Recultivation of abandoned monoculture areas

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in cooperation with:
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Partial project 5

Indicator value of the spontaneous vegetation in pre-used terra firme sites of the Central Amazon

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Final report of partial project 5

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Chapter 5 (Regeneration): M. Skatulla, excerpt from doctoral thesis
Chapter 9.2 (Species list): H. Preisinger, M. Skatulla and L.F. Coêlho
Photos: H. Preisinger

Contents

1 General information on the partial project "Vegetation"

1.1 Participating and cooperating institutions and persons

Germany

Universität Hamburg, Institut für Angewandte Botanik

Prof. Dr. Reinhard Lieberei	Project leader
Dr. Helmut Preisinger	Subproject leader (Scientific Consultant, for Universität Hamburg)
Dipl.-Biol. Martina Skatulla	PhD student (Thesis on "Regeneration in secondary forests")
Mrs. Katja Richter	Student (Examination work on "Aut-ecology of *Bellucia* spp.")

in cooperation with:

Universität Ulm, Abt. Spezielle Botanik

Prof. Dr. Gerhard Gottsberger	(flowering biology)
Dr. Albert-Dieter Stevens	(flowering biology)

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Dr. Oliver Dünisch	(ecophysiology of trees)

Brazil

EMBRAPA Amazônia Ocidental, Manaus-AM

Dr. Luadir Gasparotto	Project leader
MSc Madalena Otaviano Aguiar	Grantee of CNPq (Plant anatomy)
MSc Ronaldo Ribeiro de Morais	Grantee of CNPq (Plant anatomy, *in cooperation*)

INPA - Instituto Nacional de Pesquisas da Amazônia, Manaus-AM
Herbário

Sr. Luiz F. Coêlho	Technician (identification of plant species)

1.2 Timetable for the fields of activities carried out from September 1996 to August 2000

Fields of activities			Years				
			96	97	98	99	00
Analyses of vegetation in fallow and agricultural sites	Comparative autecological studies of a selection of frequently occurring plant species in the experimental sites	Studies on morpho-physiological traits	●	●	●	●	●
		Studies on the dynamics of leaf development			●	●	●
		Studies on anatomical traits of leaves (grantee of CNPq, M. O. Aguiar)			●	●	●
		Distribution of nutritional elements in plant organs	●	●	●		
	Synecological studies in different stages of secondary vegetation (includes the spontaneous vegetation of the SHIFT field trial	Analyses of flora	●				
		Structural analyses of vegetation	●	●	●	●	●
		Studies on sucession of secondary vegetation	●	●	●	●	●
	Studies on the regeneration of secondary vegetation (Dissertation of M. Skatulla which incorporates elements of syn- and autecological studies)		●	●	●	●	●
Comparative analysis of agricultural sites in the Central and Eastern Amazon			●				
Multivariate analyses of the SHIFT field trial, focussed on the spontaneous vegetation and the indication of site conditions			●	●	●	●	●
Species list with autecological traits					●	●	●

2 Objectives, assumptions and concepts

The comparative vegetation-science approach to the project "Recultivation ..." (ENV 23/2) is a continuation and amplification of the studies carried out from 1992 to 1996 for the predecessor ENV 23/1 project. These first studies on the spontaneous vegetation at the EMBRAPA/SHIFT experimental site near Manaus-AM had shown that the species combination and structural traits (e.g. cover, stratification and composition of growth forms) of vegetation stands are closely linked to the pre-use and present management of the sites (see Preisinger et al. 1994), which suggests that *disturbance* is one of the key factors in the variation of vegetation. The term is used here in the sense of Grime (1979) and it is being defined as "mechanisms which limit the plant biomass by causing its partial or total destruction".

Disturbance is an environmental factor in vegetation which can neither be measured nor substituted by a factor closely related to disturbance and which would permit a measurement. It was therefore decided to focus the follow-up studies on *the indicator value of common species and of vegetation types, mainly with regard to disturbance* (i.e. slashing and burning, cutting, trampling, hoeing).

