTA East Africa, proposal, vol. 1

Fischer, E. (2004), Influence of anthropogenic and natural fragmentation on diversity of flora and vegetation in montane rainforests in East Africa, in: BIOTA East Africa, Final report phase I: 2001 - 2004

Folster, H. (1994), Stability of forest ecosystems in the humid tropics, Interciencia 19 (6): 291-296

Franklin, S.B., Gibson, D.J., Robertson, P., Pohlmann, J.T. & Fralish, J.S. (1995) Parallel analysis: a method of determining significant principal components, Journal of Vegetation Science 6: 99-106

Freund, W. (2005), Effects of fragmentation and degradation of an afrotropical rain forest on the diversity structure of leaf beetle communities (Coleoptera, Chrysomelidae), Ph.D. thesis, University of Bonn, Germany

Friis, I. (1992), Forests & Forest Trees of Northeast Tropical Africa, Kew Bulletin Additional Series XV, London

Gauch, H.G. (1994), Multivariate analysis in community ecology, Cambridge

Gentry, A.H. (1982), Patterns of Neotropical Plant Species Diversity, Evolutionary Biology 15: 1-84

Gentry, A.H. (1988), Changes in plant communities diversity and floristic composition on environmental and geographical gradients, Ann. Missouri. Bot. Gard. 75 (1): 1-34

Gillespie, T.W. (2005), Predicting wood-plant species richness in tropical dry forests: A case study from South Florida, USA, Ecological Applications 15 (1): 27-37

Good, I.J. (1953), The population frequencies of species and the estimation of population parameters, Biometrika 40: 237-264

Greig-Smith, P., Austin, M.P. & Whitmore, T.C. (1966), The application of quantitative methods to vegetation survey. I.Association-analysis and principal component ordination of rain forest, Journal of Ecology 55 (2): 483-503

Greig-Smith, P. (1979), Pattern in vegetation, Journal of Ecology 67: 755-779

Greenway, P.J. (1943), Second draft report on vegetation classification for approval of the vegetation committee, pasture resaerch conference, East African Agricultural Research Station Amani

Greiner, A. (1991), Nature Conservation and local people at Kakamega Forest, ASA Project, Final Report, Stuttgart, Germany

Haines, R.W. & Lye, K.A. (1983), The sedges and rushes of East Africa, East African Natural History Society, Nairobi

Hamilton, A. (1991), A field guide to Ugandan forest trees, Institute of Environment and Natural Resources, Makere University, Kampala

Hamilton, A.C. & Perrott, R.A. (1981), A study of altitudinal zonation in the montane forest belt of Mt. Elgon, Kenya/Uganda, Vegetatio 45: 107-125

Hamilton, A.C. (1981), The quaternary history of African forests: It's relevance to conservation, African Journal of Ecology 19: 1-6

Haupt, M. (2000), Traditional use of and reliance on the forest among the Luhya people with special regard to the traditional medical system and the use of medicinal plants in Kakamega Forest, Western Kenya, Materialien zur Ostafrika-Forschung, Heft 24, Geographische Gesellschaft Trier, Jätzold, R. & Hornetz B. (eds.)

Hedberg, O. (1951), Vegetation belts of the East African mountains, Svensk Botanisk Tidskrif, Vol. 45: 1

Hedberg, I. & Edwards. S.A. (eds.), (1989) Flora of Ethiopia, Vol. III, Pittosporaceae to Araliaceae, The National Herbarium of Addis Ababa, Ethiopia

Hiura, T. (1995), Gap formation and species diversity in japanese beech forests – A test of the intermediate disturbance hypothesis on a geographical scale, Oecologia 104 (3): 265-271

Hill, M.O. (1973), Diversity and evenness: a unifying notation and its consequences, Ecology 54: 427-432

Hill, M.O. & Gauch, H.G. (1980), Detrended correspondence analysis, an improved ordination technique, Vegetatio 42: 47-58

Homeier, J. (2004), Baumdiversität, Waldstruktur und Wachstumsdynamik zweier tropischer Bergregenwälder in Ecuador und Costa Rica, Ph.D. thesis, University of Bielefed, Germany

Hornberg, G., Ohlson, M. & Zackrisson, O. (1995), Stand dynamics, regeneration patterns and long-term continuity in boreal old-growth *Picea abis*-swamp-forests, Journal of Vegetation Science 6 (2): 291-298

Hopkins, B. (1954), A new method for determining the type of distribution of plants individuals, Annals of Botany, Vol. 18, No. 70: 213-227

Hurlbert, S.H. (1971), The non-concept of species diversity: a critique and alternative parameters, Ecology 52:577-586

Jätzold, R. & Schmidt, H. (1982), Farm Management Handbook of Kenya, Vol. II/A: West Kenya, Rossdorf

Johns, R.J. (1991), Pteridophytes of Tropical East Africa, A preliminary Check-List of the species, Royal Botanic Gardens Kew, Richmond

Jongman, R.H.G., ter Braak, C.J.F. & van Tongeren O.F.R. (1995), Data analysis in communitiy and landscape ecology, Cambridge

Kalinganire, A., Harwood, C.E., Slee, M.U. & Simons, A.J. (2001) Pollination and fruit-set of *Grevillea robusta* in western Kenya, Austral Ecology, Vol. 26: 637-648

Kiami, D. & Kiyiapi (2000), Shade tolerance and regeneration of some tree species of a tropical rain forest in Western Kenya, Plant Ecology 00: 1-9

KIFCON (1994), Kakamega Forest - The official guide, Kenya Indigenous Forest Conservation Programme, Nairobi, Kenya

Kigomo, B.N. (1987), Some observations on regeneration trials in the Kakamega and south Nandi natural forests, Kenya, E. Afr. agric. For. J. 52 (3): 184-195

Kerfoot, O. (1964), The vegetation of the south-west Mau forest, E. Afr. Agr. For. J. 29: 295-318

Kempton, R.A. (1979), The structure of species abundance and measurement of diversity, Biometrics 35: 307-321

Klötzli, F. (1958), Zur Pflanzensoziologie der alpinen Stude des Kilimandscharo, Ber. Geobot. Inst. Rübel 19: 33-59

Knapp, R. (1973), Die Vegetation von Afrika, Gustav Fischer Verlag, Stuttgart

Köhler, J. (2004), Biodiversity in conversion: The influence of fragmentation and disturbance on the biodiversity of East African highland rain forests, in: BIOTA East Africa, Final report phase I: 2001 - 2004

Kokwaro, J.O. (1988), Conservation status of the Kakamega Forest in Kenya: The easternmost relic of the equatorial rain forests of Africa, Monographs in Systematic Botany from the Missouri Botanical Garden, 25: 471-489

Kokwaro, J.O. (1993), Medicinal plants of East Africa, Kenya Literature Bureau, Second Edition, Nairobi

Kokwaro, J.O. (1994), Flowering plant families of East Africa - An Introduction to plant taxonomy, East African Educational Publishers, Nairobi

Kraemer, M. (2004), Effects of habitat fragmentation on plant-pollinator interactions in East african rainforests, in: BIOTA East Africa, Final report phase I: 2001 - 2004

Krebs, C. J. (1999), Ecological Methodology, Second Edition, New York

Küper, W., Sommer, J.H., Lovett, J.C., Mutke, J., Linder, H.P., Beentje, H.J., Van Rompaey, R.S.A.R., Chatelain, C., Sosef, M. & Barthlott, W. (2004), Africa's hotspots of biodiversity redefined, Annals of the Missouri Botanical Garden 91 (4): 525-535

Laurance, W.F. & Bierregaard, R.O. (eds.) (1997), Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities, University of Chicago Press, Chigaco, Illinois

Laurance, W.F., Perez-Salicrup, D., Delamonica, P., Fearnside, P.M., D'Angelo, S. Jerozolinski, A., Pohl, L. & Lovejoy, T.E. (2001), Rain forest fragmentation and the structure of Amazonian liana communities, Ecology 82 (1): 105-116

Leeuvenberg, A.J.M. (1991), A revision of *Tabernaemontana*, The Old World Species, Royal Botanic Garden Kew, London

Letouzey, R. (1986), Manual of Forest Botany, Tropical Africa (Vol.1, 2A, 2B), Centre Technique Forestier Tropical, Nogent-Sur-Marne, France

Lieberman, D. & Lieberman, M. (1987), Forest tree growth and dynamics at La Selva, Costa Rica (1962-82), Journal of Tropical Ecology 3: 347-358

Lind, E.M. & Morrison, M.E.S. (1974), East African Vegetation, Longman, London

Lindenmayer, D.B., Margules, C.R. & Botkin, D.B. (2000), Indicators of biodiversity for ecologically sustainable forest management, Conservation Biology 14 (4): 941-950

Londo, G. (1971), Patron en process in duinvalleivegetaties laangs en gegraven mee in de Kennemerduinen, Verhandeling, Rijksinstuut voor Natuurbeheer 2: 1-279, Arnhem

Lovett, J.C. & Wasser, S. (1993) Biogeography & ecology of the rain forests of Eastern Africa, Cambridge University Press, Great Britian

Lughada, E.N., Baillie, J., Barthlott, W., Brummitt, N.A., Cheek, M.R., Farjon, A., Govaerts, R., Hardwick, K.A., Hilton-Taylor, C., Meagher, T.R., Moat, J., Mutke, J., Paton, A.J., Pleasants, L.J., Savolainen, V., Schatz, G.E., Smith, P., Turner, I., Wyse-Jackson, P., Crane, P.R. (2005), Measuring the fate of plant diversity: towards a foundation for future monitoring and opportunities for urgent action, Philosophical Transactions of the Royal Society B-Biological Sciences 360 (1454): 359-372

Lung, T. & Schaab, G. (2004) Change-Detection in Western Kenya – The documentation of fragmentation and disturbance for Kakamega Forest and associated forest areas by means of remotely-sensed imagery, in ISPRS Archives, Vol. XXXV, Part B (CD Rom), Proceedings of the ISPRS XXth Congress, 12-23 July 2004, Istanbul

Lwanga, J.S., Butynski, T.M. & Struhsaker, T.T. (1999), Tree population dynamics in Kibale National Park, Uganda 1975-1998, African Journal of Ecology 38 (3): 238-247

Lwanga, J.S. (2003), Forest succession in Kibale National Park, Uganda: implications for forest restoration and management, African Journal of Ecology 41: 9-22

MacArthur, R.H. (1965), Patterns of species diversity, Biological Reviews 40: 510-533

MacArthur, R.H. & Wilson, E.O. (1967), The theory of island biogeography, Princeton University Press, Princeton, N.J.

Magurran, A.E. (1988), Ecological diversity and its measurement, Crrom Helm, London

Mahli, Y. & Wright, J. (2004), Spatial patterns and recent trends in the climate of tropical rainforest regions, Philosophical transactions of the Royal Society of London, Series B-Biological Sciences 359 (1443): 311-329

McIntosh, R.P. (1967), An index of diversity and the relation of certain concepts to diversity, Ecology 48: 392-404

Mitchell, N. (2004), The exploitation and disturbance history of Kakamega Forest, Western Kenya, BIOTA East Report No. 1, Bielefelder Ökologische Beiträge, Band 20, Bleher, B. & Dalitz, H. (eds.)

Mueller-Dombois, D. & Ellenberg, H. (2002), Aims and Methods of Vegetation Ecology, New York

Muriithi, S. & Kenyon W. (2002), Conservation of biodiversity in the Arabuko Sokoke Forest, Kenya, Biodiversity and Conservation 11: 1437-1450

Muriuki, J.W. & Tsingalia, M.H. (1990) A new population of de Brazza’s monkey in Kenya, Oryx, Vol. 24, No. 3: 157-162

Mutangah, J.G., Mwangangi, O. & Mwaura, P.K. (1994), Kakamega Forest, Vegetation survey, Kenya Indigenous Forest Conservation Programme, Nairobi, Kenya

Mutangah J.G. (1996), An Investigation of Vegetation Status and Process in Relation to Human Disturbance in Kakamega Forest, Western Kenya, Ph.D. thesis, University of Wales Aberystwyth, Great Britian

Myers, N. (1984), The primary source: Tropical forests and our future, W.W. Norton, New York

Myers, N. (1988), Tropical forests and their species. Going, going…? In E.O. Wilson, ed., Biodiversity, National Academy Press, Washington, D.C.

Noss, R.F. (1990), Indicators for monitoring biodiversity – A hierarchical approach, Conservation Biology 4 (4): 355-364

Nzilani, N.J. (2002), The status of *Prunus africana* (Syn. *Pegium africanum* Hook. F.) in Kakamega and South Nandi forests, Kenya, Discovery and Innovation 57-67 Sp. Iss. SI

Ostendorf, B., Hilbert D.W. & Hopkins, M.S. (2001), The effect of climate change on tropical rainforest vegetation pattern, Ecological Modelling 145 (2-3): 211-224

Oyugi, J.O. (1996) Kakamega Forest is dying, EANHS Bulletin, Vol. 26: 3-4

Parker, K.R. (1979), Density estimation by variable area transect, Journal of Wildlife Management 43: 484-492

Patt, A. (2005), Effects of degradation and fragmentation on the genetic population structure of phytophagous beetles in an african rainforest, Ph.D. thesis, University of Bonn

Peet, R.K. (1974), The measurement of species diversity, Annual Review of Ecology and Systematics 5: 285-307

Perez-Vera, F. (2003), Les Orchidées de Côte d'Ivoire, Pantinope Collection, Mèze, France

Plumptre, A.J. (1996), Changes following 60 years of selective timber harvesting in the Budongo Forest Reserve, Uganda, Forest Ecology and Management 89: 101-113

Prigogine, A. (1978), Note sur les petits Indicateurs de la foret de Kakamega, Le Gerfaut 68: 87-89

Polhill, R.M. (1989), East Africa, In : Floristic Inventory of Tropical Countries, Campbell, D.G. & Hammond, D. (eds.) pp. 217-231

Rehder, H., Beck, E., Kokwaro, J.O. & Scheibe, R. (1981), Vegetation analysis of the upper Teleki Valley (Mount Kenya) and adjacent areas, J. E. Afr. Nat. His. Soc. and Nat. Mus. 171: 2-8

Rehder, H., Beck, E., & Kokwaro, J.O. (1988), The Afroalpine plant communities of Mt. Kenya (Kenya), Phytocoenologia 16: 433-463

Richards, P.W. (1996), The tropical rain forest: an ecological study, Cambrigde University Press, Cambridge, 2nd edition, 575 pp.

Roberts, M.R. & Gilliam, F.S. (1995), Patterns and mechanisms of plant diversity in forested ecosystems – Implications for forest management, Ecological Applications 5 (4): 969-977

Robyns, W. et al. (eds.) (1960-63), Flore du Congo Belge et du Ruanda-Burundi, Spermatophytes Vol. VIII-X, Publications de l`Institut Nationale pour l`Etude Agronomique due Congo Belge (I. N. E. A.C.), Bruxelles

Rowell, T. (1982) Kakamega Forest, Swara, East African Wild Life Society, Nairobi, Vol. 5: 8-9

Schmidt, R. (1987), Die Mweka-Route auf den Kilimanjaro (Tanzania): ein vegetationskundlicher Höhentransekt, Diplomarbeit Universität Bayreuth, Bayreuth

Schmidt, R. (1991), Ecology of a tropical lowland rain forest, Plant communities, soil characteristics and nutrient relations of the forests in the Shimba Hills National Reserve, Kenya, Dissertationes Botanicae, Band 179, Gebrüder Borntraeger, Stuttgart

Schmitt, K. (1985), Die Afroalpine Vegetation des Ruwenzori Gebirges, Diplomarbeit Universität Bayreuth, Bayreuth

Schmitt, K. (1991), The vegetation of the Aberdare National Park Kenya, Hochgebirgsforschung, volume 8, Universitätsverlag Wagner, Innsbruck

Schultka, W. (1975) Gehölz-Sukzessionen in Regenwald- und Feuchtsavannen-Gebieten bei Kakamega (West-Kenia), Oberhessische Naturwissenschaftliche Zeitschrift, Band 42: 35-48

Scully, C. (2001), The effect of human disturbance on the vegetation of Kakamega Forest, Kenya, Ms. thesis at the Columbia University

Semazzi, F.H.M. & Song, Y. (2001), A GCM study of climate change induced by deforestation in Africa, Climate Research 17 (2): 169-182

Senterre, B., Lejoly, J. & Sonke, B. (2004) Analysis of the climatic gradient of continentality and identification of plant communities in central African rain forests using the mega-transect method, Phytocoenologia 34 (3): 491-516

Seyani, J.H. (1991), Dombeya in Africa, Opera Botanica Belgica, Vol. II, National Botanical Garden of Belgium, Meise

Sheil, D. & Burslem, D.F.R.P. (2003), Disturbing hypotheses in tropical forests, Trends in Ecology & Evolution (TREE) 18 (1): 18-26

Sleumer, H. (1975), Flacourtiaceae, In: Flora of Tropical East Africa (FTEA), Polhill, R.M. (ed.): 1-68

Sokal, R.R. & Rohlf, F. J. (1995), Biometry, Third Edition, W. H. Freeman, New York

Sørensen, T. (1948), A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons, Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter Vol 5, No. 4: 1-34, Copenhagen

Spawls, S. (1978), A checklist of the snakes of Kenya, Journal of the East Africa Natural History Society and National Museum, Vol. 31, No. 167: 1-18

Steinbrecher R. (2004), Impact of changing biodiversity in tropical agro-forest ecosystems in Africa on the exchange potential of trace gases between ecosystems and atmosphere, in: BIOTA East Africa, Final report phase I: 2001 - 2004

Stewart, J. & Campbell, B. (1996), Orchids of Kenya, St Paul’s Bibliographies, Winchester

Swaine, M.D. & Hall, J.B. (1983), Early succession on cleared forest land in Ghana, Journal of Ecology 71: 601-627

Swaine, M.D., Hall, J.B. & Alexander, I.J. (1987), Tree population dynamcis at Kade, Ghana (1968-1982), Journal of Tropical Ecology 3: 331-345

Swaine, M.D. & Hall, J.B. (1988), The mosaic theory of forest regeneration and the determination of forest composition in Ghana, Journal of Tropical Ecology 4: 253-269

Swaine, M.D. & Whitmore, T.C. (1988), On the definition of ecological species groups in tropical rain forests, Vegetatio 75: 81-86, Kluwer Academic Press, Netherlands

Szwagryzk, J. & Czerwczak, M. (1993), Spatial patterns of trees in natural forests of East-Central Europe, Journal of Vegetation Science 4 : 469-476

Tardieu-Blot, M.L. (1964), Flore du Gabon, Pteridophytes, Vol. VIII, Muséum National D'Histoire Naturelle, Paris

ter Braak, C.J.F. & Smilauer, P. (2002), Canoco 4.5 Reference Manual, Biometris, Wageningen, Ceske Budejovice

Tichy, L. (2002) JUICE, software for vegetation classification, Journal of Vegetation Science Vol. 13: 451-453

Trapnell, C.G. & Langdale-Brown, I. (1962), The natural vegetation of East Africa, Natural Resources of East Africa, Hawkins Ltd, Nairobi

Troupin, G. (1982), Flore des plantes ligneuses du Rwanda, Insitut National de Recherche Scientifique, Butare

Troupin, G. (1983), Flore du Rwanda, Spermatophytes, Vol II, Annales du Musée de Tervuren no. 9

Troupin, G. (1987), Flore du Rwanda, Spermatophytes, Vol IV, Annales du Musée de Tervuren, no. 16

Tsingalia, M.H. (1988), Animals and the regeneration of an African rainforest tree, Ph. D. thesis, University of California, Berkely

Tsingalia, M.H. (1989), Variation in seedling predation and herbivory in *Prunus africana* in the Kakamega Forest, Kenya, African Journal of Ecology 27 (3): 207-217

Tsingalia, M.H. (1990), Habitat disturbance, severity and patterns of abundance in Kakamega Forest, Western Kenya, African Journal of Ecology, 28: 213-226

Turrill, W.B., Polhill, R. & Beentje, H., (1952 ff.) Flora of Tropical East Africa (FTEA), prepared at the Royal Botanic Gardens/Kew with assistance from the East African Herbarium

Uster, D. (2005), Tree species diversity and dispersion along gradients of disturbance and of soils, Ph.D. thesis (in prep.), University of Bielefeld, Germany

Vareschi, V. (1980), Vegetationsökologie der Tropen, 1-239, Verlag Eugen Ulmer, Stuttgart

Waas, P. (1995), Kenya´s Indigenous Forests: status, management and conservation, IUCN, Gland, Switzerland

Walter, H. & Breckle, S.-W. (2004), Ökologie der Erde, Band 2: Spezielle Ökologie der tropischen und subtropischen Zonen, Elsevier GmbH, Spektrum Akademischer Verlag, München, 3rd edition, 764 pp.

Washington, H.G. (1984), Diversity, biotic and similarity indices: a review with spatial relevance to aquatic ecosystems, Water Research 18: 653-694

Wattenberg, I. & Breckle, S.-W. (1995), Tree species diversity of a premontane rain forest in the Cordillera de Tilaran, Costa Rica, Ecotropica 1: 21-30

Williams, W.T., Lance, G.N., Webb, L.J. & Tracey, J.G. (1973), Studies in the numerical analysis of complex rain-forest communities.VI.Models for the classification of quantitative data, The Journal of Ecology 61: 47-70

Webb, L.J., Tracey, J.G., Williams, W.T. & Lance, G.N. (1970), Studies in the numerical analysis of complex rain-forest communities. V.A comparison of the properties of floristic and physiognomic-structural data, The journal of ecology 58: 203-232

Wesche, K. (2002), The high-altitude environment of Mt. Elgon (Uganda, Kenya): Climate, vegetation and the impact of fire, Ecotropical Monographs No. 2, published by the Society for Tropical Ecology, Bonn

Wesche, K. & Leyer, I. (2005), Einfach komplex – Eine kurze Einführung in die Verwendung multivariater Statistik in der Ökologie (in prep.)

White, F. (1983) The vegetation of Africa, UNESCO, Paris, printed in Switzerland

Whitmore, T.C. (1997), Tropical forest disturbance, disappearance, and species loss. In: Laurance, W.F. & Bierregaard, R.O. (eds.), Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities, University of Chigaco Press, Chigaco, Illinois, pp. 3-12

Whitmore, T.C. (2001), An introduction to Tropica Rain Forests, Second Edition, Oxford University Press

Whittaker, R.H. (1967), Gradient analysis of vegetation, Biological Reviews 42: 207-264

Wolda, H. (1981), Similarity indices, sample size and diversity, Oecologia 50: 296-302

Wright, D.D., Jessen, J.H., Burke, P. & Garza, H.D.G. (1997), Tree and liana enumeration and diversity on a one-hectare plot in Papua New Guinea, Biotropica 29 (3): 250-260

Zar, J. H. (1996), Biostatistical analysis, Third Edition, Prentice-Hall, London

Zimmermann, D.A. (1972), The avifauna of the Kakamega Forest, western Kenya, including a bird population study, Bulletin of the American Museum of Natural History 149 : 255-340

Appendix 1: List of relevés. Given are numbers, date, mean elevation, location, rectangle label, physiognomy, slope, treecover, height, number of species.

No.	date	mean elevation [m]	location	rectangle	physiognomy	slope [degree]	treecover [%]	height [m]	no. of species
1	15/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	-	80	25	33
2	15/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	-	75	25	33
3	16/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	-	70	25	42
4	16/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	4	80	25	46
5	16/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	4	65	25	29
6	17/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	1	70	25	46
7	17/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	-	80	25	50
8	17/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	-	85	25	41
9	17/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	2	75	25	43
10	17/10/01	1582	Buyangu Hill	X	middle-aged secondary forest	2	90	25	37
11	18/10/01	1597	Colobus	VI	middle-aged secondary forest	-	70	25	46
12	18/10/01	1597	Colobus	VI	middle-aged secondary forest	-	70	25	47
13	18/10/01	1597	Colobus	VI	middle-aged secondary forest	-	80	25	42
14	18/10/01	1597	Colobus	VI	middle-aged secondary forest	-	80	25	45
15	18/10/01	1597	Colobus	VI	middle-aged secondary forest	-	85	25	44
16	18/10/01	1597	Colobus	VI	middle-aged secondary forest	-	75	25	39
17	19/10/01	1597	Colobus	VI	middle-aged secondary forest	-	85	25	39
18	19/10/01	1597	Colobus	VI	middle-aged secondary forest	-	45	25	50
19	19/10/01	1597	Colobus	VI	middle-aged secondary forest	-	70	25	42
20	19/10/01	1597	Colobus	VI	middle-aged secondary forest	-	65	25	48
21	21/10/01	1566	Camp forest	VIII	young secondary forest	-	60	10	55
22	21/10/01	1566	Camp forest	VIII	young secondary forest	-	75	10	62
23	22/10/01	1568	Kisere	IV	near-primary forest	-	70	30	48
24	22/10/01	1568	Kisere	IV	near-primary forest	-	70	30	48
25	22/10/01	1568	Kisere	IV	near-primary forest	-	60	30	46
26	22/10/01	1568	Kisere	IV	near-primary forest	-	85	30	47
27	22/10/01	1568	Kisere	IV	near-primary forest	-	40	30	39
28	23/10/01	1580	Camp forest	VII	young secondary forest	-	65	10	60
29	23/10/01	1580	Camp forest	VII	young secondary forest	-	75	10	53
30	23/10/01	1580	Camp forest	VII	young secondary forest	-	70	10	41
31	24/10/01	1539	Isiukhu	IX	young secondary forest	4	65	20	61
32	24/10/01	1539	Isiukhu	IX	young secondary forest	5	60	20	64
33	24/10/01	1539	Isiukhu	IX	young secondary forest	5	75	20	56
34	24/10/01	1539	Isiukhu	IX	young secondary forest	5	85	20	52
35	24/10/01	1539	Isiukhu	IX	young secondary forest	5	70	20	49
36	07/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	90	35	46
38	07/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	80	35	47
37	07/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	65	35	38
39	07/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	75	35	48
40	07/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	55	35	38

No.	date	mean elevation [m]	location	rectangle	physiognomy	slope [degree]	treecover [%]	height [m]	no. of species
41	08/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	90	35	44
42	08/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	85	35	43
43	08/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	40	35	43
44	08/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	90	35	42
45	08/03/02	1520	Salazar	XIV	middle-aged secondary forest	-	95	35	46
46	11/03/02	1619	Malava	I	heavily logged and planted forest	-	90	20	42
47	11/03/02	1619	Malava	I	heavily logged and planted forest	1	90	25	58
48	11/03/02	1619	Malava	I	heavily logged and planted forest	-	90	20	48
49	12/03/02	1658	Malava	II	heavily logged and planted forest	1	75	25	50
50	12/03/02	1658	Malava	II	heavily logged and planted forest	5	60	20	48
51	01/11/02	1658	Malava	II	heavily logged and planted forest	-	75	20	47
52	01/11/02	1658	Malava	II	heavily logged and planted forest	-	85	25	47
53	01/11/02	1658	Malava	II	heavily logged and planted forest	-	70	25	52
54	01/11/02	1658	Malava	II	heavily logged and planted forest	-	85	25	42
55	12/03/02	1658	Malava	II	heavily logged and planted forest	-	70	25	39
56	04/11/02	1528	Yala	XXIV	old secondary forest	-	85	25	52
57	04/11/02	1528	Yala	XXIV	old secondary forest	-	80	25	54
58	04/11/02	1528	Yala	XXIV	old secondary forest	-	80	25	41
59	04/11/02	1528	Yala	XXIV	old secondary forest	1	75	25	48
60	15/03702	1528	Yala	XXIV	old secondary forest	-	85	25	70
61	15/03702	1528	Yala	XXIV	old secondary forest	-	90	25	69
62	15/03702	1528	Yala	XXIV	old secondary forest	-	90	25	55
63	15/03702	1528	Yala	XXIV	old secondary forest	-	95	25	61
64	15/03702	1528	Yala	XXIV	old secondary forest	-	95	25	51
65	15/03702	1528	Yala	XXIV	old secondary forest	-	95	25	57
66	18/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	35	25	66
67	18/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	85	25	58
68	18/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	75	25	65
69	18/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	70	25	45
70	18/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	90	25	46
71	18/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	95	25	45
72	19/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	90	25	40
73	19/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	85	25	49
74	19/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	-	90	25	43
75	19/03/02	1595	Ikuywa	XXII	middle-aged secondary forest	1	80	25	46
76	20/03/02	1567	Isecheno	XIX	middle-aged secondary forest	-	65	25	59
77	20/03/02	1567	Isecheno	XIX	middle-aged secondary forest	-	60	25	60
78	20/03/02	1567	Isecheno	XIX	middle-aged secondary forest	-	90	25	59
79	20/03/02	1567	Isecheno	XIX	middle-aged secondary forest	-	90	25	62
80	20/03/02	1567	Isecheno	XIX	middle-aged secondary forest	-	75	25	58
81	20/03/02	1587	Isecheno	XX	middle-aged secondary forest	-	95	25	56
82	20/03/02	1587	Isecheno	XX	middle-aged secondary forest	-	95	25	43

No.	date	mean elevation [m]	location	rectangle	physiognomy	slope [degree]	treecover [%]	height [m]	no. of species
83	21/03/02	1587	Isecheno	XX	middle-aged secondary forest	-	80	25	58
84	21/03/02	1587	Isecheno	XX	middle-aged secondary forest	1	95	25	56
85	21/03/02	1587	Isecheno	XX	middle-aged secondary forest	-	90	25	73
86	22/03/02	1638	Kaimosi	XXIX	heavily logged and planted forest	8	65	20	33
87	22/03/02	1638	Kaimosi	XXIX	heavily logged and planted forest	8	90	20	36
88	22/03/02	1638	Kaimosi	XXIX	heavily logged and planted forest	5	95	20	32
89	22/03/02	1638	Kaimosi	XXIX	heavily logged and planted forest	5	95	20	30
90	22/03/02	1638	Kaimosi	XXIX	heavily logged and planted forest	1	95	20	39
91	22/03/02	1630	Kaimosi	XXVIII	heavily logged and planted forest	5	95	20	54
92	26/03/02	1630	Kaimosi	XXVIII	heavily logged and planted forest	5	90	20	55
93	26/03/02	1630	Kaimosi	XXVIII	heavily logged and planted forest	5	90	20	53
94	26/03/02	1630	Kaimosi	XXVIII	heavily logged and planted forest	5	95	20	53
95	26/03/02	1630	Kaimosi	XXVIII	heavily logged and planted forest	5	90	20	43
96	25/03/02	1581	Kisere	III	near-primary forest	-	95	30	43
97	25/03/02	1581	Kisere	III	near-primary forest	-	75	30	49
98	25/03/02	1581	Kisere	III	near-primary forest	-	95	30	40
99	25/03/02	1581	Kisere	III	near-primary forest	-	95	30	56
100	25/03/02	1581	Kisere	III	near-primary forest	-	95	30	55
101	28/10/02	1539	Busambuli	XV	middle-aged secondary forest	1	90	25	56
102	28/10/02	1539	Busambuli	XV	middle-aged secondary forest	-	80	25	64
103	28/10/02	1539	Busambuli	XV	middle-aged secondary forest	-	95	25	48
104	28/10/02	1539	Busambuli	XV	middle-aged secondary forest	-	90	25	53
105	09/03/02	1539	Busambuli	XV	middle-aged secondary forest	-	70	25	54
106	09/03/02	1539	Busambuli	XV	middle-aged secondary forest	1	60	25	41
107	09/03/02	1539	Busambuli	XV	middle-aged secondary forest	1	70	25	46
108	09/03/02	1539	Busambuli	XV	middle-aged secondary forest	-	80	25	37
109	09/03/02	1539	Busambuli	XV	middle-aged secondary forest	-	70	25	44
110	09/03/02	1539	Busambuli	XV	middle-aged secondary forest	-	80	25	38
111	26/10/02	1566	Camp forest	VIII	young secondary forest	-	75	10	71
112	26/10/02	1566	Camp forest	VIII	young secondary forest	-	75	10	73
113	26/10/02	1566	Camp forest	VIII	young secondary forest	-	85	10	74
114	26/10/02	1566	Camp forest	VIII	young secondary forest	-	60	8	63
115	26/10/02	1566	Camp forest	VIII	young secondary forest	-	95	10	66
116	30/10/02	1539	Isiukhu	IX	young secondary forest	8	80	12	86
117	30/10/02	1539	Isiukhu	IX	young secondary forest	10	90	10	97
118	01/11/02	1539	Isiukhu	IX	young secondary forest	10	70	12	81
119	01/11/02	1539	Isiukhu	IX	young secondary forest	3	75	10	83
120	01/11/02	1539	Isiukhu	IX	young secondary forest	-	75	10	46
121	15/11/02	1559	Buyangu-top	XI	old secondary forest	8	75	25	40
122	15/11/02	1559	Buyangu-top	XI	old secondary forest	9	85	20	49
123	15/11/02	1559	Buyangu-top	XI	old secondary forest	9	90	25	51
124	15/11/02	1559	Buyangu-top	XI	old secondary forest	10	80	25	52

No.	date	mean elevation [m]	location	rectangle	physiognomy	slope [degree]	treecover [%]	height [m]	no. of species
125	15/11/02	1559	Buyangu-top	XI	old secondary forest	12	85	25	42
126	15/11/02	1559	Buyangu-top	XI	old secondary forest	15	85	25	38
127	15/11/02	1559	Buyangu-top	XI	old secondary forest	12	75	25	35
128	16/11/02	1559	Buyangu-top	XI	old secondary forest	12	90	20	45
129	16/11/02	1559	Buyangu-top	XI	old secondary forest	12	90	20	39
130	16/11/02	1559	Buyangu-top	XI	old secondary forest	8	75	20	36
131	11/07/03	1568	Kisere	IV	near-primary forest	-	85	30	42
132	11/07/03	1568	Kisere	IV	near-primary forest	-	85	30	50
133	11/07/03	1568	Kisere	IV	near-primary forest	10	80	30	47
134	11/07/03	1568	Kisere	IV	near-primary forest	10	80	30	41
135	11/07/03	1568	Kisere	IV	near-primary forest	10	80	35	31
136	15/07/03	1601	Colobus	V	middle-aged secondary forest	-	85	30	57
137	15/07/03	1601	Colobus	V	middle-aged secondary forest	-	85	30	51
138	15/07/03	1601	Colobus	V	middle-aged secondary forest	-	90	25	44
139	15/07/03	1601	Colobus	V	middle-aged secondary forest	-	75	25	48
140	17/07/03	1638	Kaimosi	XXIX	heavily logged and planted forest	-	75	25	50
141	17/07/03	1638	Kaimosi	XXIX	heavily logged and planted forest	-	75	25	57
142	17/07/03	1638	Kaimosi	XXIX	heavily logged and planted forest	-	70	25	44
143	17/07/03	1630	Kaimosi	XXVIII	heavily logged and planted forest	-	75	25	49
144	17/07/03	1630	Kaimosi	XXVIII	heavily logged and planted forest	1	80	25	46
145	17/07/03	1630	Kaimosi	XXVIII	heavily logged and planted forest	1	70	25	48
146	18/07/03	1601	Colobus	V	middle-aged secondary forest	-	80	20	54
147	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	70	25	47
148	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	85	25	49
149	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	85	25	42
150	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	70	25	58
151	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	70	25	45
152	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	75	30	58
153	21/07/03	1555	Isecheno	XVIII	middle-aged secondary forest	-	70	25	31
154	22/07/03	1528	Yala	XXV	old secondary forest	-	70	25	58
155	22/07/03	1528	Yala	XXV	old secondary forest	-	80	30	62
156	22/07/03	1528	Yala	XXV	old secondary forest	1	80	30	57
157	22/07/03	1528	Yala	XXV	old secondary forest	1	75	30	52
158	22/07/03	1528	Yala	XXV	old secondary forest	-	70	25	51
159	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	70	25	43
160	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	55	25	47
161	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	70	30	34
162	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	70	35	44
163	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	70	25	44
164	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	70	30	48
165	23/07/03	1581	Shiamololi	XVI	middle-aged secondary forest	-	80	35	50
166	25/07/03	1598	Kibiri	XXVI	heavily logged and planted forest	-	70	18	68