In Central Europe, indicator value systems had been developed from the middle of the last century (Ellenberg 1974, 1979; Landolt 1977; Ellenberg et al. 1991), in part based on laboratory experiments (see Ellenberg 1953). Ellenbergs "indicator values" have been applied with success in agriculture, landscape planning and nature conservancy, in particular for the indication of site factors of the soil (e.g. water and nutritional state). Independently from this approach, in the anglo-saxon countries concepts for the comprised description of the autecological behaviour of frequently occurring flowering plant species had been developed ("life history theories", see Grime 1979; Tilman 1982, 1988, 1990a, b). CSR theory (Grime 1979) assumes for higher plants the existence of three main selection processes (= strategies: stress - disturbance - competition), which lead to specific plant types with regard to physiological and morphological traits and to specific life and growth-form types. The CSR system (Grime, Hodgson & Hunt 1988) is a life history concept which includes the disturbance factor, and which has already proven its practical validity for anthropogenic vegetation of temperate regions (see e.g. Preisinger 1991).

In the approach presented here it is assumed that the behaviour of vascular plants in the humid tropics can also be explained in part with the help of CSR theory. However, the applicability of the theory in practice depends largely on the information available on flora and vegetation. The approach presented below had therefore to take into account that the information available on flora and vegetation in the Amazon is very poor compared to Europe.

The starting point for the autecological studies is the classification of species in a growth form system (see Preisinger et al. 1998, 1999 and Appendix, chapter 9.1) and morphological traits that are thought likely to be closely linked to important ecological factors, such as types of pre-use or of management (= extent and frequency of disturbance events), which are key factors in the suitability of sites for agriculture. The conclusions are to be incorporated in an indicator value system of practical applicability. Such a system would be useful for assessing the potential of fallow land for agricultural recultivation. In this context, the vegetation subproject can be divided into four partial objectives, each of which must first be accomplished in order to proceed to the next stage:

- Recording of important autecological traits of frequently occurring secondary forest species and comparison with corresponding traits of useful plants which were planted in the experimental site.
- Attempts to devise a functional description of successional stages of vegetation, growing in the agricultural experimental plantation and in surrounding secondary and primary forests.
- Development of an indicator value system of practical applicability, especially to indicate types of pre-use, i.e. suitability for agricultural use.
- Analysis of the field experiment using multivariate analysis techniques and the indicator system.

The approach required three main branches of activity: *floristic*, *autecological* and *synecological* (see Table 2.1).

Recording of the *flora* is the basic precondition for the other approaches. Because very little is known of the ecological behaviour of the vast majority of the approximately 1.200 species of vascular plants occurring in the experimental site, it is necessary to accumulate a basic knowledge of the *autecology* of selected secondary forest "sample species". The species to be studied in detail were selected by personal judgement, taking into account both the (assumed) importance of the species in the successional sequence and the species' frequency and biomass production. In a *synecological approach*, a sequence of vegetation types, ranging from extensively used primary forest sites to agricultural land, is compared with regard to floristic composition and structural traits (composition of growth-form types, propagation and regeneration types, inter alia.

The *approach for the analysis of regenerative mechanisms* carried out in a sequence from primary forest to fallow sites had been developed as a separate work (doctoral thesis), incorporating a combination of all the three approaches mentioned above.

Table 2.1:
Overview of the main data sets built up in the vegetation subproject

1. Floristic data - **Recording of all vascular plants** in the habitats mentioned below, preferably on the species level (approx. 1.200 species); - **Classification** of the most frequently occurring species with regard to **growth form types** and **regenerative behaviour** (approx. 1.000 species classified).
2. Synecological data - **Habitats recorded:** extensively used primary forest plots of 100 m² each (2.200 m² total), secondary forest plots of 100 m² each of 8 years of age and more (10.000 m² total) and plots of 1.600 m² used for the agricultural systems to be tested in the EMBRAPA/SHIFT experimental site (140.000 m² total); plots of 100 m² on farm land and fallow areas of smallholders near Manaus (total area of approx. 3.000 m²); - **Structural traits recorded:** stratification, distribution and dynamics of diameters of tree individuals (> 1 cm), total vegetation cover and cover of single growth form types [%] in the plots of the experimental site; biomass of all tree individuals (> 1 cm of diameter) in a 100 m² secondary forest plot; - **Temporal sequences recorded:** 1. in all plots of the experimental sites: vegetation cover before planting of the useful plants in 1993, and after two, five and seven years (1995, 1998, 2000); 2. in the secondary forest: all plots in 1994, 10 plots in 1996 and 1998; - **Seed rain and dynamics of seedling populations** in primary forest, secondary forest and Capoeira plots.
3. Autecological data - **Morphological and anatomical traits** of individuals of 13 frequently occurring secondary forest plant species of different plant families (sample species), as well as biomass and content of mineral nutrients of the overground parts of plants; - **Life history of leaf development** of individuals of most of the sample species; - **Phenology** of frequently occurring species of flowering plants; characteristics of fruits and seeds.

3 Floristic and synecological studies

3.1 Overview

The vegetation types which were studied in the EMBRAPA/SHIFT experimental site represent a combination of a spatial and a temporal sequence (cf. Table 2.1), and are the result of different types of pre-use (= different intensities and frequencies of disturbance). The vegetation was recorded in a quantitative form and its floristic and structural traits analysed. Table 3.1 summarizes the floristic, taxonomic and structural traits of the vegetation types under study.

The number of species found in the 1.600 m² plots decreases drastically with the intensity and frequency of disturbance, from approximately 500 in the primary forest to 30 in the agricultural plots. The different vegetation types are characterized by a specific range of plant families, indicating that different taxonomic groups show a specific range of ecological behaviour. Hence, some of the plant families present in a vegetation can be used as "key families" for the different types of habitat. The structural and functional traits presented in Table 3.1 are restricted to stratification, growth form types and types of reproduction and/or regeneration. In Table 3.1, the different layers are named after the growth form type of which they are mainly composed, and numbered from top to bottom.

The physiognomy of the *Terra Firme primary forest* studied is characterized by a canopy of tall trees up to 40 m of height and an understorey layer of palm trees (*Astrocaryum* spp., *Oenocarpus* spp., inter alia, see chapter 9.3, Photo 1). Applying the Beard (1955) classification system, the forest has to be classified as "tropical rain forest", but showing a tendency towards an "evergreen seasonal forest". It is not possible to decide whether the forest type is similar to the "open forest with palms" of Pires & Prance (1985), because of the concise description given there. Klinge (1973) and Prance, Rodriguez & da Silva (1976) do not propose any classification. In our first vegetation survey, carried out in 1994, the *secondary forest* had reached a height of 10 m (see chapter 9.3, Photo 2). It was dominated by low trees, e.g. *Vismia guianensis*, and treelets, whereas *Miconia* (Melastomataceae) represented the largest number of species. These characteristics are special to the site studied and cannot be generalized for other secondary forests of the same age in the Central Amazon, because the course of succession greatly depends on the initial site conditions soon after the disturbance event, which might be different elsewhere. The *spontaneous vegetation* (see chapter 9.3, Photo 9) of the agricultural plots show a decline in the proportion of tree species, compared to primary and secondary forest, but the proportion of liana species remained ±constant. There are also differences in the number of species and structural traits between the different mixed cropping systems (not considered in Table 3.1).

The *reproduction of woody plant species* by seeds plays an important role in the primary and secondary forest. In the primary forest, seed production is comparably low, the majority of the seeds are large and the dispersors are mainly larger animals. Seed production in the secondary forest is higher and the seeds are smaller than in the primary forest. In both the primary and the secondary forest, the site conditions are favourable to seed germination, but poor light conditions on the ground normally prevent the immediate growing of the seedlings. Seed production in the Capoeira and in the secondary forest is similar, but the majority of the seedlings in the Capoeira does not survive for more than one year. In the agricultural plots, the woody plants *regenerate vegetatively by roots and shoots*, but do not reach the reproduction phase.

Table 3.1:
Charcteristics of a sequence of Terra Firme sites with different use histories in the Central Amazon (EMBRAPA/SHIFT experimental site near Manaus-AM); n = number of species of vascular plants found in an area of 1.600 m²; see text for more details.