No.	date	mean elevation [m]	location	rectangle	physiognomy	slope [degree]	treecover [%]	height [m]	no. of species
167	25/07/03	1598	Kibiri	XXVI	heavily logged and planted forest	-	70	18	55
168	25/07/03	1598	Kibiri	XXVI	heavily logged and planted forest	-	70	18	71
169	25/07/03	1622	Kibiri	XXVII	heavily logged and planted forest	-	70	15	61
170	25/07/03	1622	Kibiri	XXVII	heavily logged and planted forest	-	70	18	51
171	26/07/03	1578	Vihiga	XVII	young secondary forest	-	80	10	66
172	26/07/03	1578	Vihiga	XVII	young secondary forest	-	65	8	66
173	26/07/03	1578	Vihiga	XVII	young secondary forest	-	70	10	73
174	26/07/03	1578	Vihiga	XVII	young secondary forest	-	75	10	57
175	26/07/03	1578	Vihiga	XVII	young secondary forest	-	75	12	67
176	26/07/03	1629	Ileho	XXI	heavily logged and planted forest	-	75	25	60
177	26/07/03	1629	Ileho	XXI	heavily logged and planted forest	-	70	25	59
178	26/07/03	1629	Ileho	XXI	heavily logged and planted forest	-	70	25	56
179	26/07/03	1629	Ileho	XXI	heavily logged and planted forest	-	70	25	48
180	26/07/03	1629	Ileho	XXI	heavily logged and planted forest	-	70	20	61
181	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	1	70	10	62
182	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	-	70	10	71
183	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	1	65	8	54
184	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	1	75	6	52
185	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	1	75	6	69
186	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	-	70	4	39
187	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	-	65	4	40
188	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	-	75	5	47
189	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	-	75	6	51
190	27/07/03	1582	Buyangu-sec.	XII	very young secondary forest	-	65	8	47
191	28/07/03	1595	Ikuywa	XXII	old secondary forest	1	90	35	41
192	28/07/03	1595	Ikuywa	XXII	old secondary forest	-	80	35	47
193	28/07/03	1595	Ikuywa	XXII	old secondary forest	-	70	30	44
194	28/07/03	1595	Ikuywa	XXII	old secondary forest	1	85	35	41
195	28/07/03	1595	Ikuywa	XXII	old secondary forest	1	75	35	45
196	30/07/03	1557	Ghostisland	XIII	old secondary forest	-	75	30	51
197	30/07/03	1557	Ghostisland	XIII	old secondary forest	-	85	30	50
198	30/07/03	1557	Ghostisland	XIII	old secondary forest	-	80	35	52
199	30/07/03	1557	Ghostisland	XIII	old secondary forest	-	75	30	54
200	30/07/03	1557	Ghostisland	XIII	old secondary forest	-	70	30	49

Appendix 2: Species list of trees, shrubs and climbers with their ecological characteristics. Given are life form, distribution in Kenya, succession type, stage mainly occuring, preferred habitat and geographical origin. C = Climber, T = Trees, S = Shrub, K = Kenya, o = only Kakamega Forest

family	**species**	**life form**	**distribution**	**succession type**	**stage**	**habitat**	**geographical element**
Fabaceae	*Abrus spec.*	C	K	climax	early	forest	afromontane
Mimosaceae	*Acacia abyssinica*	T	K	pioneer	early	bushland	afromontane
Mimosaceae	*Acacia montigena*	T	o	climax	late	forest	guineo-congolian
Euphorbiaceae	*Acalypha bipartia*	S	K 5	climax	late	forest	guineo-congolian
Euphorbiaceae	*Acalypha neptunica*	S	K	climax	late	forest	guineo-congolian
Euphorbiaceae	*Acalypha ornata*	S	K	climax	late	forest	afromontane
Euphorbiaceae	*Acalypha psilostachya var. glandulosa*	S	K	pioneer	early	forest	afromontane
Euphorbiaceae	*Acalypha racemosa*	S	K	pioneer	early	forest	afromontane
Acanthaceae	*Acanthopale pubescens*	S	K	climax	early	forest	afromontane
Acanthaceae	*Acanthus eminens*	S	K	climax	late	forest	afromontane
Acanthaceae	*Acanthus pubescens*	S	K	pioneer	early	bushland	afromontane
Lamiaceae	*Achyrospermum parviflorum*	S	o	pioneer	early	bushland	afromontane
Passifloraceae	*Adenia cissampeloides*	C	K 5	pioneer	early	forest	guineo-congolian
Sapotaceae	*Afrosersalisia cerasifera*	T	K 3, 5	climax	late	forest	guineo-congolian
Connaraceae	*Agelaea pentagyna*	C	K 4, 7, 5	climax	late	forest	guineo-congolian
Alangiaceae	*Alangium chinense*	T	K	climax	late	forest	afromontane/guineo-congolian
Mimosaceae	*Albizia grandibracteata*	T	K	climax	early	forest	guineo-congolian
Mimosaceae	*Albizia gummifera*	T	K	climax	late	forest	afromontane
Euphorbiaceae	*Alchornea laxiflora*	S	K 5, 7	climax	early	forest	afromontane/guineo-congolian
Sapindaceae	*Allophylus abyssinicus*	S	K	climax	late	forest	afromontane
Sapindaceae	*Allophylus africanus*	T	K	climax	early	forest	afromontane
Sapotaceae	*Aningeria altissima*	T	o	climax	late	forest	guineo-congolian
Moraceae	*Antiaris toxicaria*	T	K 5, 7	climax	early	forest	guineo-congolian
Icacinaceae	*Apodytes dimidiata*	S	K	climax	early	bushland	afromontane
Euphorbiaceae	*Argomuellera macrophylla*	T	K	climax	late	forest	guineo-congolian
Annonaceae	*Artabotrys likimensis*	C	K 3, 5	climax	late	forest	guineo-congolian
Basellaceae	*Basella alba*	C	K	pioneer	early	forest	afromontane
Sapotaceae	*Bequaertiodendron oblanceolatum*	T	o	climax	late	forest	guineo-congolian
Melianthaceae	*Bersama abyssinica*	S	K	pioneer	early	bushland	afromontane
Sapindaceae	*Blighia unijugata*	T	K	climax	late	forest	guineo-congolian
Euphorbiaceae	*Bridelia micrantha*	T	K	pioneer	early	bushland	afromontane/guineo-congolian
Apocynaceae	*Carissa edulis*	S	K	pioneer	early	bushland	guineo-congolian
Flacourtiaceae	*Casaeria battiscombei*	T	K	climax	late	forest	afromontane

family	species	life form	distribution	succession type	stage	habitat	geographical element
Flacourtiaceae	*Casaeria gladiiformis*	T	K 5, 7	climax	late	forest	afromontane
Rhizophoraceae	*Cassipourea ruwensorensis*	T	o	climax	late	forest	afromontane
Ulmaceae	*Celtis africana*	T	K	climax	early/late	forest	afromontane
Ulmaceae	*Celtis gomphophylla*	T	K	climax	early/late	forest	guineo-congolian
Ulmaceae	*Celtis mildbraedii*	T	K	climax	late	forest	guineo-congolian
Bignoniaceae	*cf. Fernandoa magnifica*	T	K 5, 7	climax	late	forest	guineo-congolian
Rubiaceae	*cf. Pancovia golungesis*	T	K 5, 7	climax	late	forest	guineo-congolian
Apocynaceae	*cf. Tabernaemontana stapfiana*	T	K 4, 7, 5	climax	late	forest	guineo-congolian
Ulmaceae	*Chaetacme aristata*	S	K	climax	late	forest	afromontane
Rubiaceae	*Chassalia cristata*	C	K 3, 5	climax	early	forest	guineo-congolian
Oleaceae	*Chionanthus mildbraedii*	T	o	climax	late	forest	guineo-congolian
Sapotaceae	*Chrysophyllum albidum*	T	o	climax	late	forest	afromontane
Sapotaceae	*Chrysophyllum viridifolium*	T	K 4, 7, 5	climax	late	forest	afromontane
Rutaceae	*Clausena anisata*	S	K	pioneer	early	forest	afromontane/guineo-congolian
Ranunculaceae	*Clematis brachiata*	C	K	pioneer	early	bushland	afromontane/guineo-congolian
Ranunculaceae	*Clematis simensis*	C	K	pioneer	early	bushland	afromontane/guineo-congolian
Verbenaceae	*Clerodendrum buchholzii*	C	o	climax	late	forest	guineo-congolian
Verbenaceae	*Clerodendrum johnstonii*	C	K	climax	late	forest	guineo-congolian
Verbenaceae	*Clerodendrum myricoides*	C	K	climax	late	forest	guineo-congolian
Euphorbiaceae	*Clutia abyssinica*	S	K	pioneer	early	bushland	afromontane
Rubiaceae	*Coffea eugenioides*	S	K	climax	late	forest	guineo-congolian
Combretaceae	*Combretum collinum*	T	K	pioneer	early	bushland	afromontane
Connaraceae	*Connarus longistipitatus*	C	K 5, 7	climax	late	forest	guineo-congolian
Boraginaceae	*Cordia africana*	T	K	climax	early	bushland/forest	afromontane
Fabaceae	*Craibia brownii*	T	K	climax	late	forest	afromontane
Rubiaceae	*Craterispermum schweinfurthii*	T	o	climax	late	forest	guineo-congolian
Euphorbiaceae	*Croton macrostachyus*	T	K	climax	early	forest	afromontane
Euphorbiaceae	*Croton megalocarpus*	T	K	climax	early	forest	afromontane
Euphorbiaceae	*Croton sylvaticus*	T	K	climax	early	forest	afromontane/guineo-congolian
Araceae	*Culcasia falcifolia*	C	K	climax	late	forest	guineo-congolian
Fabaceae	*Dalbergia lactea*	S	K	climax	early	forest	afromontane/guineo-congolian
Sapindaceae	*Deinbollia kilimandscharica*	T	K	climax	late	forest	afromontane
Ebenaceae	*Diospyros abyssinica*	T	K	climax	late	forest	afromontane
Sterculiaceae	*Dombeya burgessiae*	T	K	pioneer	early	bushland	afromontane/guineo-congolian
Sterculiaceae	*Dombeya rotundifolia*	T	K	pioneer	early	bushland	afromontane/guineo-congolian
Flacourtiaceae	*Dovyalis macrocalyx*	S	K	climax	early/late	forest	afromontane/guineo-congolian
Dracaenaceae	*Dracaena fragrans*	S	o	climax	late	forest	guineo-congolian

family	species	life form	distribution	succession type	stage	habitat	geographical element
Dracaenaceae	*Dracaena laxissima*	S	K	climax	late	forest	guineo-congolian
Asclepediaceae	*Dregea abyssinica*	C	K	climax	early/late	forest	guineo-congolian
Boraginaceae	*Ehretia cymosa*	T	K	climax	early	forest	afromontane/guineo-congolian
Meliaceae	*Ekebergia capensis*	T	K	climax	late	forest	afromontane
Myrsinaceae	*Embelia schimperi*	S	K	climax	early/late	forest	afromontane
Musaceae	*Ensete edule*	S	K	climax	late	forest	guineo-congolian
Meliaceae	*Entandophragma angolense*	T	o	climax	late	forest	guineo-congolian
Fabaceae	*Erythrina abyssinica*	T	K	pioneer	early	bushland	afromontane
Euphorbiaceae	*Erythrococca atrovirens*	S	K 5	climax	late	forest	afromontane/guineo-congolian
Euphorbiaceae	*Erythrococca trichogyne*	S	K 5	climax	late	forest	afromontane/guineo-congolian
Rutaceae	*Fagaropsis angolensis*	T	K	pioneer	early	forest	afromontane
Moraceae	*Ficus asperifolia*	S	K 3, 5	climax	late	forest	guineo-congolian
Moraceae	*Ficus bubu*	T	K 5, 7	climax	late	forest	guineo-congolian
Moraceae	*Ficus cyathistipula*	T	K	climax	late	forest	guineo-congolian
Moraceae	*Ficus exasperata*	T	K	climax	late	forest	guineo-congolian
Moraceae	*Ficus lutea*	T	K	climax	early	forest	guineo-congolian
Moraceae	*Ficus natalensis*	T	K	climax	late	forest	afromontane/guineo-congolian
Moraceae	*Ficus spec.*	T	K	climax	late	forest	afromontane/guineo-congolian
Moraceae	*Ficus sur*	T	K	climax	late	forest	afromontane/guineo-congolian
Moraceae	*Ficus thonningii*	T	K	climax	early/late	forest	afromontane/guineo-congolian
Moraceae	*Ficus vallis-choudae*	T	K	climax	late	forest	guineo-congolian
Flacourtiaceae	*Flacourtia indica*	S	K	pioneer	early	bushland	afromontane/guineo-congolian
Apocynaceae	*Funtumia africana*	T	K 5, 7	climax	early/late	forest	guineo-congolian
Clusiaceae	*Garcinia buchananii*	T	K	climax	late	forest	guineo-congolian
Rhamnaceae	*Gouania longispicata*	C	K	pioneer	early	bushland	guineo-congolian
Tiliaceae	*Grewia similis*	S	K	pioneer	early	bushland	afromontane/guineo-congolian
Guttiferae	*Harungana madagascariensis*	T	K	pioneer	early	bushland	guineo-congolian
Rubiaceae	*Heinsenia diervilleoides*	T	K	climax	late	forest	afromontane/guineo-congolian
Celastraceae	*Hippocratea africana*	C	K	climax	late	forest	guineo-congolian
Hernandiaceae	*Illigera pentaphylla*	C	o	climax	late	forest	guineo-congolian
Oleaceae	*Jasminum fluminense*	C	K	climax	early	bushland	guineo-congolian
Oleaceae	*Jasminum schimperi*	C	K	climax	early	bushland	guineo-congolian
Rubiaceae	*Keetia gueinzii*	C	K	climax	early/late	bushland/forest	afromontane
Bignoniaceae	*Kigelia africana*	T	K	climax	late	forest	afromontane/guineo-congolian
Apocynaceae	*Landolphia buchananii*	C	K	climax	late	forest	guineo-congolian
Verbenaceae	*Lantana camara*	S	K	pioneer	early	bushland	afromontane/guineo-congolian
Verbenaceae	*Lantana trifolia*	S	K	pioneer	early	bushland	afromontane/guineo-congolian

family	species	life form	distribution	succession type	stage	habitat	geographical element
Vitaceae	*Leea guineense*	S	o	climax	late	forest	guineo-congolian
Meliaceae	*Lepidotrichilia volkensis*	T	K	climax	late	forest	afromontane
Rubiaceae	*Leptactina platyphylla*	S	K 5, 7	climax	late	forest	guineo-congolian
Euphorbiaceae	*Macaranga kilimandscharica*	T	K	pioneer	early	forest	afromontane
Myrsinaceae	*Maesa lanceolata*	T	K	pioneer	early	bushland	afromontane/guineo-congolian
Rhamnaceae	*Maesopsis eminii*	T	o	pioneer	early	forest	guineo-congolian
Euphorbiaceae	*Mallotus oppositifolius*	T	K	climax	late	forest	afromontane/guineo-congolian
Sapotaceae	*Manilkara butugi*	T	K	climax	late	forest	afromontane
Euphorbiaceae	*Margaritaria discoidea*	T	K	pioneer	early	forest	afromontane/guineo-congolian
Bignoniaceae	*Markhamia lutea*	T	K	climax	late	forest	afromontane
Celastraceae	*Maytenus heterophylla*	S	K	climax	early/late	forest	afromontane/guineo-congolian
Rubiaceae	*Meyna tetraphylla*	S	K	pioneer	early	forest	afromontane/guineo-congolian
Acanthaceae	*Mimulopsis arborescens*	S	K	climax	early	forest	afromontane/guineo-congolian
Acanthaceae	*Mimulopsis solmsii*	S	K	climax	early	forest	afromontane/guineo-congolian
Annonaceae	*Monanthotaxis buchananii*	C	K 5, 7	climax	late	forest	guineo-congolian
Asclepediaceae	*Mondia whitei*	H	K 4, 5	pioneer	early	bushland	guineo-congolian
Annonaceae	*Monodora myristica*	T	o	climax	late	forest	guineo-congolian
Moraceae	*Morus mesozygia*	T	K 5 (7)	climax	late	forest	afromontane/guineo-congolian
Rubiaceae	*Mussaenda arcuata*	C	K 3, 5	pioneer	early	bushland	guineo-congolian
Euphorbiaceae	*Neoboutonia macrocalyx*	T	K	pioneer	early	bushland	afromontane
Loganiaceae	*Nuxia congesta*	T	K	climax	late	forest	afromontane
Lauraceae	*Ocotea argylei*	T	K 5	climax	late	forest	guineo-congolian
Oleaceae	*Olea capensis*	T	K	climax	late	forest	afromontane
Flacourtiaceae	*Oncoba spinosa*	S	K	climax	early/late	forest	afromontane
Poaceae	*Oreobambus buchwaldii*	S	o	climax	early	bushland	guineo-congolian
Ochnaceae	*Ouratea densiflora*	S	o	climax	late	forest	guineo-congolian
Ochnaceae	*Ouratea hiernii*	S	o	climax	late	forest	guineo-congolian
Rubiaceae	*Oxyanthus speciosus*	S	K	climax	early	forest	afromontane
Passifloraceae	*Passiflora caerulea*	C	K	pioneer	early	bushland	guineo-congolian
Passifloraceae	*Passiflora subpeltata*	C	K	pioneer	early	bushland	guineo-congolian
Sapindaceae	*Paullinia pinnata*	C	K	pioneer	early	bushland	afromontane/guineo-congolian
Rubiaceae	*Pavetta oliveriana var. oliveriana*	S	K	climax	early/late	forest	guineo-congolian
Rubiaceae	*Pavetta ternifolia*	S	K 3, 5	climax	early/late	forest	guineo-congolian
Malvaceae	*Pavonia urens*	S	K	pioneer	early	bushland	afromontane/guineo-congolian
Thymeleaceae	*Peddiea fischeri*	S	K	climax	early/late	forest	afromontane
Asclepediaceae	*Periploca linearifolia*	C	K	climax	early	bushland	guineo-congolian
Palmae	*Phoenix reclinata*	S	K	climax	early	forest	afromontane/guineo-congolian