<table>
<tr><th rowspan="2">Vegetation type</th><th rowspan="2" colspan="2">History of sites</th><th colspan="2">Floristic and taxonomic traits</th><th colspan="2">Some structural and functional characteristics of vegetation</th></tr>
<tr><th>n</th><th>Key families[1]
Dominant species</th><th>Stratification and growth form types of spontaneous vegetation</th><th>Characteristics of reproduction and regeneration</th></tr>
<tr><td>(1)
Primary forest</td><td colspan="2">extensively used for timber extraction (mainly *Minquartia guianensis* Aubl. = Acuaricuara)</td><td>500</td><td>Sapotaceae, Chrysobalanaceae, Burseraceae, Lecithidaceae
Astrocaryum spp.</td><td>1. Epiphytes
2. Tall Trees
3. Medium and Low Trees; Lianas and Spread-climbers
4. Rosette Trees (palms)
5. Regenerating Trees
6. Herbs</td><td>Preferably reproduction by low quantities of large seeds; autochory, anemochory (large, winged seeds); zoochory (bats, large specialized frugivorous birds, large mammals)</td></tr>
<tr><td>(2)
8 year old secondary forest (in 1994)</td><td colspan="2">Primary forest slashed and burned, rubber trees planted and abandoned 2 years after</td><td>200</td><td>Melastomataceae, Moraceae, Rubiaceae, Bignoniaceae
Vismia guianensis agg.
Miconia spp.
Bellucia spp.</td><td>(Epiphytes)
1. Medium and Low Trees; Lianas
2. Treelets
3. Regenerating Trees
4. Stolon Grasses and Herbs</td><td>Preferably reproduction by higher quantities of small seeds; autochory, anemochory, zoochory (unspecialised, frugivorous birds, bats, large mammals)</td></tr>
<tr><td>(3)
5 year old Capoeira</td><td rowspan="4">as in (2), but slashed and burned for a second time</td><td>sites left unattended</td><td>30-60</td><td rowspan="2">Bignoniaceae, Rubiaceae
Vismia spp.</td><td rowspan="2">1. Low (Medium and Tall) Trees
2. "Shrubs"[2] and Lianas
3. Stolon Grasses</td><td rowspan="2">Regeneration and subsequent spreading of woody plants by shoots and roots; reproduction by small seeds; anemochory, zoochory (unspecialised frugivorous birds and bats)</td></tr>
<tr><td>(4)
Forestry system</td><td>timber trees planted in rows</td><td>30-60</td></tr>
<tr><td>(5)
Mixed cropping system</td><td>3 plantation systems</td><td>20-50</td><td rowspan="2">Poaceae, Bignoniaceae, Rubiaceae
Pueraria phaseoloides, *Homolepis aturensis*; locally dominace is reached by other species, e.g. *Clidemia hirta*</td><td rowspan="2">1. Stolon and Tussock Grasses, herbaceous and woody Lianas, Herbs, regenerating Trees, "Shrubs"[2]</td><td rowspan="2">Regeneration of woody plants and grasses by stolons, rhizomes, roots and by tillering; reproduction of herbs and grasses by small seeds; anemochory, zoochory (unspecialised frugivorous birds and bats)</td></tr>
<tr><td>(6)
Monoculture system</td><td>4 plantation systems</td><td>30-60</td></tr>
</table>

[1] Families which respresent the largest number of species in the vegetation types
[2] "Real shrubs", marked by a basipetalic growth (see Raunkiaer 1934), obviously do not exist in the humid tropics. The growth form type "shrub" in the Table is characterized by a mesopetalic growth and a low maximum height;

The ability to regenerate vegetatively after slashing and/or burning is one of the most important attributes governing the survival of the majority of woody plant species in a frequently disturbed environment. Lianas, grasses and herbs, but only few tree species can invade such open sites, spreading by stolons and rhizomes and reproducing by small seeds. In the experimental site, the habitats "primary forest", "secondary forest" and "Capoeira" are situated in close proximity to one another. Nevertheless, plant species do not often spread from one habitat to another and a spreading of primary forest species into the Capoeira was seldom observed, propably because the dispersors (e.g. large mammals and birds) avoid the open landscape (Howe 1990).