family	species	life form	distribution	succession type	stage	habitat	geographical element
Euphorbiaceae	*Phyllanthus fischeri*	S	K	pioneer	early	forest	afromontane/guineo-congolian
Phytolaccaceae	*Phytolacca dodecandra*	S	K	climax	early	bushland	afromontane
Caesalpinaceae	*Piliostigma thonningii*	T	K	pioneer	early	bushland	afromontane
Piperaceae	*Piper capense*	H	K	climax	late	forest	afromontane/guineo-congolian
Piperaceae	*Piper guineense*	C	o	climax	early/late	forest	guineo-congolian
Piperaceae	*Piper umbellatum*	S	K	pioneer	early	forest	afromontane/guineo-congolian
Nyctaginaceae	*Pisonia aculeata*	C	o	climax	early	bushland	guineo-congolian
Pittosporaceae	*Pittosporum viridiflorum ssp. viridiflorum*	T	K	pioneer	early	forest	guineo-congolian
Araliaceae	*Polyscias fulva*	T	K	pioneer	early	bushland/forest	afromontane
Verbenaceae	*Premna angolensis*	T	o	climax	early	forest	guineo-congolian
Rosaceae	*Prunus africana*	T	K	climax	early/late	forest	afromontane
Acanthaceae	*Pseuderanthenum ludovicianum*	H	o	climax	early	forest	guineo-congolian
Anacardiaceae	*Pseudospondias microcarpa*	T	K 5	climax	early	forest	afromontane
Rubiaceae	*Psychotria bagshawei*	S	K 3, 5	climax	late	forest	guineo-congolian
Rubiaceae	*Psychotria mahonii*	S	K	climax	late	forest	afromontane
Rubiaceae	*Psychotria peduncularis*	S	K 3, 5	climax	late	forest	guineo-congolian
Rubiaceae	*Psydrax schimperiana ssp. schimperiana*	S	K	climax	early	forest	afromontane
Myrsinaceae	*Rapanea melanophloeos*	T	K	pioneer	early	forest	afromontane
Palmae	*Raphia farinifera*	S	K	climax	early	forest	guineo-congolian
Apocynaceae	*Rauvolfia caffra*	T	K	climax	early	forest	afromontane/guineo-congolian
Flacourtiaceae	*Rawsonia lucida*	S	K	climax	late	forest	afromontane/guineo-congolian
Rhamnaceae	*Rhamnus prinoides*	S	K	pioneer	early	bushland	afromontane
Vitaceae	*Rhoicissus tridentata*	C	K	pioneer	early	bushland	afromontane
Anarcardiaceae	*Rhus natalensis*	S	K	pioneer	early	bushland	afromontane
Violaceae	*Rinorea brachypetala*	S	K 3, 5	climax	late	forest	guineo-congolian
Capparaceae	*Ritchiea albersii*	S	K	climax	late	forest	afromontane
Rubiaceae	*Rothmannia longiflora*	S	o	climax	late	forest	guineo-congolian
Rubiaceae	*Rothmannia spec.*	S	o	climax	late	forest	guineo-congolian
Rubiaceae	*Rothmannia urcelliformis*	S	K	climax	late	forest	afromontane/guineo-congolian
Rubiaceae	*Rytigynia bugoyensis*	S	K	climax	late	forest	afromontane/guineo-congolian
Celastraceae	*Salacia cerasifera*	C	K 3, 5	climax	late	forest	guineo-congolian
Euphorbiaceae	*Sapium ellipticum*	T	K	climax	early	forest	afromontane/guineo-congolian
Oleaceae	*Schrebera alata*	T	K	pioneer	early	bushland	afromontane
Rhamnaceae	*Scutia myrtina*	S	K	pioneer	early	bushland	afromontane
Asclepediaceae	*Secamone punctulata*	C	K	climax	late	forest	guineo-congolian
Amaranthaceae	*Sericostachys scandens*	C	K 5	pioneer	early	bushland	afromontane/guineo-congolian
Smilacaceae	*Smilax anceps*	C	K	pioneer	early	bushland	guineo-congolian

family	species	life form	distribution	succession type	stage	habitat	geographical element
Solanaceae	*Solanum mauritianum*	S	K 3, 4, 5	pioneer	early	bushland	afromontane/guineo-congolian
Solanaceae	*Solanum terminale*	S	K	pioneer	early	bushland	afromontane
Bignoniaceae	*Spathodea campanulata*	T	K	pioneer	early	bushland	afromontane/guineo-congolian
Menispermaceae	*Stephania abyssinica*	C	K	pioneer	early	bushland	afromontane/guineo-congolian
Bignoniaceae	*Stereospermum kunthianum*	T	K	climax	early	bushland	afromontane/guineo-congolian
Olacaceae	*Strombosia scheffleri*	T	K	climax	late	forest	afromontane
Loganiaceae	*Strychnos usambarensis*	T	K 4, 7, 5	climax	late	forest	afromontane/guineo-congolian
Euphorbiaceae	*Suregada procera*	T	K 4, 5	climax	late	forest	afromontane
Myrtiaceae	*Syzygium guineense*	T	K	climax	late	forest	afromontane
Asclepediaceae	*Tacazzea galactogoga*	C	K	climax	late	forest	guineo-congolian
Rubiaceae	*Tarenna pavettoides*	S	K 4, 5	climax	early	forest	guineo-congolian
Rutaceae	*Teclea nobilis*	T	K	climax	late	forest	afromontane
Menispermaceae	*Tiliacora funifera*	C	K	climax	late	forest	guineo-congolian
Lamiaceae	*Tinnea aethiopica*	S	K	pioneer	early	bushland	afromontane/guineo-congolian
Rutaceae	*Toddalia asiatica*	C	K	pioneer	early	forest	guineo-congolian
Ulmaceae	*Trema orientalis*	T	K	pioneer	early	forest	afromontane/guineo-congolian
Meliaceae	*Trichilia emetica*	T	K	climax	late	forest	guineo-congolian
Hamamelidaceae	*Trichocladus ellipticus*	T	K	climax	late	forest	afromontane
Moraceae	*Trilepisium madagascariense*	T	K	climax	late	forest	afromontane/guineo-congolian
Flacourtiaceae	*Trimeria grandifolia*	S	K	climax	early	bushland	afromontane/guineo-congolian
Meliaceae	*Turraea abyssinica*	T	K	climax	late	forest	afromontane/guineo-congolian
Meliaceae	*Turraea holstii*	T	K	climax	late	forest	afromontane
Rubiaceae	*Uncaria africana*	C	o	pioneer	early	bushland	guineo-congolian
Urticaceae	*Urera hypselodendron*	C	K	climax	late	forest	afromontane
Urticaceae	*Urera trinervis*	C	K	climax	late	forest	afromontane
Annonaceae	*Uvariopsis congensis*	T	o	climax	late	forest	guineo-congolian
Rubiaceae	*Vangueria apiculata*	S	K	pioneer	early	forest	afromontane
Asteraceae	*Vernonia amygdalina*	S	K	pioneer	early	bushland	afromontane/guineo-congolian
Asteraceae	*Vernonia conferta*	S	o	pioneer	early	forest	guineo-congolian
Verbenaceae	*Vitex fischeri*	T	K	pioneer	early	bushland	afromontane/guineo-congolian
Rutaceae	*Zanthoxyllum gillettii*	T	K	climax	late	forest	afromontane

Appendix 3:

Species list

This list contains all flowering plant and fern species recorded from relevés, line transects and additional records in Kakamega Forest.

Pteridophyta

Adiantaceae
- cf. *Doryopteris spec.*
- *Coniogramme africana* Hieron.
- *Doryopteris kirkii* (Hook.) Alston
- *Pellaea* cf. *schweinfurthii*
- *Pellaea viridis* (Forssk.) Prantl.
- var. *glauca* (Sim) Sim

Aspleniaceae
- *Asplenium anisophyllum* Kunze
- *Asplenium* cf. *buettneri* Hieron.
- *Asplenium* cf. *bugoiense* Hieron.
- *Asplenium* cf. *gemmifera* Schrad.
- *Asplenium dregeanum* Kunze
- *Asplenium erectum* Willd.
- *Asplenium protensum* Schrad.
- *Asplenium* sp. A aff. *gemmifera*
- *Asplenium* sp. B aff. *gemmifera*
- *Asplenium* sp. C
- *Asplenium* sp. D
- *Asplenium theciferum* (Kunth.) Mett.

Dryopteridaceae
- *Tectaria gemmifera* (Fee) Alston

Oleandraceae
- *Nephrolepis undulata* (Sw.) J. Sm.

Pteridaceae
- *Pteris catoptera* Kunze
- *Pteris dentata* Forssk.
- *Pteris friesii* Hieron.
- *Pteris preusii* Hieron.

Thelypteridaceae
- *Pneumatopteris unita* (Kunze) Holttum

Spermatophyta – Angiospermae

Acanthaceae
- *Acanthopale pubescens* (Engl.) C. B. Cl.
- *Acanthus eminens* C. B. Cl.
- *Acanthus pubescens* (Oliv.) Engl.
- *Asystasia gangetica* (L.) T.Anders.
- *Brillantaisia cicatricosa* Lindau
- *Brillantaisia madagascariensis* Lindau
- *Brillantaisia vogeliana* (Nees) Benth.
- cf. *Isoglossa* spec.
- *Isoglossa laxa* Oliv.
- *Isoglossa lactea* Lindau
- *Isoglossa* spec.
- *Justicia flava* Vahl
- *Justicia* spec.
- *Macrorungia pubinervia* (Benth.) C. B. Cl.
- *Mimulopsis arborescens* C. B. Cl.
- *Mimulopsis solmiss* Schweinf.
- *Pseuderanthemum ludovicianum* (Buettn.) Lindau
- *Thunbergia alata* Boj. ex Sims
- *Thunbergia* spec.

Alangiaceae
- *Alangium chinense* (Lour.) Harms

Amaranthaceae
- *Achyranthes aspera* L.
- *Celosia schweinfurthiana* Schinz.
- *Sericostachys scandens* Gilg. & Lopr.

Anarcardiaceae
- *Pseudospondias microcarpa* (A. Rich.) Engl.
- *Rhus natalensis* Krauss

Annonaceae
- *Artabotrys likimensis* De Wild.
- *Monanthotaxis buchananii* (Engl.) Verdc.
- *Monodora myristica* (Gaertn.) Dun.
- *Uvariopsis congensis* Robyns & Ghesq.

Apiaceae
- *Hydrocotyle mannii* Hook. f.
- *Hydrocotyle* spec.
- *Sanicula elata* D. Don

Apocynaceae
- *Carissa edulis* (Forssk.) Vahl.
- *Funtumia africana* (Benth.) Stapf
- *Landolphia buchananii* (Hall.f.) Stapf

Rauvolfia caffra Sond.
cf. *Tabernaemontana ventricosa* A. DC.

Araceae
Amorphophallus spec.
Culcasia falcifolia Engl.

Araliaceae
Polyscias fulva (Hiern.) Harms

Asclepediaceae
Dregea abyssinica (Hochst.) K.Schum.
Mondia whitei (Hook. f.) Skeels
Periploca linearifolia Dill & Rich.
Secamone punctulata Decne.
Tacazzea galactogaga Bullock

Asteraceae
Acmella calirhiza Del.
Adenostemma mauritianum DC.
Ageratum conyzoides L.
Aspilia cf. *mossambicensis* (Oliv.) Wild
Bidens pilosa L.
cf. *Mikania cordata*
Crassocephalum vitellinum (Benth.) S. Moore
Dichrocephala integrifolia O. Kuntze
Galinsoga parviflora Cav.
Helichrysum cf. *nudifolium* (L.) Less
Helichrysum glumaceum O. Hoffm.
Melanthera scandens (Schumach. & Thonn.) Roberty
Microglossa spec.
Mikania cordata (Burm. f.) B. L. Robinson
Senecio spec.
Senecio syringifolius O. Hoffm.
Sphaeranthus gomphrenoides O. Hoffm.
Spilanthes mauritiana (Pers.) DC.
Tithonia diversifolia (Hemsl.) Gray
Vernonia amygdalina Delile
Vernonia conferta Benth.
Vernonia spec.

Balsaminaceae
Impatiens burtonii Hook.f.
Impatiens hochstetteri Warb.
Impatiens niamniamensis s.l. Gilg
Impatiens stuhlmannii Warb.

Basellaceae
Basella alba L.

Bignoniaceae
cf. *Fernandoa magnifica*
Kigelia africana (Lam.) Benth.
Markhamia lutea (Benth.) K. Schuman.
Spathodea campanulata P. Beauv.
Stereospermum kunthianum Cham.

Boraginaceae
Cordia africana Lam.
Ehretia cymosa Thonn.

Caesalpiniaceae
Piliostigma thonningii (Schumach.) Milne Redhead
Senna spec.

Capparaceae
Ritchiea albersii Gilg

Caryophyllaceae
Stellaria mannii Hook. f.

Celastraceae
Hippocratea africana (Willd.) Loes.
Maytenus heterophylla (Eckl. & Zeyh.) N. Robson
Salacia cerasifera Oliv.

Clusiaceae
Garcinia buchananii Bak.
Harungana madagascariensis Poir.

Combretaceae
Combretum collinum Fres.

Commelinaceae
Commelina africana L.
Commelina albiflora Faden, sp. nov.
Commelina spec.
Murdannia simplex (Vahl) Brenan
Pollia condensata C. B. Cl.

Connaraceae
Agelaea pentagyna (Lam.) Baill.
Connarus longistipitatus Gilg

Convolvulaceae
Ipomoea spec.

Crassulaceae
Crassula absinoides (Hook. f.) Engl.

Kalanchoe crenata (Andrews) Haworth
Kalanchoe spec.

Cucurbitaceae
Coccinia spec.
Cucumis spec.
Momordica cissoides Planch
Momordica spec.

Cupressaceae
Cupressus lusitanica Mill.

Cyperaceae
Cyperus spec.
Fimbristylis spec.
Mariscus spec.
Pycreus spec.
Scelaria spec.

Dioscoreaceae
Dioscorea schimperiana Kunth
Dioscorea spec.

Ebenaceae
Diospyros abyssinica (Hiern) White

Euphorbiaceae
Acalypha bipartia Muell. Arg.
Acalypha neptunica Muell. Arg.
Acalypha ornata A. Rich.
Acalypha psilostachya var. *glandulosa* Hutch.
Acalypha racemosa Baill.
Alchornea laxiflora (Benth.) Pax & K. Hoffm.
Argomuellera macrophylla Pax
Bischoffia javanica Bl.
Bridelia micrantha (Hochst.) Baill.
Clutia abyssinica Jaub. & Spach.
Croton macrostachyus Del.
Croton megalocarpus Hutch.
Croton sylvaticus Hochst.
Erythrococca atrovirens (Pax) Prain
Erythrococca trichogyne (Muell. Arg.) Prain
Macaranga kilimandscharica Pax
Mallotus oppositifolius (Geisel.) Muell. Arg.
Margaritaria discoidea (Baill.) Webster
Neoboutonia macrocalyx Pax
Phyllanthus fischeri Pax
Sapium ellipticum (Krauss) Pax
Suregada procera (Prain) Croizat
Tragia brevipes Pax

Fabaceae
Abrus spec.
Asparagus spec.
cf. *Crotalaria* spec.
cf. *Dalbergia* spec.
Craibia brownii
Crotalaria spec.
Dalbergia lactea Vatke
Desmodium adscendens (Sw.) DC.
Desmodium repandum (Vahl) DC.
Desmodium sp. A (s. Agnew & Agnew)
Erythrina abyssinica DC.
Glycine wightii (Wight & Arn.) Verdc.
Indigofera spec.
Trifolium spec.
Vigna vexillata (L.) A. Rich.

Flacourtiaceae
Casearia battiscombei R. E. Fries
Casearia gladiiformis Mast.
Dovyalis macrocalyx (Oliv.) Warb.
Flacourtia indica (Burm.f.) Merrill
Oncoba spinosa Forssk.
Rawsonia lucida Harv. & Sond
Trimeria grandifolia (Hochst.) Warb.
ssp. *tropica* (Burkill) Sleumer

Hamamelidaceae
Trichocladus ellipticus Eckl. & Zeyh.

Hernandiaceae
Illigera pentaphylla Welw.

Icacinaceae
Apodytes dimidiata Arn.

Iridaceae
Aristea alata Bak.

Lamiaceae
Achyrospermum parviflorum S. Moore
Becium obovatum (E. Mey.) N. E. Br.
Leonotis nepetifolia (L.) Ait. f.
Leucas spec.
Ocinum spec.
Plectanthrus spec.
Plectanthrus spec. A
Plectanthrus spec. B
Plectanthrus sylvestris Guerke
Tinnea aethiopica Hook. f.

Lauraceae
Ocotea argylei Robyns & Wilczek
Persea americana Mill.

Liliaceae
Gloriosa superba L.

Loganiaceae
Nuxia congesta Fres.
Strychnos usambarensis Gilg

Malvaceae
Hibiscus cannabinus L.
Pavonia urens Cav.
Sida rhombifolia L.
Urena lobata L.

Melastomataceae
Dissotis spec.
Tristemma mauritianum J. F. Gmel.

Meliaceae
Ekebergia capensis Sparrm.
Entandophragma angolense (Welw.) C. DC.
Khaya anthotheca (Welw.) C. DC.
Lepidotrichilia volkensis (Guerke) Lerroy
Trichilia emetica Vahl
Turraea abyssinica A. Rich.
Turraea holstii Guerke

Melianthaceae
Bersama abyssinica Fres.

Menispermaceae
Stephania abyssinica (Dillon & A. Rich.) Walp.
Tiliacora funifera (Miers) Oliv.

Mimosaceae
Acacia abyssinica Benth.
Acacia montigena Brenan & Exell
Albizia grandibractea Taub.
Albizia gummifera (J. F. Gmel) C. A. Sm. var. *gummifera*

Moraceae
Antiaris toxicaria (Pers.) Lesch.
Dorstenia brownii Rendle
Dorstenia sp. nov.
Ficus asperifolia Miq.
Ficus bubu Warb.
Ficus cyathistipula Warb.
Ficus exasperata Vahl.
Ficus lutea Vahl.
Ficus natalensis Hochst.
Ficus spec.
Ficus sur Forssk.
Ficus thonningii Bl.
Ficus vallis-choudae Del.
Morus mesozygia Stapf.
Trilepisium madagascariense DC.

Musaceae
Ensete edule (J. F. Gmel.) Horan

Myrsinaceae
Embelia schimperi Vatke
Maesa lanceolata Forssk.
Rapanea melanophloeos (L.) Metz

Myrtaceae
Eucalyptus saligna Sm.
Psidium guajava L.
Syzygium guineense (Willd.) DC.

Nyctaginaceae
Pisonia aculeata L.

Ochnaceae
Ouratea densiflora De Wild & Th. Dur.
Ouratea hiernii (van Tiegh.) Exell

Olacaceae
Strombosia scheffleri Engl.

Oleaceae
Chionanthus mildbraedii (Gilg & Schellenb. Stearn
Jasminum fluminense Vell.
Jasminum schimperi Vatke
Olea capensis L.
Schrebera alata (Hochst.) Welw.

Orchidaceae
Calanthe sylvatica (Thou.) Lindley
Disperis anthoceros Reichb. f.
Disperis aphylla Kraenzl.
Eulophia streptopetala Lindley
Habenaria malacophylla Reichb. f.
Liparis cf. *deistelii* Schltr.
Malaxis weberbaueriana (Kraenzl.) Summerh.

Palmae
Phoenix reclinata Jacq.
Raphia farinifera (Gaertn.) Hyland

Passifloraceae
Adenia cissampleoides (Benth.) Harms
Adenia spec.
Passiflora caerulea L.
Passiflora subpeltata Ortega

Phytolaccaceae
Phytolacca dodecandra L´Hérit
Hilleria latifolia (Lam.) Walter

Pinaceae
Pinus patula Schiede ex. Schltdl. & Cham.

Piperaceae
Peperomia tetraphylla (Forst.) Hook. & Arn.
Piper capense L.
Piper guineense Schumach. & Thonn.
Piper umbellatum L.

Pittosporaceae
Pittosporum viridiflorum Sims
ssp. *viridiflorum* (s.l.)

Plantaginaceae
Plantago palmata Hook. f.

Poaceae
Eragrostis spec. A
Eragrostis spec. B
Isachne mauritiana Kunth.
Leptaspis cochleata Thwaites
Oplismenus hirtellus (L.) P. Beauv.
Oreobambus buchwaldii K. Schum.
Panicum spec.
Paspalum conjugatum Berg.
Paspalum spec.
Pseudochinoleana polystachya (Kunth.) Stapf
Sacciolepsis spec.
Setaria longiseta P. Beauv.
Setaria megaphylla (Steud.) Th. Dur. & Schinz
Setaria spec.
Sporobolus pyramidales P. Beauv.

Polygonaceae
Polygonum setosulum A. Rich.

Primulaceae
Ardisiandra sibthorpioides Hook. f.

Ranunculaceae
Clematis brachiata Thunb.
Clematis simensis Fres.
Ranunculus multifidus Forssk.
Thalictrum rhynchocarpum Dillon & A. Rich.

Rhamnaceae
Gouania longispicata Engl.
Maesopsis eminii Engl.
Rhamnus prinoides L´Hérit.
Scutia myrtina (Burm.f.) Kurz.

Rhizophoraceae
Cassipourea ruwensorensis (Engl.) Alston

Rosaceae
Alchemilla spec.
Hirtella spec.
Prunus africana (Hook. f.) Kalkm.
Rubus spec.

Rubiaceae
Canthium spec.
cf. *Chassalia* spec.
Chassalia cristata (Hiern) Brem.
Coffea eugenioides S. Moore
Craterispermum schweinfurthii Hiern
Galium scioanum Chiov.
Geophila repens (L.) I. M. Johnst.
Heinsenia diervilleoides K. Schum.
Keetia gueinzii (Sond.) Bridson
Leptactina platyphylla (Hiern) Wernh.
Meyna tetraphylla (Hiern) Robyns
Mussaenda arcuata Poir.
Oldenlandia spec.
Oxyanthus speciosus DC. ssp. *stenocarpus*
(K. Schum.) Bridson
Pavetta oliveriana Hiern var. *oliveriana*
Pavetta ternifolia (Oliv.) Hiern
Psychotria bagshawei Petit
Psychotria mahonii C. Wright
Psychotria peduncularis (Salisb.) Steyerm.
Psydrax schimperiana (A. Rich.) Bridson
ssp. *schimperiana*
Rothmannia longiflora Salisb.
Rothmannia spec.
Rothmannia urcelliformis (Hiern) Robyns
Rubia cordifolia L.

Rytigynia uhligii (K. Schum. & K. Krause) Verdc.
Rytigynia bugoyensis (K. Krause) Verdc.
Spermacoce princeae (K. Schum.) Verdc.
Tarenna gravolens (S. Moore) Brem.
Tarenna pavettoides (Harv.) Sim.
Uncaria africana G. Don.
Vangueria apiculata K. Schum.

Ruscaceae
Dracaena fragrans (L.) Ker-Gawl.
Dracaena laxissima Engl.

Rutaceae
Clausena anistata (Willd.) Benth.
Fagaropsis angolensis (Engl.) Dale
Teclea nobilis Del.
Toddalia asiatica (L.) Lam.
Zanthoxyllum gillettii (De Wild.) Waterm.

Sapindaceae
Allophylus abyssinicus (Hochst.) Radlk.
Allophulus africanus P. Beauv.
Blighia unijugata Bak.
cf. *Pancovia golungensis*
Deinbollia kilimandscharica Taub.
Paullinia pinnata L.

Sapotaceae
Afrosersalisia cerasifera (Welw.) Aubrev.
Aningeria altissima (A. Chév.) Aubrév. & Pellegr.
Bequaertiodendron oblanceolatum (S. Moore) Heine & J. H. Hemsl.
Chrysophyllum albidum G. Don
Chrysophyllum viridifolium Wood & Franks
Manilkara butugi Chiov.

Scrophulariaceae
Lindernia cf. *diffusa* (L.) Wettst.
Lindernia nummularifolia (Don.) Wettst.
Striga asiatica (L.) O. Ktze.

Smilacaceae
Smilax anceps Willd.

Solanaceae
Cestrum aurantiacum Lindl.
Solanum cf. *sessilistellatum* Bitter
Solanum mauritianum Scop.
Solanum terminale Forsk.

Sterculiacae
Dombeya burgessiae Gerrard
Dombeya rotundifolia (Hochst.) Planch.

Thymeleaceae
Peddiea fischeri Engl.

Tiliaceae
Grewia similis K. Schum.
Triumfetta brachyceras K. Schum.
Triumfetta pentandra A. Rich.
Triumfetta rhomboidea Jacq.
Triumfetta tomentosa Boj.

Ulmaceae
Celtis africana Burm. f.
Celtis gomphophylla Bak.
Celtis mildbraedii Engl.
Chaetacme aristata Planch.
Trema orientalis (L.) Bl.

Urticaceae
Boehmeria macrophylla Hornem.
Laportea ovalifolia (Schum.) Chew
Pilea rivularis Wedd.
Pilea spec.
Urera hypselodendron (A. Rich.) Wedd.
Urera trinervis (Hochst.) Friis & Immelmann
Urtica spec.

Verbenaceae
Clerodendrum buchholzii Guerke
Clerodendrum johnstonii Oliv.
Clerodendrum myricoides (Hochst.) Vatke
Lantana camara L.
Lantana trifolia L.
Premna angolensis Guerke
Vitex fischeri Guerke

Violaceae
Rinorea brachypetala (Turcz.) O. Ktze.

Vitaceae
Cissus humbertii Robyns & Lawalree
Cissus spec.
Leea guineensis G. Don.
Rhoicissus tridentata (L. f.) Willd.
& Drummond

Zingiberaceae
  Renealmia cf. *engleri* K. Schum.
  Aframomum cf. *subsericeum*
  (Oliv. & T. Hanb.) K. Schum.
  Aframomum mala (K. Schum.) K. Schum.
  Aframomum spec.
  Aframomum zambesiacum (Bak.) K. Schum.

Appendix 4: Vegetation table. Given are vegetation units in arabic letters, differential species, companions, number of relevés. Species names: bold = trees, normal = shrubs, cursive = herbs, bold and cursive = lianas.

vegetation units	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
number of relevés	**4**	**3**	**12**	**15**	**5**	**28**	**7**	**32**	**16**	**12**	**11**	**14**	**5**	**16**	**10**	**5**	**5**
differential species of the Deinbollia kilimandscharica - Markhamia lutea Alliance																	
Trichocladus ellipticus	IV																
Trichocladus ellipticus	IV																
Ficus cyathistipula		V															
Uvariopsis congensis	III		I	I													
Uvariopsis congensis	V	IV	V	II			I			I			II	III	I		
Uvariopsis congensis	V		III	I				I				II	II	III	II		
cf. Fernandoa magnifica				III	II								II				
cf. Fernandoa magnifica				III				I									
cf. Fernandoa magnifica				I	II										I		
Rapanea melanophloeos											I		II				
Rapanea melanophloeos					V						I						
Rapanea melanophloeos			I	I	III						I		II				
Nuxia congesta				I	II								II				
Nuxia congesta			I	I	III	I					I		III				
Nuxia congesta				II	V	I					I						
Acanthus eminens				I	V	I	II	III	I	I							
Acanthus eminens			I	I	V	I	II	III	I	I							
Deinbollia kilimandscharica			I	II		I											
Deinbollia kilimandscharica		V	III	III		IV	III	I	I	I	I		II	II	I	II	III
Deinbollia kilimandscharica		IV	III	IV		III	I		I	I	I		II	II	I	V	
Markhamia lutea		IV	I	II		I							II	I		II	
Markhamia lutea	III		III	III	IV	III	I	I	I	I	II		II	V	I	V	IV
Markhamia lutea		II	II	II		II		I			II		III	II		IV	II
companions of the Deinbollia kilimandscharica - Markhamia lutea Alliance																	
Rawsonia lucida			I	I	II	I				I							
Rawsonia lucida	V	II	IV	III	V	IV	I	II	II	I	I		II		III	II	
Rawsonia lucida	V	II	V	III	V	III	I	II	III	III	II				I		
Strychnos usambarensis	IV	V	III	III	II	III			I	I					I		
Strychnos usambarensis	II		III	V	IV	IV		II	I	I	I	I			V		
Strychnos usambarensis	V	V	IV	III	III	IV		I				I			IV		
Craterispermum schweinfurthii	II						III	I	II								
Craterispermum schweinfurthii	V		I				III	I	I	I				I			
Craterispermum schweinfurthii	V		I				IV	I	I	I				II			
differential species of the Celtis mildbraedii - Craibia brownii Alliance																	
Suregada procera							IV										
Suregada procera							III										
Suregada procera							II				I						
Pseuderanthemum ludovicianum			I				III	V									
Pseuderanthemum ludovicianum	II		I				III	V			I				I		
Strombosia scheffleri							II	II	III					II			
Strombosia scheffleri				I			I	II	IV					V			II
Strombosia scheffleri							II	III	V	I				V			III
Celtis mildbraedii				II		I	V	II	III	I							
Celtis mildbraedii				I		I	IV	III	II	III							II
Celtis mildbraedii							III	II	III	II							
Craibia brownii			I	I	III		I	IV	IV	II							
Craibia brownii	II		II	I	V		II	II	II	III					I		II
Craibia brownii	II		II	I	IV		III	III	III	I		I					

Croton megalocarpus						I	III	III	III	III				I			II
Croton megalocarpus								I	I			I		I			
Croton megalocarpus		II	I			I		I	I					I		II	
companions of the Celtis mildbraedii - Craibia brownii Alliance																	
Raphia farinifera							I	I	I	I							
Raphia farinifera							I		I								
Mimulopsis arborescens						I	II	II	I	II				III			
Mimulopsis arborescens						I	I	I	I	I				II			II
Mimulopsis solmsii								I	I	II				I	I		
Mimulopsis solmsii									I								
differential species of the Antiaris toxicaria - Diospyros abyssinica Alliance																	
Antiaris toxicaria		V	II	V	III	V	I	II	III	III			II	II	II	III	
Antiaris toxicaria	V	IV	III	IV	V	IV	II	III	IV	III	II	I	II	V	V	V	IV
Antiaris toxicaria	IV		IV	III	V	IV	III	IV	V	IV	II	III	III	V	IV	IV	IV
Diospyros abyssinica	IV	II	II	I		III		I		I							
Diospyros abyssinica	III	IV	IV	III	V	II	III	III	IV	I	III	II			V	IV	III
Diospyros abyssinica	V	IV	V	IV	V	V	V	V	V	V	II	III	V	I	IV	V	II
Dorstenia brownii	V	V	V	V	V	IV	II	IV	V	III	I			I	II	V	IV
companions of the Antiaris toxicaria - Diospyros abyssinica Alliance																	
Bequaertiodendron oblanceolatum		IV	II	II	IV	I	II	I	I	II							
Bequaertiodendron oblanceolatum	III	II	III	II	IV	IV	II	III	II	III	I	I	II		I	III	III
Bequaertiodendron oblanceolatum	V	IV	V	II	III	IV	V	IV	IV	IV	I	III	II		II	II	III
Culcasia falcifolia	V	IV	IV			III	III	III	III	IV	I	II	II	V	III	III	IV
Culcasia falcifolia	V	II	III			I	II	II	II	I	I			II	IV	III	III
Dracaena fragrans	V	V	V	V	V	V	V	V	V	V	II	I	II	IV	V	V	IV
Dracaena fragrans	V	V	V	V	V	V	V	V	V	V	II	II		IV	V	V	V
Tiliacora funifera					II			I	I					V	I		
Tiliacora funifera	V	V	IV	II	V	IV	V	V	V	V	III	I	II	I	V	V	V
Tiliacora funifera	IV	IV	IV	III	V	IV	V	V	IV	V	II	I		IV	V	III	IV
Trichilia emetica	III	II	I	II	II	I	I	I			I			I	I	II	
Trichilia emetica	IV	II	IV	III	V	II	I	I	II	II	II	II	III	II	IV	V	II
Trichilia emetica	III		II	I	V	II	II	I	II	III	II	I	II	III	IV	III	IV
Trilepisisum madagascariense		II	II	IV	II	III	II	III	III	I				IV		III	II
Trilepisisum madagascariense	III	IV	III	III	II	IV	III	IV	III	II	I	I	II	V	I	IV	II
Trilepisium madagascariense	II	IV	III	IV	IV	V	IV	V	V	III	I	I		V		II	IV
Acalypha spec.						I			I								
Acalypha spec.			II	II	III	III	V	V	IV	III	I	I	II		III		IV
Acalypha spec.			III	I	V	III	IV	IV	IV	III	II		IV		III	III	
Leptaspis cochleata	V		IV	IV	III	IV	V	II	III	IV					I		
Heinsenia diervilleoides	II		III	IV	III	III	I	I	I	II					I		
Heinsenia diervilleoides	V		IV	V	V	V	V	V	V	IV	II			II	V	II	IV
Heinsenia diervilleoides	IV		III	V	V	IV	II	II	III	III	II		II	I	III		
Hippocratea africana					V					I							
Hippocratea africana	V	V	V	IV	V	V	V	V	V	V	I			V	III	III	IV
Hippocratea africana	IV	V	IV	III	IV	IV	III	V	V	IV	I		II	III	III	II	IV
Coffea eugenioides	V	IV	V	V	V	IV	I	I	I	III	I				IV		IV
Coffea eugenioides	V	V	V	V	V	III	III	II	II	IV	I				IV	II	
Cassipourea ruwensorensis	II					I	I	I									
Cassipourea ruwensorensis	V	II	III			IV	III	II	III	III				I	V	IV	II
Cassipourea ruwensorensis	IV		III			II	III	II	V	III				I	II		II
Rinorea brachypetala						I	I	I	I								
Rinorea brachypetala	II	II	III	I	II	I	V	IV	IV	II							
Rinorea brachypetala	IV		III		II	I	IV	IV	IV	IV							II
Dracaena laxissima	III	IV	I	I	V	II	III	III	IV	V	I			I	II		III
Dracaena laxissima	V	IV	I	I	V	II	III	II	III	V	II			II	I		
Salacia cerasifera	II						III	I		I							

Salacia cerasifera	IV		I				II	II	I	II				I			
Salacia cerasifera	I	II						I	I	I				I			
Agelaea pentagyna	III	II	II	II		I		I	I						III		
Agelaea pentagyna	II	II	II	II		II	II	I	I						III	III	
Agelaea pentagyna	II	II	I	I		I			I	I							
Brillantaisia spec.														I		II	
Brillantaisia spec.		II	I	II		II	I	II	I	I	I				I	III	III
Brillantaisia spec.									I					II			
Geophila repens	IV		III	III	III	III	II	II	II	II	I			II	II		II
Chaetacme aristata		IV	I	II	II	III		I						I	II		II
Chaetacme aristata			II	II	III	I		I	I	I		I			II	II	
Chaetacme aristata						I				I	I		II		I		
Laportea ovalifolia													II				
Laportea ovalifolia		II	I	III	III	I	III	II	II	III			II	II	II		
Morus mesozygia			I			I	I	I		I				I	I	II	II
Morus mesozygia	III	II	II	I		I	III	I	III	I				I	IV	IV	III
Morus mesozygia	IV	II	I			I	II	II	II	III					III	II	
Chrysophyllum albidum			II	III	V	II		I	I	II							
Chrysophyllum albidum			I	II	V	II	II	II	III	II					II		
Chrysophyllum albidum	V		III	II	V	II	II	II	II	III					II		
Acanthaceae spec. 1							I	I	I						I	II	
Acanthaceae spec. 1		II	I		IV		II	I	I	I			II		III	III	
Acanthaceae spec. 1								I									
Landolphia buchananii		IV	I			I	IV	I	III	I	I	I		I	I		
Landolphia buchananii			I			I	I	I	II	I	I	I		I	I		
Casearia gladiiformis	IV			I		I	V	II	II	I				I			
Casearia gladiiformis			I			II	I	II	III	III	II			I		V	III
Casearia gladiiformis							II	I	II	I	I	I		I		II	
Ficus exasperata		II	I	I		I	I	II	III	III				I			IV
Ficus exasperata				I		I		I	I	I	II	I	II	I			II
Ficus exasperata				II		I		I	I		I	I	II				
Canthium spec.			I	I		I		I	II	II	II	II	II	IV			
Canthium spec.	V	II	I	I		I		II	II	III	II	I	II	II			II
Chrysophyllum viridifolium		II	I			I							II				
Chrysophyllum viridifolium		V	I			I		I	I			II				IV	
Chrysophyllum viridifolium		II	I			I	I	I		I	I	I				II	V
Commelina spec.				I	V	I	III	III	II	II	II		III			III	
Dregea abyssinica			I	II	V	II		I	I		I		III	I			II
Dregea abyssinica				I							I	I					
Dregea abyssinica					V	I				I	I	III	II				
Pollia condensata		IV	I	IV		II		II	I	II	I	I					
Pteridophyta spec. 1	IV		I	IV	V	I		III	IV	IV	I		III	III			
Connarus longistipitatus					III	I		I		I							
Connarus longistipitatus				I	II	I					I						
Connarus longistipitatus				I		I		I									
Erythrococca atrovirens	II		I	I		I			I	I				I			
Erythrococca atrovirens	IV		II	I		I			II	II				II			
Ficus vallis-choudae				II	II	I		I	I		I						
Ficus vallis-choudae			I	II		I		I	II	I	I			I			
Ficus vallis-choudae			I	I		I		I		I							
Monodora myristica				I				I									
Monodora myristica			I					I	I								
Monodora myristica						I		I	I								
Adenostemma mauritianum								I									
Adenostemma maurtitianum			I	I	II	I	I	I	I	II				I			