3.2 Experimental areas, sites and plots

The experimental sites for the vegetation project are part of the SHIFT experimental site, situated in the experimental area of EMBRAPA, 28 km north of Manaus, Amazonas. Moreover, additional sites for comparision were established on farmland of smallholders near Presidente Figueiredo, situated 100 km north of Manaus (along the road AM-240), and near Rio Preto da Eva, situated 130 km north-east of Manaus (road AM-10, km 130).

The sites mentioned were studied with regard to flora, vegetation and site factors. The EMBRAPA experimental area shows ± uniform natural site conditions. The soil type througout the area is "Yellow Latosol" or "Xanthic Ferralsol" within the FAO classification system. The main differentiating "environmental complex[1]" between the sites selected for the vegetation studies are *different histories of use*.

The studies on flora and vegetation are based on experimental plots which permit analyses of flora and vegetation in a comparative approach. The size of the smallest plot in the primary and secondary forest is 10 x 10 m². This size had been choosen for practical requirements and not because 100 m² is believed to be an adequate plot size for tropical forest vegetation: It is much too small to represent either the primary or the secondary forest, in terms of floristic and structural characteristics, but the size is still small enough to survey the area while carrying out the field work. The size of the plots in the SHIFT field experiment is 48 x 32 m² = 1.536 m², which is the size of the agricultural plots. The overall study area in the primary forest is 1.600 m², and 10.000 m² in the secondary forest. The study of larger forest areas would have been desirable, but was not practicable because of the limitations of the project with regard to personell and money. Note that within the CTFS Research Programs of the Smithonian Institution, 50-ha-plots have been installed in various parts of he world for comparative studies of tropical forests (cf. Hubbell et al. 1999, Condit et al 2000). However, in the present project, the forest plots serve as references for the spontaneous vegetation in the agricultural plots of the SHIFT field experiment. For that reason, the small plot size might be acceptable, even if the total primary forest area of 1.600 m² analysed is equal to one of the 90 agricultural plots. In detail, the following types of sites in the experimental area of EMBRAPA were surveyed (in brackets: abbreviations for total numbers of plots and area sizes; see also Fig. 3.1):

<u>Site 1:</u> Primary forest (16 plots of 100 m² each = 1.600 m²)

The primary forest is being used by occasional cuttings of trees, in particular of

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[1] see Billings (1952) and Preisinger (1991)

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Acuaricuara (*Minquartia guianensis*). As a side effect, changes in the structure of litter and the upper soil layer are taking place, especially by trampling along the paths.

Site 2: Secondary forest (100 plots of 100 m² each = 10.000 m²)
The primary forest was cut and burnt in 1982, and a rubber tree experimental plantation had been installed (experiment: "Competição de clones ...I" of EMBRAPA), which was abandoned soon after (approx. after 1½ years), because the fungus *Microcyclus ulei* had damaged the plantation in a way that a continuation of the field trial was not possible. Approximately 8 years after abandonment, our vegetation studies began (in 1994).

Site 3: Fallow (90 plots of 1.536 m² each = 138.240 m²)
The fallow area has the same site history than the scondary forest (site 2), but the 8 year old secondary forest was cut and burnt again in autumn 1992. The first vegetation survey was carried out 5 months after slashing and burning, in march 1993, just before the installation of of the experimental polyculture plantation (site 4). Site 3 represents as well the regeneration of the secondary vegetation as the invasion of short-lived, mainly herbaceous plant species.

Site 4: Agricultural area of poly- and monoculture systems (80 plots of 1.536 m² each = 122.880 m²)
The former fallow areas, converted into three different polyculture and four monoculture plantation systems.

Site 5: Plots of the forestry system (5 plots of 1.536 m² each = 7.680 m²)
The forestry plots consist of several forestry tree species planted in rows. The rows were kept free of secondary vegetation, but between the rows the vegetation could develop without any disturbance.