Adenostemma maurtitianum								I									
differential species of the Maesa lanceolata subcommunity																	
Maesa lanceolata					II						III	I					
Maesa lanceolata			I								IV	III	II				
Maesa lanceolata		IV	I	I		I		I			III	III		I	I	II	
Pavonia urens											V		II				
Pavonia urens											IV	I	IV				
Acanthus pubescens											III	III	II				
Acanthus pubescens											II	II				II	
differential species of the Pittosporum viridiflorum community																	
Pittosporum viridiflorum												V	II				
Pittosporum viridiflorum												III				V	
Pittosporum viridifolium			I									I					
Nephrolepis undulata											II	V					
companions of the Maesa lanceolata - Pittosporum viridiflorum community group																	
Combretum collinum											III	III	III				
Combretum collinum											V	IV	III				
Combretum collinum											I	I					
Rhamnus prinoides											II	IV	II				
Rhamnus prinoides											III	II	III				
Rhamnus prinoides													II				
Vernonia amygdalina													II				
Vernonia amygdalina												II	III				
Vernonia amygdalina									I		I	III	IV				
Justicia flava											I		II				
Justicia flava											II	III	III			II	
Mussaenda arcuata											I						
Mussaenda arcuata									I		I	II		I			
Mussaenda arcuata											II	II	III				
differential species of the Harungana madagascariensis - Desmodium adscendens Alliance																	
Harungana madagascariensis											V	V	II	I		III	IV
Harungana madagascariensis											II	III	II				
Harungana madagascariensis						I					II	II	II	II			
Desmodium adscendens											IV	V	III	I			V
companions of the Harungana madagascariensis - Desmodium adscendens Alliance																	
Bridelia micrantha											III	IV	IV			III	
Bridelia micrantha								I			IV	III	II	I			IV
Bridelia micrantha											IV	II	II	I	II		III
Embelia schimperi	II	II				I		I		I	IV	IV	II	II			
Embelia schimperi										I	II	II	II				
Habenaria malacophylla			I	I	III						IV	V	V	I		II	IV
Paullinia pinnata									I		IV	III	IV			II	
Paullinia pinnata											I	II	II			II	
Piper umbellatum						I		I			II	I	III		I		III
Piper umbellatum	II	II	I	I		I		I	I		IV	III	III		I		V
Psidium guajava											II	II	III				II
Psidium guajava						I					V	V	II				IV
Psidium guajava						I					II	II	II				III
Smilax anceps	II										II	I	III	I			
Smilax anceps					II						IV	IV	III	I			
Tarenna pavettoides				I							I	I					
Tarenna pavettoides				I							IV	IV	III				
Tarenna pavettoides				I							II	II			I		
Erythrina abyssinica											I		II				
Erythrina abyssinica											I						

Erythrina abyssinica												I					
Ficus lutea								I			I	I					
Ficus lutea												I					
Ficus lutea												I					
Ficus lutea						I							II				
Phoenix reclinata											I	I					
Phoenix reclinata											II	II	II				
Acacia abyssinica											I	II	III				
Acacia abyssinica															I		
Acacia abyssinica						I		I				I	II				
Apodytes dimidiata											I	II					
Apodytes dimidiata								I			IV	III				II	
Apodytes dimidiata											I	I	II				
Clematis simensis											I	II					
Clematis simensis											II	I					II
Dioscorea spec.			II			I		I			I						III
Dioscorea spec.	II		I			I		I			II	III	III	I	I	III	IV
Jasminum fluminense		II	I		II	I	II	I			III	III	II	I			III
Jasminum fluminense			I			I					II	II	II				
Justicia spec.				I							I	I					
Justicia spec.				I	III	I		I	I		IV	II	II		I		II
Margaritaria discoidea					II					I		I					
Margaritaria discoidea				I	IV	I		I	I		II	I			I		
Margaritaria discoidea					V			I				I	II				
Margaritaria discoidea												I					
Pseudospondias microcarpa					II						I	I					
Pseudospondias microcarpa			I		III				I		II	II	II		I	III	
Pseudospondias microcarpa					III	I					I	I	III			III	
Saniclua elata			I	I		I					III	III	III		I		II
Secamone punctulata		II					I	I	I		II	I	II	I			
Secamone punctulata	II	II				I	I	I	I	I	III	III	II	II			II
Syzygium guineense				I	II						I				I		
Syzygium guineense						I					III	II	II	I		II	
Syzygium guineense											II	II	II	I	I		
Toddalia asiatica												II		I			
Toddalia asiatica						I					III	III	II				IV
Toddalia asiatica						I					III	II	III				
Urena lobata									I			III	II				
Urena lobata												IV		I		II	II
differential species of the plantation group																	
Afrosersalisia cerasifera														V			
Afrosersalisia cerasifera														V			
Afrosersalisia cerasifera														V			
Khaya anthotheca																	
Khaya anthotheca																	
Khaya anthotheca																	
Maesopsis eminii																V	II
Maesopsis eminii									I			I				II	II
Maesopsis eminii									I					I	I		II
Bischoffia javanica															I	III	V
Bischoffia javanica												I				III	IV
Bischoffia javanica															I	II	IV
companions of the plantation group																	
Zanthoxylum gillettii				I	III			I	I	I				II	III		
Zanthoxylum gillettii						I		I	I					I	I		III

Zanthoxylum gillettii														I			III
Vangueria apiculata												I					
Vangueria apiculata						II						III				V	V
Vangueria apiculata			I			II						I					V
differential species of a dry peripheral semi-evergreen Guineo-Congolian transitional rainforest (incl. pioneer-vegetation)																	
Allophylus abyssinicus	IV	II	IV	III	V	IV	III	III	IV	III	V	IV	V	V	IV	V	V
Allophylus abyssinicus	V	V	V	V	V	IV	III	V	V	V	V	V	IV	V	IV	IV	V
Desmodium repandum	V	V	IV	V	V	IV	III	V	V	V	V	V	V	V	V	V	V
companions of a dry peripheral semi-evergreen Guineo-Congolian transitional rainforest (incl. pioneer-vegetation)																	
Blighia unijugata	III	IV	III	II	V	III		II	I	I			II	I	III	III	
Blighia unijugata	IV	V	III	II	V	V	II	V	V	IV	IV	III	III	V	V	III	V
Blighia unijugata	V	V	IV	II	V	IV	III	V	V	V	I	II		V	IV	V	V
Clerodendrum spec.	II	II	II	II	V	II	III	II	II	III	IV	III	IV	III	III	II	II
Clerodendrum spec.	III	II	III	IV	V	IV	III	III	V	V	IV	III	V	V	IV	V	V
Clerodendrum spec.	II	II	II	IV	IV	I		I	III	II	II		III	I	I	II	III
Dovyalis macrocalyx			I	II	II	I				I					I		
Dovyalis macrocalyx	II	V	III	V	IV	IV	III	III	IV	V	III	III	II	IV	V	V	III
Dovyalis macrocalyx	V	V	V	V	V	V	III	IV	IV	V	V	III	V	III	V	V	III
Funtumia africana	IV	V	III	IV	IV	III	III	II	III	IV	I	I	II	V	I		III
Funtumia africana	V	V	IV	IV	V	IV	III	III	V	IV	V	IV	III	V	IV	V	V
Funtumia africana	V	V	IV	V	V	IV	II	IV	IV	V	IV	III	V	V	III		V
Oplismenus/Pseudochinoleana	IV	IV	IV	IV	V	III	V	IV	V	V	V	V	V	IV	IV	V	IV
Piper capense		IV	I	I		I		II	II	III	II	I	III	V	IV	V	V
Piper capense	II	V	IV	V	V	IV	III	IV	IV	V	IV	IV	V	V	V	V	V
Piper guineense	III	IV	III	IV	III	IV	III	IV	IV	II	III	II	II	V	II		V
Piper guineense	II	V	II	V	IV	IV	IV	III	IV	IV	IV	III	II	IV	II	V	V
Psychotria peduncularis		II	I	II	V	II		II	III	II	III	I	II	III			IV
Psychotria peduncularis	V	II	IV	IV	V	IV	III	III	V	V	V	III	IV	V	III		V
Renealmia engleri				I							II	I					
Renealmia engleri		IV	I	III	V	II	II	II	II	IV	V	IV	IV	I	III	II	III
Teclea nobilis		II	II	III	IV	II	III	III	II	II				I			
Teclea nobilis	V	IV	IV	IV	V	IV	III	IV	V	II	V	III	III	III	III	V	II
Teclea nobilis	III	IV	IV	V	V	IV	V	V	V	V	II	II	III	II	II	II	II
Aframomum spec.								I		I	I	I		I			II
Aframomum spec.		IV	III	I	II	III	III	II	IV	IV	IV	V	V	I	II		V
Amorphophallus spec.	II		III	IV	V	I	IV	III	III	II	III	II	IV		II	III	III
Celtis africana	II	II	IV	III	IV	II	I	I	I		I				I		II
Celtis africana			I	IV	V	II		I	I		III	III	V	I	II	V	II
Celtis africana			II	II	II	I		I			III	II	IV	I	I	II	III
Celtis gomphophylla	IV		I	I		I	II	II	II	II			II	II			
Celtis gomphophylla	II	V	I	I		II	I	II	III	II	I	II	II	III	II	IV	III
Celtis gomphophylla						I		II	III	III	I	I	II	III	I	V	
Erythrococca trichogyne					IV	I											
Erythrococca trichogyne			I	I	IV	I			I	I	II	II	II	III	I	IV	V
Erythrococca trichogyne			I	I	IV	I		I	I	I	III	II	II	I	I		IV
Leea guineensis				I		I			I	I	IV	II	IV		I	III	
Leea guineensis		IV	I	II	V	I		III	II	II	V	IV	V	I	I	IV	III
Lepidotrichilia volkensis		II	I			I		II	I	I	II	II	II	I	I	V	
Lepidotrichilia volkensis			I			I		I	I	I	I	I		I			
Manilkara butugi		II	I			II	I	I	I								
Manilkara butugi		V	I	I	II	I	III	I	I	I	I	II	II			III	II
Manilkara butugi							III	I	I		II						II
Aningeria altissima	IV	IV	II	I		II	I	II	II	I					IV		
Aningeria altissima	III	V	I			I		II	II	II	I	I			I	II	II
Aningeria altissima	V	II	III			II	I	II	III	III	I	I			I	II	
Polyscias fulva		IV	I	II	III	I		II	I	I	III	I	III	I			IV

Polyscias fulva			I	I		I	I	I	I	I	I	II	II	I	I	IV	IV
Polyscias fulva		II	II	I	IV	II	III	I	III	III	II	II	III	IV		IV	V
Maytenus heterophylla												I	II				
Maytenus heterophylla		II	II			II	I	I	I	I	IV	IV	III	I	I	III	V
Maytenus heterophylla		II				I		I	I		IV	IV		I		III	V
Monanthotaxis buchananii	II				IV	I					II	I	II	I			
Monanthotaxis buchananii	IV	II	II	III	III	II				I	III	I	II	II	I		
Monanthotaxis buchananii				I	II	I		I	I		III	I	II	I			
Olea capensis	III		II		III	I		I	I	I		I			I		
Olea capensis			I	I		I		I	I		II	III	II	I	III	V	
Olea capensis	III							I	II	I	I	II	II		I		
Ouratea densiflora								I									
Ouratea densiflora			I			I		I	I	II	I	I		I		II	
Ouratea densiflora	II	II	I					I		II	I	I		I			
Pancovia golungensis												I					
Pancovia golungensis						II	II	I	I	I	II		II		I		III
Pancovia golungensis			I			II	I	I	I	I	I				I		
Pavetta ternifolia			I			I								I	I		
Pavetta ternifolia	II		I			II		I	II		II			IV	III	II	V
Pavetta ternifolia	III	II						I		I	I	I		II	I		II
Peddiea fischeri											II		II				
Peddiea fischeri		II				I	I	I	I	II	IV	II		I	I		II
Peddiea fischeri	IV		II			I	III	I	I	I	IV	II	II	I	I		II
Phyllanthus fischeri			I	I	II			I	I	I	II	II	II	I			III
Phyllanthus fischeri	II		I	II	IV	I	I	II	I	I	IV	III	V	I	I	V	IV
Phyllanthus fischeri											I					II	II
Prunus africana			I		III	I				I	II	II	II	I		III	
Prunus africana									I		III	III	V	I			III
Prunus africana			I			I			I	I	I	II	II	I			IV
Sapium ellipticum									I		I	I		II			II
Sapium ellipticum					II			I			II	III	IV	I		II	
Sapium ellipticum					IV			I	I	I	II	I		I	I		II
Turraea holstii			I		II												
Turraea holstii	IV		I			II		II	II	II	III	I	III			IV	IV
Turraea holstii	II		I			I		I	II	II	II	II	II			II	III
Urera spec.			I					I	I		I	II					
Urera spec.				I	II	I		I		I	IV	I					
Fagaropsis angolensis					II				I	I				I			
Fagaropsis angolensis			I		II					II	I	I		II	I	II	
Fagaropsis angolensis	I		I			I	I	I	I	III	II	II	II	III			II
Ficus asperifolia			I		II	I		I	I	I	I	II	II	IV	I	III	III
Ficus asperifolia	II		I	II	III	II		I	II	II	I	I	III	III	II	V	II
Ficus asperifolia				I													
Peperomia spec.			I	II	IV	I		I	II		I		II	I			
Achyranthes aspera											IV	IV	V	II			II
Achyranthes aspara		II	II	III		III	III	II	III	III					III	V	
Achyrospermum parviflorum				I				I	II	I	I	I			I		II
Achyrospermum parviflorum		II	II	III	III	II	I	I	I	III	II	II	II	II	III		II
Bersama abyssinica											I						
Bersama abyssinica				I		I			I	I	I					II	
Bersama abyssinica		IV	I	I	III	I		I	I	III	I	I	III	I	I		
Cissus humbertii			II			I	III	IV	IV	II	II	II	II	II	I	III	II
Cissus humbertii						I	II	II	I	III	I	II				III	III
Clausena anisata								I	I	I							
Clausena anistata		II	I			I	I	I	I		II	II	II	I	I	II	III
Clausena anistata		IV	I			I	II	I	I	I	III	II	II	II	I	V	IV

Meyna tetraphylla		IV	I	II	II	I	I	I		I	III			III		II	II
Meyna tetraphylla					II	I		I	I		III	I	III	II			II
Stephania abyssinica			I	II	V	I	I	I	II	II	I	II	III	I	I		IV
Stephania abyssinica					III			I	I		I	II	III		I	IV	
Keetia gueinzii		IV	I	II	III	I					III	III	III		I	II	
Keetia gueinzii	II	V	IV	III	V	IV		I			V	V	IV	I	II	II	
Keetia gueinzii											II	II				III	
Ficus sur			I	I		I	III	I	I	I			II	I	I	II	III
Ficus sur			I			I	I					I		I	I		IV
Ficus sur						I						II				II	II
Alangium chinense				I				I						II		V	
Alangium chinense					II		I		II			I	II	I		III	II
Alangium chinense						I	II	I	I	I		I		I		III	
Oncoba spinosa					IV					I	II	I	II		II		
Oncoba spinosa					IV			I	I	I	V	I	III	I	V		
Oncoba spinosa	II		I		IV	I		I	I	I	IV	I	IV	I	III		
Albizia gummifera			I			I	II	I	I		I	I	II	I	I		II
Albizia gummifera				I		II	I	I	II	II	II	II	IV	III	IV	II	II
Albizia gummifera			II	III		II	II	I	IV	III	III	III	III	V	IV	II	III
Cordia africana						I	I	I	I	I			II	I	I	II	II
Cordia africana					II			I	I						I		
Cordia africana									I								
rare species																	
Abrus spec.											I						
Acacia montigena	II						II	I	I	I							
Acacia montigena	II							I						I			III
Acacia montigena							III	I	II			I		I			
Acanthaceae spec. 2							I										
Acanthaceae spec. 2						I	II		I					I			
Acanthaceae spec. 3								I	I	I							
Acanthopale pubescens				I				I	I								
Acanthopale pubescens				II		I		I	I	I	I			I			
Adenia cissampeloides											I	I	II				
Alchemilla spec.											I						
Alchornea laxiflora			I														
Allophyllus africanus											I						
Apocynaceae														I			
Apocynaceae											I			I			
Apocynaceae											I						
Argomuellera spec.											I						
Artabotrys likimensis	II		I			II		I	II					I	I		
Artabotrys likimensis								I	I					I			
Asclepediaceae				I													
Asparagus spec.																	II
Asplenium anisophyllum var. mircophyllum											I						
Asplenium c.f. buettneri													II		I		
Asplenium c.f. gemmifera														II			
Asplenium dregeanum							I										
Asplenium lunulatum var. erectum							II	I						II			
Asplenium protensum											I						
Asplenium sp. A gemmifera	II					II			I								
Asplenium sp. C		IV	I			I	III	I									
Asplenium sp. D							II	I	II	I							
Asplenium theciferum											I						
Basella alba									I								
Boehmeria macrophylla						I						I					