Site 6: Remaining fallow plots (5 plots of 1.536 m² each = 7.680 m²)
Plots which were left unattended and where the wild vegetation could develop without any disturbance.

The spontaneous vegetation growing in the plots of sites 4, 5 and 6 was surveyed after 2, 5 and 7 years of plantation management. Consequently, the six ecotopes represent a combination of "real" and "false" temporal sequences.

The studies on secondary forest regeneration were also based on the plot sizes mentioned and were carried out in the same experimental site, but with some modifications and supplementary plots in the primary forest (methodology see chapter 5).

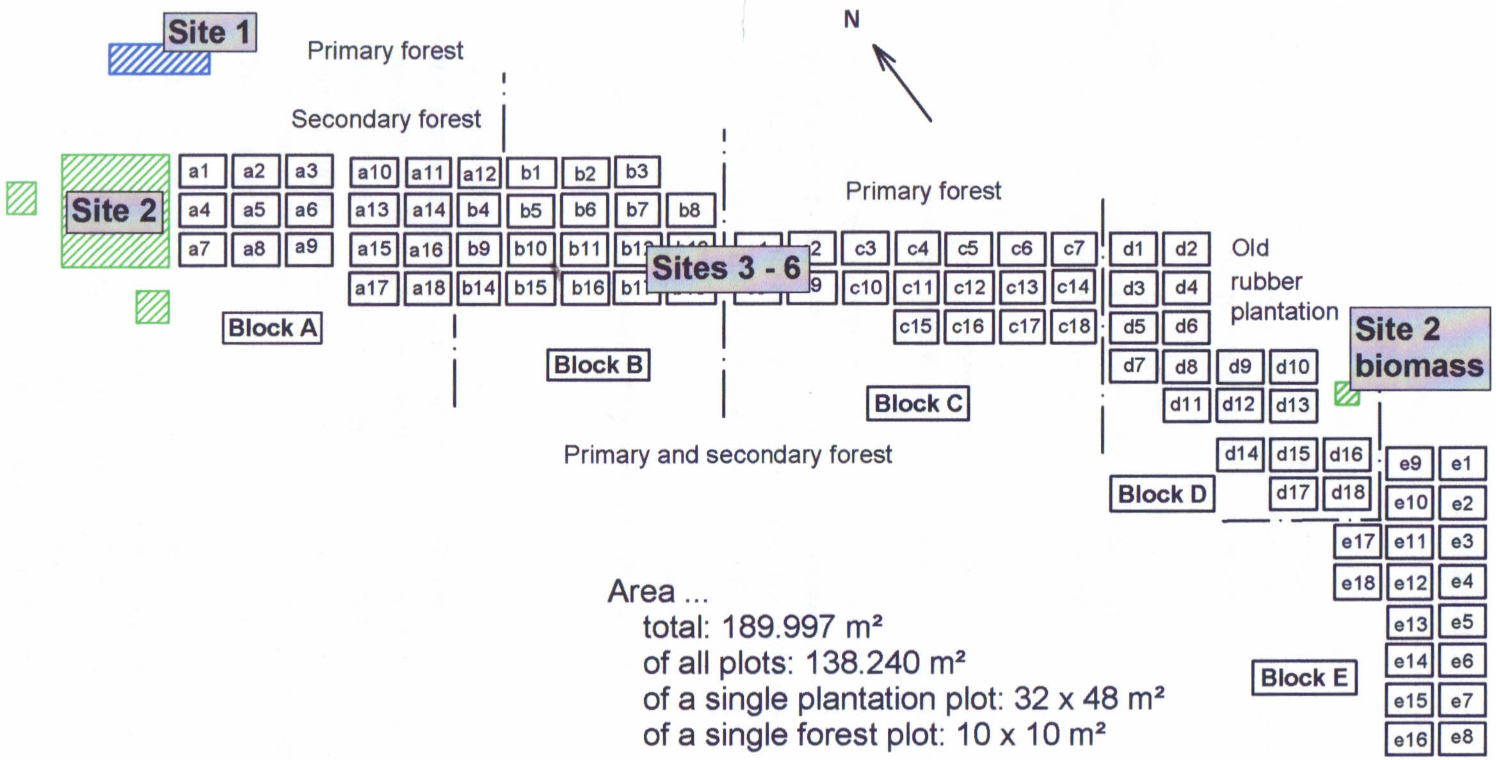

Fig. 3.1:
Experimental plots of the vegetation project within the SHIFT experimental site at EMBRAPA Amazônia Ocidental, Manaus.

Site 1 = primary forest plots;

Site 2 = secondary forest plots; **Site 2 biomass** = additional secondary forest plot (plant biomass and structure of dominance);

Sites 3-6 = plots of the agricultural field experiment.

See text for further explanations.

3.3 Floristic analyses of forest and agricultural sites

3.3.1 Methods

The analysis of flora, being the basis for the other synecological studies, was carried out in all the experimental plots. The forest plots were analysed once in 1994, whereas the floristic surveys in the plots of the field experiment were carried out three times (in 1993, 1995 and 1998). The surveys resulted in presence-absence tables for the flora in the plots of the primary forest, the secondary forest and the field experiment. Every species of vascular plants occurring in the plots was identified (flowering plants, gnetophytes, ferns and fern allies), at which the herbarium of INPA served as a collection of reference. The majority of the plant species (approx. 95 %) was found only in a vegetative state (= without flowers and fruits) and had therefore be identified mainly from the characteristics of the leaves, the position of leaves, type of bark etc. For that reason, an identification on the species level was not possible for all the individuals found. As far as the species were present in the "Checklist of the vascular plants of the Guayanas" (Bogan et al. 1992), the nomenclature refers to that work. For species showing a distribution restricted to the Central Amazon or being endemic, the nomenclature used in the herbarium of INPA was adapted.

3.3.2 Plant collection and list of species

For every species collected and identified, one or more samples were kept in a "collection for reference" in the EMBRAPA. This collection, which consists of more than 1.000 species found in the ecotopes mentioned above, and preferably of unfertile material, is determined for the comparison and identification of plant material which will be collected in future mainly in secondary forests, fallow areas and agricultural land. The collected material is unique in the Amazon (Coêlho, pers. comm.) because it comprises vegetative, newly regenerated parts of woody plant species after disturbance events like slashing and burning, and which are identified as accurate as possible. It is as difficult as time consuming to identify such material, because its characteristics are often quite different from those of the adult plant. The plant collection is the first one which had been installed in EMBRAPA Amazônia Ocidental. It might be of use for the agronomist who wants to compare and identify plants from fallow and agricultural areas.

For documentation and as a work of reference, at least one sample of every species was photographed on negative films (see examples in the appendix, chapter 9.3).

The species list (see appendix, chapter 9.2) contains all the species found in the different experimental sites near Manaus and, additionally, some species from Capoeiras of the Eastern Amazon which were needed for comparisons (see Preisinger, Baar & Denich 1998).

3.3.3 Floristic comparisons between the habitats

The search for sustainable agricultural land use forms in the humid tropics includes the problem of the regeneration of the natural forest vegetation after the abandonment of a site. For prognoses on a future development of vegetation it is therefore interesting to compare the floristic composition of the natural vegetation cover, i.e. the primary forest (= climax vegetation), with successional stages of vegetation which were caused by present or past agricultural uses. This would require the observation of temporal vegetation changes in a certain area, or "real" time sequences, caused by agricultural activities. Such data sets are very rare. The present data permit a combined analysis of "real" and "false" temporal sequences (see above). Another problem for an ecologically meaningfull floristic comparision of forest vegetation with vegetation in agricultural land are the different spatial patterns formed by these vegetation types (the "scale problem": see e.g. Palmer 1988, Wiegleb 1989, Condit 2000).