Boehmeria macrophylla						I						I				IV	V
Boehmeria nivea											II						
Boehmeria nivea											II						
c.f. Polystachya spec.							I				I						
Caesalpiniaceae												I					
Caesalpiniaceae											III	I			I		
Caesalpiniaceae											I	I					
Calanthe sylvatica						I		I	I		I						
Carissa edulis												I					
Carissa edulis											I						
Carissa edulis											I						
Casearia battiscombei								I									
Celosia schweinfurthiana			I			I								I			
Chassalia cristata						I											
Chassalia cristata																	II
Chassalia cristata												I		II			
Chionanthus mildbraedii	II		I			I	I										
Chionanthus spec.											I						
Clutia spec.											I						
Coccinia spec.								I			I						
Coccinia spec.							I				II	I					
Crotalaria spec.											I	II					
Crotalaria spec.												I					
Croton macrostachyus								I									
Croton macrostachyus											II		II				
Croton macrostachyus											I						
Cucumis spec.						I					II		III		I		
Cucumis spec.		II			II	I	I			I	I	I		I		III	II
Cyperus spec.											I	I					
Dalbergia lactea						I											
Dalbergia lactea						I				I				I			
Dalbergia lactea										I							
Desmodium sp. A																	II
Dichrocephala integrifolia							I										
Disperis aphylla				I	II	I					I	II	II				II
Dombeya burgessiae													II				
Dombeya burgessiae													II				
Dombeya burgessiae													II				
Doryopteris kirkii		IV	I			I		I			II	II		I		II	II
Ehretia cymosa															I	III	
Ehretia cymosa									I							II	
Ehretia cymosa								I						I			
Ensete edule														I			
Eucalyptus saligna																	II
Eulophia spec.											III	I					
Euphorbiaceae spec.												I					
Euphorbiaceae spec.													II				
Ficus spec.						I											
Ficus spec.				I											I		
Ficus spec.				I				I			I						
Ficus thonningii		II				I		I		I	I						
Ficus thonningii											II	II	II				
Ficus thonningii								I		I		I					
Ficus thonningii				I				I									
Flacourtia spec.												II					
Galium spec.												I					

Garcinia buchananii					I											
Garcinia buchananii			I		I											
Garcinia buchananii		I	I		I							II				
Gloriosa superba							I			I	I	II	II		II	III
Gouania longispicata												II				
Hydrocotyle mannii										I	II					
Illigera pentaphylla							I	I					I			
Illigera pentaphylla					I	I							I			
Impatiens hochstetteri			I	II	I				I	III	I					
Ipomoea spec.										II		III				
Isoglossa lactea														I		
Isoglossa laxa		I					I									
Isoglossa laxa		I														
Kalanchoe crenata												II				
Kalanchoe spec.										I		II				
Kigelia africana						I										
Kigelia africana						II	II	I	I				I	I		II
Kigelia africana		I			I	I	I						I			
Lantana spec.												II				
Lantana spec.			I								I	III				II
Lantana spec.		I	I							I		III				
Leptactina platyphylla						I										
Leucas spec.											I					
Macaranga kilimandscharica								I					I			
Macaranga kilimandscharica													I			
Macrorungia pubinervia							I									
Macrorungia pubinervia							I									
Mallotus oppositifolius								I					I			
Mallotus oppositifolius								I					I			
Melastomataceae spec. 1			I													
Melastomataceae spec. 1			I													
Meliaceae spec. 1					I											
Microglossa spec.							I					II				
Microglossa spec.							I				I					
Mikania cordata												II				
Mimosaceae spec.										I						
Momordica spec.							I			I						
Momordica spec.										II						
Mondia whitei	II	I			I		I			I			I			
Mondia whitei							I	I								
Neoboutonia macrocalyx			I	II				I					I			
Neoboutonia macrocalyx				II			I	I								
Neoboutonia macrocalyx				III			I		I				I			
Ocotea argylei													I			
Orchidaceae spec. 1							I	I	I				II	III		
Orchidaceae spec. 2							I									
Orchidaceae spec. 3					I											
Orchidaceae spec. 4										I						
Orchidaceae spec. 5		I									I				II	II
Oxyanthus speciosus														I		
Oxyanthus speciosus														I		
Paspalum spec.											I					
Passiflora subpeltata													I			
Passiflora subpeltata					I					I	I	II	I			II
Pellaea viridis		I					I	I			II	II			II	
Persea americana													I			

Phytolacca dodecandra									I		I						II
Pilea spec.																II	
Piliostigma thonningii			I														
Piliostigma thonningii			I														
Piliostigma thonningii													II				
Pisonia aculeata						I						I					
Pneumatopteris unita								I						I			
Premna angolensis						I										II	
Premna angolensis						I								I		II	
Pteridophyta spec. 2								I									
Pteridophyta spec. 3							I	I	I			I				III	IV
Pteridophyta spec. A								I									
Pteris catoptera								I	I		I						
Pteris preussii								I						I			III
Rauvolfia caffra								I	I	II						II	II
Rauvolfia caffra	III		I			I	I	I	I	II				I			
Rhoicissus tridentata								I			I						
Rhoicissus tridentata								I				I	II				
Rhus natalensis				I													
Rhus natalensis													II				
Ritchiea albersii														I			
Ritchiea albersii			I				I	I									
Ritchiea albersii								I						I			
Rothmannia longiflora	II		I				II	I	II								
Rothmannia longiflora	II								II								
Rothmannia spec.						I					I				II		
Rothmannia spec.															I		
Rothmannia urcelliformis														II			
Rothmannia urcelliformis														I			
Rubia cordifolia													II				
Rubiaceae spec. 1						I											
Rubiaceae spec. 2														I			
Rubiaceae spec. 2														I			
Rubiaceae spec. 3			I														
Rubus spec.											I			I			
Rubus spec.											II	I	II	I			V
Rubus spec.																II	
Rytigynia buboyensis											I						
Rytigynia buyogensis				I													
Sapotaceae spec.												I					
Scelaria spec.																	II
Schrebera alata												II	II				
Scutia myrtina				I				I				I	II			II	II
Scutia myrtina																	III
Senecio syringifolius					III	I		II	I	III					I		
Senecio syringifolius								I	I	I	I						
Setaria spec.											I	I	II				II
Sida rhombifolia											I			I			
Sida rhombifolia											I						
Solanum indicum															I		
Solanum mauritianum								I		I			II				
Solanum mauritianum						I		I	I		I	I	II	I	I	III	II
Solanum mauritianum						I		I		I					I		
Spathodea campanulata										I	I			I			II
Spathodea campanulata							I					I					II
Spathodea campanulata																	II

spec. 1				I											
spec. 1		I		I											
spec. 1		I													
spec. 2		I													
spec. 3		I													
spec. 4		I													
spec. 5		I													
spec. 5		I													
spec. 5		I													
spec. 6		I													
spec. 7		I													
spec. 7		I		I											
spec. 7							I								
spec. 8	I														
spec. 9		I													
spec. 11				I											
spec. 12									I						
spec. 13									I		II				
spec. 14									I		II				
spec. 15											II				
spec. 16		I		I											
spec. 17				I											
spec. 18				I											
spec. 19									I						
spec. 19									I						
spec. 20									I						
spec. 20									I		II				
spec. 21									I						
spec. 22			II												
spec. 23			II												
spec. 24					I										
spec. 25						I									
spec. 26															II
Spermacoce princeae									I	I					
Stellaria mannii				I											
Stereospermum kunthianum				I											
Tacazzea galactogoga									I						
Tectaria gemmifera	I			I		I	I								
Thalictrum rhynchocarpum						I	I		I		II	I	I	II	
Thunbergia alata						I					II				
Thunbergia alata											II				
Tragia brevipes				I					II				I		
Tragia brevipes						I									
Trema orientalis			II												II
Trema orientalis															II
Trema orientalis													I		II
Trimeria grandifolia	I								I	III				III	
Tristemma mauritianum		I													
Tristemma mauritianum		I							I						
Triumfetta rhomboidea									II						
Triumfetta rhomboidea									I		II				
Triumfetta spec.									I						
Triumfetta spec.									I	III					II
Turraea abyssinica	I			II											
Turraea abyssinica															III
Turraea abyssinica				I						I					II

Uncaria africana	II																
Uncaria africana	II							I	I	I		I				II	
Vernonia conferta									I								
Vigna vexillata																	II
Vigna vexillata						I		I			I	I	III				II
Vitex fischeri									I								
Vitex fischeri														I			
Vitex fischeri								I		I				I			
Croton sylvaticus						I	I		I							II	
Croton sylvaticus				I		I						I					II
Croton sylvaticus		II				I			I			I		I			III
Ekebergia capensis				I													
Ekebergia capensis						I					I	I			I	II	
Ekebergia capensis									I	I		I			I		

Appendix 5: Constancy table. Given are vegetation units in arabic letters, differential species, companions, number of relevés.

vegetation units	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
number of relevés	**4**	**3**	**12**	**15**	**5**	**28**	**7**	**32**	**16**	**12**	**11**	**14**	**5**	**16**	**10**	**5**	**5**
differential species of the Deinbollia kilimandscharica - Markhamia lutea Alliance																	
Trichocladus ellipticus	V																
Ficus cyathistipula		V															
Uvariopsis congensis	V	IV	V	II			I	I		I		II	II	IV	III		
cf. Fernandoa magnifica				V	II			I					II		I		
Rapanea melanophloeos			I	I	V						I		II				
Nuxia congesta			I	II	V	I					I		III				
Acanthus eminens			I	I	V	I	II	III	I	I							
Deinbollia kilimandscharica		V	IV	IV		IV	III	I	I	I			III	II	II	V	III
Markhamia lutea	III	IV	III	III	IV	IV	I	I	I	I	III		V	V	II	V	IV
companions of the Deinbollia kilimandscharica - Markhamia lutea Alliance																	
Rawsonia lucida	V	IV	V	IV	V	V	II	III	IV	III	II		II		IV	II	
Strychnos usambarensis	V	V	V	V	IV	V		II	I	I	I	I			V		
Craterispermum schweinfurthii	V		I				IV	I	II	I				II			
differential species of the Celtis mildbraedii - Craibia brownii Alliance																	
Suregada procera							V				I						
Pseuderanthemum ludovicianum	II		I				III	V			I						
Strombosia scheffleri				I			III	III	V	I				V			III
Celtis mildbraedii				II		I	V	IV	IV	III							
Craibia brownii	II		II	II	V		IV	IV	IV	IV		I			II		II
Croton megalocarpus		II	I			I	III	III	III	III		I		II		II	II
companions of the Celtis mildbraedii - Craibia brownii Alliance																	
Raphia farinifera							II	I	II	I							
Mimulopsis arborescens						I	II	II	I	II				III			II
Mimulopsis solmsii								I	I	II				I	II		
differential species of the Antiaris toxicaria - Diospyros abyssinica Alliance																	
Antiaris toxicaria	V	V	V	V	V	V	IV	V	V	V	III	III	III	V	V	V	V
Diospyros abyssinica	V	V	V	V	V	V	V	V	V	V	IV	III	V	I	V	V	III
Dorstenia brownii	V	V	V	V	V	IV	II	IV	V	III	I			I	II	V	IV
companions of the Antiaris toxicaria - Diospyros abyssinica Alliance																	
Bequaertiodendron oblanceolatum	V	V	V	III	V	V	V	IV	V	V	II	III	III		II	IV	IV
Culcasia falcifolia	V	V	IV			III	V	IV	IV	IV	I	II	II	V	IV	V	V
Dracaena fragrans	V	V	V	V	V	V	V	V	V	V	II	II	II	V	V	V	V
Tiliacora funifera	V	V	V	III	V	V	V	V	V	V	III	II	II	V	V	V	V
Trichilia emetica	V	IV	IV	IV	V	III	III	II	IV	IV	III	II	IV	IV	V	V	V
Trilepisisum madagascariense	IV	V	IV	V	IV	V	V	V	V	IV	II	I	II	V	I	V	V
Leptaspis cochleata	V		IV	IV	III	IV	V	II	III	IV					II		
Heinsenia diervilleoides	V		V	V	V	V	V	V	V	V	II		II	III	V	II	IV
Hippocratea africana	V	V	V	IV	V	V	V	V	V	V	I		II	V	III	III	IV
Coffea eugenioides	V	V	V	V	V	IV	III	II	II	V	II				V	II	IV
Chaetacme aristata		IV	II	IV	IV	III		I	I	I	I	I	II	I	V	II	II
Cassipourea ruwensorensis	V	II	III			IV	IV	IV	V	III				I	V	IV	III
Rinorea brachypetala	IV	II	IV	I	II	II	V	V	IV	IV							II
Dracaena laxissima	V	V	I	II	V	III	IV	IV	IV	V	II			II	II		III
Salacia cerasifera	V	II	I				III	III	II	III							
Agelaea pentagyna	IV	IV	III	III		II	II	I	II	I					III	III	
Brillantaisia spec.		II	I	II		II	I	II	I	I	I			II	I	III	III
Geophila repens	IV		III	III	III	III	II	II	II	II	I			II	II		II
Laportea ovalifolia		II	I	III	III	I	III	II	II	III			II	II	II		
Morus mesozygia	V	IV	III	I		III	IV	II	IV	III				I	V	V	IV
Chrysophyllum albidum	V	II	III	V	V	III	III	III	III	IV					II		
Acanthaceae spec. 1		II	I		IV		III	II	I	I			II		III	IV	
Landolphia buchananii		IV	I			I	IV	II	III	I	I	II		I	I		
Casearia gladiiformis	IV		I	I		II	V	III	IV	III	II	I		II		V	III
Ficus exasperata		II	I	II		II	I	II	III	III	III	I	III	I			IV
Canthium spec.	V	II	I	I		I		III	III	III	III	II	III	IV	IV		II
Chrysophyllum viridifolium		V	I			II	I	I	I	I	I	II	II			IV	V

Commelina spec.				I	V	I	III	III	II	II	II		III			III	
Dregea abyssinica			I	III	V	II		I	I	I	II	III	III	I	II		II
Pollia condensata		IV	I	IV		II		II	I	II	I	I					
Pteridophyta spec. 1	IV		I	IV	V	I		III	IV	IV	I		III	III	II		
Connarus longistipitatus				I	III	I		I		I	I				II		
Erythrococca atrovirens	IV		II	I		I			II	II				II	II		
Ficus vallis-choudae			I	III	II	I		II	II	I	I			I	II		
Monodora myristica			I	I		I		I							III		
Acalypha spec.			III	III	V	IV	V	V	IV	III	II	I	IV		III	III	IV
Adenostemma mauritianum			I	I	II	I	I	I	I	II				I	II		
differential species of the Maesa lanceolata subcommunity																	
Maesa lanceolata		IV	I	I	II	I		I			V	IV	II	I	I	II	
Pavonia urens											V	I	IV				
Acanthus pubescens											IV	III	II			II	
differential species of the Pittosporum viridiflorum community																	
Pittosporum viridiflorum			I									V	II			V	
Nephrolepis undulata											II	V					
companions of the Maesa lanceolata - Pittosporum viridiflorum community group																	
Combretum collinum											V	V	V				
Rhamnus prinoides											IV	V	IV				
Vernonia amygdalina									I		I	IV	V				
Justicia flava											II	III	III			II	
Mussaenda arcuata									I		III	III	III	I			
differential species of the Harungana madagascariensis - Desmodium adscendens Alliance																	
Harungana madagascariensis						I					V	V	III	II		III	IV
Desmodium adscendens											IV	V	III	I			V
companions of the Harungana madagascariensis - Desmodium adscendens Alliance																	
Bridelia micrantha								I			V	V	V	I	II	III	IV
Embelia schimperi	II	II				I		I		II	IV	IV	III	II			
Habenaria malacophylla			I	I	III						IV	V	V	I		II	IV
Paullinia pinnata									I		V	V	IV			II	
Piper umbellatum	II	II	I	I		I		I	I		IV	III	IV		I		V
Psidium guajava						I					V	V	IV				IV
Smilax anceps	II				II						V	IV	III	I			
Tarenna pavettoides				I							IV	V	III		I		
Erythrina abyssinica											II	I	II				
Ficus lutea						I		I			I	II	II				
Phoenix reclinata											III	II	II				
Acacia abyssinica						I		I			I	II	III		I		
Apodytes dimidiata								I			IV	IV	II			II	
Clematis simensis											III	III					II
Dioscorea spec.	II		II			I		I			II	III	III	I	I	III	V
Jasminum fluminense		II	I		II	I	II	I			III	IV	III	I			III
Justicia spec.				I	III	I		I	I		IV	II	II		I		II
Margaritaria discoidea				I	V	I		I	I	I	II	III	II		I		
Pseudospondias microcarpa			I		IV	I			I		III	III	III		I	IV	
Saniclua elata			I	I		I					III	III	III		I		II
Secamone punctulata	II	II				I	II	I	I	I	IV	III	III	III			II
Syzygium guineense				I	II	I					IV	II	II	I	I	II	
Toddalia asiatica						I					V	V	IV	I			IV
Urena lobata									I			V	II	I		II	II
differential species of the plantation group																	
Afrosersalisia cerasifera														V			
Khaya anthotheca															II		
Maesopsis eminii												I		I	I	V	IV
Bischoffia javanica												I			I	V	V
companions of the plantation group																	
Zanthoxylum gillettii				I	III	I		I	II	I				III	III		IV
Vangueria apiculata			I			III						III				V	V
differential species of a dry peripheral semi-evergreen Guineo-Congolian transitional rainforest (incl. pioneer-vegetation)																	
Allophylus abyssinicus	V	V	V	V	V	V	IV	V	V	V	V	V	V	V	V	V	V
Desmodium repandum	V	V	IV	V	V	IV	III	V	V	V	V	V	V	V	V	V	V

companions of a dry peripheral semi-evergreen Guineo-Congolian transitional rainforest (incl. pioneer-vegetation)																	
Blighia unijugata	V	V	V	III	V	V	III	V	V	V	IV	III	III	V	V	V	V
Clerodendrum spec.	III	IV	IV	V	V	IV	III	IV	V	V	V	IV	V	V	IV	V	V
Dovyalis macrocalyx	V	V	V	V	V	V	IV	V	V	V	V	IV	V	V	V	V	V
Funtumia africana	V	V	V	V	V	V	V	IV	V	V	V	V	V	V	IV	V	V
Oplismenus/Pseudochinoleana	IV	IV	IV	IV	V	III	V	IV	V	V	V	V	V	IV	IV	V	IV
Piper capense	II	V	IV	V	V	V	III	IV	V	V	V	IV	V	V	V	V	V
Piper guineense	III	V	III	V	IV	V	IV	IV	V	IV	V	IV	II	V	II	V	V
Psychotria peduncularis	V	II	IV	IV	V	IV	III	IV	V	V	V	IV	IV	V	III		V
Renealmia engleri		IV	I	III	V	II	II	II	II	IV	V	IV	IV	I	III	II	III
Teclea nobilis	V	V	V	V	V	V	V	V	V	V	V	IV	IV	III	III	V	III
Aframomum spec.		IV	III	I	II	III	III	II	IV	IV	V	V	V	I	II		V
Amorphophallus spec.	II		III	IV	V	I	IV	III	III	II	III	II	IV		II	III	III
Celtis africana	II	II	IV	IV	V	III	I	I	I		IV	IV	V	I	II	V	IV
Celtis gomphophylla	V	V	II	I		II	II	IV	V	IV	II	II	III	IV	II	V	III
Erythrococca trichogyne			I	I	IV	I		I	I	I	IV	III	III	IV	II	IV	V
Leea guineensis		IV	I	II	V	II		III	II	III	V	IV	V	I	II	V	III
Lepidotrichilia volkensis		II	I			I		II	I	I	II	II	II	I	I	V	
Manilkara butugi		V	II	I	II	II	IV	I	I	I	II	II	II			III	III
Aningeria altissima	V	V	IV	I		III	II	III	IV	III	I	I			IV	III	II
Polyscias fulva		IV	II	III	V	II	III	III	IV	III	IV	IV	IV	IV	I	V	V
Maytenus heterophylla		IV	II			II	I	I	I	I	V	V	III	II	I	V	V
Monanthotaxis buchananii	V	II	II	IV	V	III		I	I	I	V	II	III	III	I		
Olea capensis	V		III	I	III	I		II	III	I	III	IV	II	I	III	V	
Ouratea densiflora	II	II	II			I		II	I	III	II	II		I		II	
Pancovia golungensis			I			III	III	I	I	I	II	I	II		II		III
Pavetta ternifolia	III	II	II			II		II	II	I	III	I		IV	II	II	V
Peddiea fischeri	IV	II	II			II	III	I	II	III	V	III	III	I	I		II
Phyllanthus fischeri	II		I	II	IV	I	I	II	I	II	IV	IV	V	II	I	V	V
Prunus africana			II		III	II			I	II	IV	IV	V	II		III	IV
Sapium ellipticum					IV			I	I	I	III	III	IV	II	I	II	III
Turraea holstii	IV		II		II	II		III	II	III	IV	II	III			IV	V
Urera spec.			I	I	II	I		II	I	I	IV	II					
Fagaropsis angolensis	I		I		III	I	I	I	I	III	II	III	II	IV	I	II	II
Ficus asperifolia	II		I	III	III	II		I	II	II	I	II	III	V	II	V	III
Peperomia spec.			I	II	IV	I		I	II		I		II	I			
Achyranthes aspera		II	II	III		III	III	II	III	III	IV	IV	V	II	II	V	II
Achyrospermum parviflorum		II	II	III	III	II	I	I	II	III	II	II	II	II	III		II
Bersama abyssinica		IV	I	I	III	I		I	I	III	I	I	III	I	I	II	
Cissus humbertii			II			I	IV	IV	IV	IV	II	III	II	II	I	IV	III
Clausena anisata		IV	II			II	III	I	I	I	IV	III	III	II	II	V	V
Meyna tetraphylla		IV	I	II	II	II	I	I	I	I	IV	I	III	III		II	II
Stephania abyssinica			I	II	V	I	I	I	II	II	I	III	III	I	I	IV	IV
Keetia gueinzii	II	V	IV	IV	V	IV		I			V	V	V	I	II	V	
Ficus sur			I	I		II	III	I	I	I		II	II	I	I	II	IV
Alangium chinense				I	II	I	II	I	II	I		I	II	III		V	II
Oncoba spinosa	II		I		V	I		I	I	II	V	II	V	I	V		
Albizia gummifera			II	II		III	III	II	IV	III	III	III	V	V	V	III	IV
Cordia africana					II	I	I	I	I	I			II	I	II	II	II
rare species																	
Abrus spec.											I						
Acacia montigena	III						III	I	II	I		I		I			III
Acanthaceae spec. 2						I	II		I					I			
Acanthaceae spec. 3								I	I	I							
Acanthopale pubescens				II		I		I	I	I	I			I			
Adenia cissampeloides											I	I	II				
Alchemilla spec.											I						
Alchornea laxiflora			I														
Allophyllus africanus											I						
Apocynaceae											I			I			
Argomuellera spec.											I						
Artabotrys likimensis	II		I			II		I	II					I	I		
Asclepediaceae				I													

Asparagus spec.																	II
Asplenium anisophyllum var. mircophyllum											I						
Asplenium c.f. buettneri													II		I		
Asplenium c.f. gemmifera														II			
Asplenium dregeanum							I										
Asplenium lunulatum var. erectum							II	I						II			
Asplenium protensum											I						
Asplenium sp. A gemmifera	II					II			I								
Asplenium sp. C		IV	I			I	III	I									
Asplenium sp. D							II	I	II	I							
Asplenium theciferum											I						
Basella alba									I								
Boehmeria macrophylla						I						I				IV	V
Boehmeria nivea											II						
c.f. Polystachya spec.							I				I						
Caesalpiniaceae											III	I			I		
Calanthe sylvatica						I		I	I		I						
Carissa edulis											I	I					
Casearia battiscombei								I									
Celosia schweinfurthiana			I			I								I			
Chassalia cristata						I						I		II			II
Chionanthus mildbraedii	II		I			I	I										
Chionanthus spec.											I						
Clutia spec.											I						
Coccinia spec.							I	I			II	I					
Crotalaria spec.											I	II					
Croton macrostachyus								I			II		II				
Croton sylvaticus		II		I		II	I		I			I		I		II	IV
Cucumis spec.		II			II	I	I			I	II	I	III	I	I	III	II
Cyperus spec.											I	I					
Dalbergia lactea						I				I				I			
Desmodium sp. A																	II
Dichrocephala integrifolia							I										
Disperis aphylla				I	II	I					I	II	II				II
Dombeya burgessiae													II				
Doryopteris kirkii		IV	I			I		I			II	II		I		II	II
Ehretia cymosa								I	I					I	I	III	
Ekebergia capensis				I					I	I	I	II			I	II	
Ensete edule														I			
Eucalyptus saligna																	II
Eulophia spec.											III	I					
Euphorbiaceae spec.												I	II				
Ficus spec.				I		I		I			I				I		
Ficus thonningii		II		I		I		I		I	III	III	II				
Flacourtia spec.												II					
Galium spec.												I					
Garcinia buchananii			I	I		I							II				
Gloriosa superba								I			I	I	II	II		II	III
Gouania longispicata													II				
Hydrocotyle mannii											I	II					
Illigera pentaphylla						I	I	I	I					I			
Impatiens hochstetteri				I	II	I				I	III	I					
Ipomoea spec.											II		III				
Isoglossa lactea																	
Isoglossa laxa			I					I									
Kalanchoe crenata													II				
Kalanchoe spec.											I		II				
Kigelia africana			I			I	III	II	I	I				I	I		II
Lantana spec.			I	I							I	I	III				II
Leptactina platyphylla							I										
Leucas spec.												I					
Macaranga kilimandscharica									I					I			
Macrorungia pubinervia								I									

Mallotus oppositifolius									I					I			
Melastomataceae spec. 1				I													
Meliaceae spec. 1						I											
Microglossa spec.								I				I	II				
Mikania cordata													II				
Mimosaceae spec.											I						
Momordica spec.								I			II						
Mondia whitei		II	I			I		I	I		I			I			
Neoboutonia macrocalyx				I	II			I	I	I				I			
Ocotea argylei														I			
Orchidaceae spec. 1								I	I	I				II	III		
Orchidaceae spec. 2								I									
Orchidaceae spec. 3						I											
Orchidaceae spec. 4											I						
Orchidaceae spec. 5			I									I				II	II
Oxyanthus speciosus															I		
Paspalum spec.												I					
Passiflora subpeltata						I					I	I	II	I			II
Pellaea viridis			I					I	I			II	II			II	
Persea americana														I			
Phytolacca dodecandra									I		I						II
Pilea spec.																II	
Piliostigma thonningii			I										II				
Pisonia aculeata						I						I					
Pneumatopteris unita								I						I			
Premna angolensis						I								I		II	
Pteridophyta spec. 2								I									
Pteridophyta spec. 3							I	I	I			I				III	IV
Pteridophyta spec. A								I									
Pteris catoptera								I	I		I						
Pteris preussii								I						I			III
Rauvolfia caffra	III		I			I	I	II	II	II				I		II	II
Rhoicissus tridentata								I			I	I	II				
Rhus natalensis				I									II				
Ritchiea albersii			I				I	I						I			
Rothmannia longiflora	II		I				II	I	II								
Rothmannia spec.						I					I				II		
Rothmannia urcelliformis														II			
Rubia cordifolia													II				
Rubiaceae spec. 1						I											
Rubiaceae spec. 2														I			
Rubiaceae spec. 3			I														
Rubus spec.											III	I	II	I		II	V
Rytigynia buboyensis				I							I						
Sapotaceae spec.												I					
Scelaria spec.																	II
Schrebera alata												II	II				
Scutia myrtina				I				I				I	II			II	III
Senecio syringifolius					III	I		III	II	III	I				I		
Setaria spec.											I	I	II				II
Sida rhombifolia											I			I			
Solanum indicum															I		
Solanum mauritianum						I		II	I	I	I	I	III	I	I	III	II
Spathodea campanulata							I			I	I	I		I			IV
spec. 1				I		I											
spec. 11						I											
spec. 12											I						
spec. 13											I		II				
spec. 14											I		II				
spec. 15													II				
spec. 16				I		I											
spec. 17						I											
spec. 18						I											

spec. 19											I						
spec. 2				I													
spec. 20											I		II				
spec. 21											I						
spec. 22					II												
spec. 23					II												
spec. 24							I										
spec. 25								I									
spec. 26																	II
spec. 3				I													
spec. 4				I													
spec. 5				I													
spec. 6				I													
spec. 7				I		I			I								
spec. 8			I														
spec. 9				I													
Spermacoce princeae											I	I					
Stellaria mannii						I											
Stereospermum kunthianum						I											
Tacazzea galactogoga											I						
Tectaria gemmifera			I			I		I	I								
Thalictrum rhynchocarpum								I	I		I		II	I	I	II	
Thunbergia alata								I					II				
Tragia brevipes						I		I			II				I		
Trema orientalis					II										I		III
Trimeria grandifolia			I								I	III				III	
Tristemma mauritianum				I							I						
Triumfetta rhomboidea											III		II				
Triumfetta spec.											I	III					II
Turraea abyssinica			I			II						I					III
Uncaria africana	II							I	I	I		I				II	
Vernonia conferta									I								
Vigna vexillata						I		I			I	I	III				II
Vitex fischeri								I	I	I				I			

Danksagung

> „Naturwissenschaftler sind ein freundliches, gottloses, hart arbeitendes, biertrinkendes Volk, dessen Verstand mit Sex, Schach und Fußball beschäftigt ist, wenn er einmal nicht an Wissenschaft denkt.“
>
> *„Schiffbruch mit Tiger“ von Yann Martel*

Eine solch langjährige Arbeit wäre ohne die Hilfe von vielen lieben Menschen nicht möglich gewesen, denen ich an dieser Stelle danken möchte.

Zu Beginn möchte ich Manfred Kraemer danken, der nicht nur meine Diplomarbeit betreut hat, sondern mir durch seine Unterstützung einen nahtlosen Übergang zur Doktorarbeit ermöglichte – er ist an allem schuld.

An der Universität Koblenz-Landau fand ich eine neue Möglichkeit, weiter wissenschaftlich im Rahmen des BIOTA-Projekts E 04 – bei Prof. Dr. Eberhard Fischer zu arbeiten. Für seine Aufnahme und wertvolle Unterstützung während der letzten Jahre möchte ich mich herzlich bei ihm bedanken.

Bei Prof. Dr. Wilhelm Barthlott, Rheinische-Friedrich-Wilhelms Universität Bonn, möchte ich mich für die Übernahme des Koreferates bedanken.

Am Institut für Integrierte Naturwissenschaften an der Universität Koblenz-Landau wurde mir viel Unterstützung von lieben Menschen wie Dagmar Savelsberg, Brigitte Nilow-Lange, Thomas Wagner und Nikolai Mette zuteil, die mir Halt und viel Zuneigung gaben. Bei und mit ihnen konnte ich eine schöne Zeit verbringen.

Eine sehr schöne Zeit und gemeinsame aufregende und wunderliche Erlebnisse konnte ich mit vielen BIOTA-Mitgliedern, wie Wolfram Freund, Dana Uster, Alexandra Patt, Thomas Bergsdorf, Lars Kühne, Andreas Solga, Stefan Kiefer, Jörn Köhler und Bärbel Bleher, in Kenia und in dem mir sehr ans Herz gewachsenen Kakamega Forest teilen. Das Zusammenleben, das Teilen von Freud und Leid, die Zusammenarbeit, die abendlichen Diskussionen über den Wald, der rege Gedankenaustausch und die gegenseitige Unterstützung machten den Reiz der letzten Jahre aus und machen sie unvergessen.

An dieser Stelle möchte ich auch dem Wald selber danken, der mir bei seiner Erforschung so manches abverlangt hat, aber in dem ich mich sehr wohl gefühlt habe.

Diesen Wald zu erkunden und zu erforschen wäre mir nicht möglich gewesen ohne die grandiose Hilfe eines ganz besonderen Menschen, Bonny Dumbo. Er hat mir die Pflanzen auf seine Weise näher gebracht und mir ein besonderes Gefühl für diesen Wald und seine Lebewesen, die schrecklichen und die schönen, vermitteln können.
Merci beaucoup, mon bon ami et grand maître!

Ein weiterer wichtiger Begleiter und großer Freund „seines“ Waldes ist Caleb Analo. Seine unermüdliche Hilfe sowie sein liebenswertes Wesen zeichnen ihn aus. Ohne ihn und Bonny wäre die Zeit im Wald nur halb so schön gewesen. Eines seiner Sprichworte „It’s part of the entertainment“ umfaßt alles, was dieser Wald und seine Bewohner so zu bieten haben.

Die Aufgaben in Kenia wären ohne die wichtige und wertvolle Zusammenarbeit mit verschiedenen Institutionen und ihren Mitarbeitern nicht durchzuführen gewesen. Neben vielen Menschen in und um Kakamega Forest, wie Fred – „The magic cook of Kakamega“, dessen unglaubliche, allabendliche Essenskreationen die Stimmung im Camp stets oben gehalten haben, gibt es zahlreiche in den Institutionen des National Museums of Kenya (NMK), Kenya Wildlife Service (KWS), Forest Department (FD) und Kakamega Environmental Education Programme (KEEP) arbeitende Menschen, die vieles erleichtert und einiges möglich gemacht haben. Allen voran Geoffrey Mwachala, der mir viel bei der Herbararbeit geholfen hat – Asante sana!

Die Durchführung dieser Arbeit und die Möglichkeit in einem Verbundprojekt mit vielen weiteren wissenschaftlichen Aspekten und Fachrichtungen zu arbeiten, wurde durch die Finanzierung des Bundesministeriums für Bildung und Forschung (BMBF) und die Hilfe des Projektträgers, dem Deutschen Zentrum für Luft- und Raumfahrt (DLR), unterstützt. Ein herzlicher Dank dafür.

Das Analysieren und die Auswertung der erfaßten Daten ging mit viel Unterstützung und Hilfe von vielen Leuten einher.

Ein großer Teil dieser Arbeit wäre nicht möglich gewesen ohne die Bereitstellung von Kartenmaterial, GIS-Daten, Luft- und Satellitenbildern seitens Getrud Schaab, Tobias Lung, Rainer Steinbrecher und Tanja Kraus. Der unermüdliche Einsatz und die viele investierte Zeit, insbesondere von Gertrud Schaab, haben sehr zum guten Gelingen der Arbeit beigetragen. Vielen, lieben Dank dafür.

Die Analyse der pflanzensoziologischen Daten wäre ohne die Hilfe und die Kenntnisse von Herrn Karsten Wesche, Martin-Luther-Universität Halle-Wittenberg, nicht möglich gewesen. Unterschlupf und liebevolle Umsorgung erfuhr ich durch Urte Bachmann. Ganz lieben Dank für die freundliche Aufnahme und die vielen Gespräche.

In nahezu allen Lebenslagen wurde mir eine immerwährende und großartige Unterstützung von Sierk Engels zuteil. Er half mir nicht nur bei der statistischen Auswertung und war ein stets wertvoller Diskussionspartner, sondern tat sich auch mein Englisch an und las alles sehr fleißig Korrektur. Ganz herzlichen Dank dafür!

Vom ganzen Herzen bedanke ich mich bei meiner Familie, insbesondere bei meiner Mutter und bei meinem Bruder, sowie bei meinen Freunden für die Unterstützung in der schönen, aber auch nicht gerade stressfreien Zeit.

“Hayawi hayawi, huwa.“

It may seem that what you are doing will
never come to an end, but finally, the end comes and gives you a lot of relief.
- Kenianisches Sprichwort

Curriculum Vitae

Arnhild Johanna Althof

Persönliche Daten:

Name, Vorname:	Althof, Arnhild Johanna
Geburtsdatum:	11. August 1975
Geburtsort:	Bochum / Deutschland
Staatsangehörigkeit:	deutsch
Familienstand:	ledig

Schulbildung:

1982 – 1986	Städt. Katholische Grundschule Zülpich-Sinzenich
1986 – 1995	Franken-Gymnasium Zülpich
14. Juni 1995	Abitur

Auslandsaufenthalt:

Juni 1995 – September 1995	Sendai, Japan

Studium:

1995 – 2001	Rheinische Friedrich-Wilhelms-Universität Bonn
17. Mai 2001	Abschluß als Diplom-Biologin
Seit April 2002	Promotionsstudium an der Universität Koblenz-Landau

Berufspraxis:

Februar 2001	Studentische Hilfskraft im Semiblock „Morphologie und Evolution der Cheliceraten“, im Museum Alexander Koenig, Bonn
01. Juni 2001 – 31. Mai 2004	Wissenschaftliche Angestellte / Doktorandin im Projekt BIOTA East Africa (E 04) an der Universität Koblenz-Landau
Seit 01. Oktober 2004	Wissenschaftliche Angestellte im Projekt BIOTA East Africa (E 10) an der Universität Bielefeld

Forschungsaufenthalt im Kakamega Forest, Kenia:

September	2001	–	November	2001
März	2002	–	April	2002
Oktober	2002	–	November	2002
Juni	2003	–	August	2003

Erklärung:

Ich versichere, daß ich die vorliegende Arbeit selbständig verfasst habe und alle von mir für die Arbeit benutzten Hilfsmittel in der Arbeit angegeben, sowie die Anteile anderer Autoren klar gekennzeichnet habe.

Koblenz, den (Arnhild Johanna Althof)