Species-area curves can be a help for the estimation of the number of species to be expected in an area being homogenous with regard to all site factors (cf. Palmgren 1922)[2]. They can also be used to compare several areas in one graph. The species-area curces and the jackknife estimators for the areas analysed in the primary forest (site 1), the secondary forest (site 2) and the spontaneous vegetation in the field experiment (sites 3-5) were calculated using the program PC-Ord (McCune & Mefford 1997). The jackknife estimators (Burnham & Overton 1979, Heltshe & Forrester 1983, Palmer 1990, 1991) permit the extrapolation of the number of species found in an area by subsampling with smaller sample units. The number of observed species in a subsample will typically be smaller than the true number of species.

As expected, the species richness decreases from primary via secondary forest to the agricultural area (Fig. 3.2). For the smallest sample size which can be compared directly ("level of comparison" = 1.600 m^2), the observed numbers of species are 490, 193, 34, 22 and 21 in the ecotopes mentioned, while the number of species observed in the largest areas surveyed are 490, 409, 300, 251 and 209. Moreover, the graph shows that slashing and burning of the secondary forest in 1993 lead to a drastic loss of species and that after two years of plantation management (from 1993 to 1995) another loss of species had took place. However, in 1998 the number of species increased again. Subsequent structural analyses of vegetation will show that this indicates a shift in species composition from forest species, which are mainly woody, to disturbance-tolerant, mostly herbaceous plants.

The jackknife estimator reveals approx. 800 species for the primary forest, which might be roughly underestimated, because the area surveyed is much too small for a reliable calculation. From our own practical experience it might be estimated that 1.200 species for a large, homogeneous area are more realistic. This would be in accordance with data from Klinge (1973), who recorded a similar number of species in adjacent areas. The relatively high estimates of number of species in the secondary forest indicate that the secondary forest, which regenerated after the first slashing, burning and planting of rubber trees, has still the potentiallity for a successive development back to a mature rain forest.

The ecological implications which can be drawn from the comparison of number of species in different habitats is limited, if only little is known on the taxonomic and ecological characteristics of the species present in a site. There is very few knowledge available on *ecological characteristics* of most of the Amazonian species. One of the aim of the vegetation project was to improve this knowledge, focussed on the plant species of the secondary forest (see below, chapter 4). Much of the efforts in plant science carried out in the humid tropics concentrated - and still concentrates - on plant taxonomy. *Taxonomic characters* may be inadequate for the

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2 The concept of species-area curves was discussed critically in the past. It is not possible to review the fundamental difficulties here.

description of ecological variation, as well on the species as on other levels of the taxonomic hierarchy, because "the criteria used by the taxonomist for the delineation of taxa are chosen deliberately from the conservative and stable features of morphology that are not subject to genetic variation, polymorphism or phenotyc change" (Harper 1982). However, in practice *plant species* remain the only readily recognizable entity in the field (Grime 1985), and even *plant families*, being taxonomically ±well defined groups of species, contain also ecological information. The problem with all taxonomic categories is that the range of ecological behaviour (= ecological amplitudes) is subject to a large variation within different groups on the same taxonomic level. On the family level, two examples might illustrate the different possibilities of behaviour: Chenopodiaceae comprises mainly short-lived herbs (R-strategists in accordance with Grime 1979), whereas Euphorbiaceae comprises the whole range of life- and growth-forms, or strategy types respectively, ranging from short-lived herbs to large trees.

From the preceding it can be stated that spectra of plant families might be useful for the characterization of certain vegetation types, but an ecological interpretation is only possible in a very general form. Each of the three habitats under study (primary forest, secondary forest and experimental plantation) show a specific spectrum of families (Table 3.2). There are families characteristic for either the primary forest, the secondary forest or the plantation, and others which do not show a preference for one of the habitats (see families set off in Table 3.2). Melastomataceae occurs with many species in the secondary forest plot, preferably with shrubs, treelets, small and medium-sized trees (cf. growth-form system, chapter 9.1). However, this is not a general feature of Central Amazonian secondary forests, but a characteristic of that specific plot. The reasons must be sought in its use history and the surrounding sites, but nothing can be said about the mechanisms responsible for this striking trait. Bignoniaceae occurs in all of the three habitats mainly with woody lianas, Moraceae with treelets and a large diversity of trees, and Rubiaceae with herbs, herbaceous lianas, shrubs and trees.

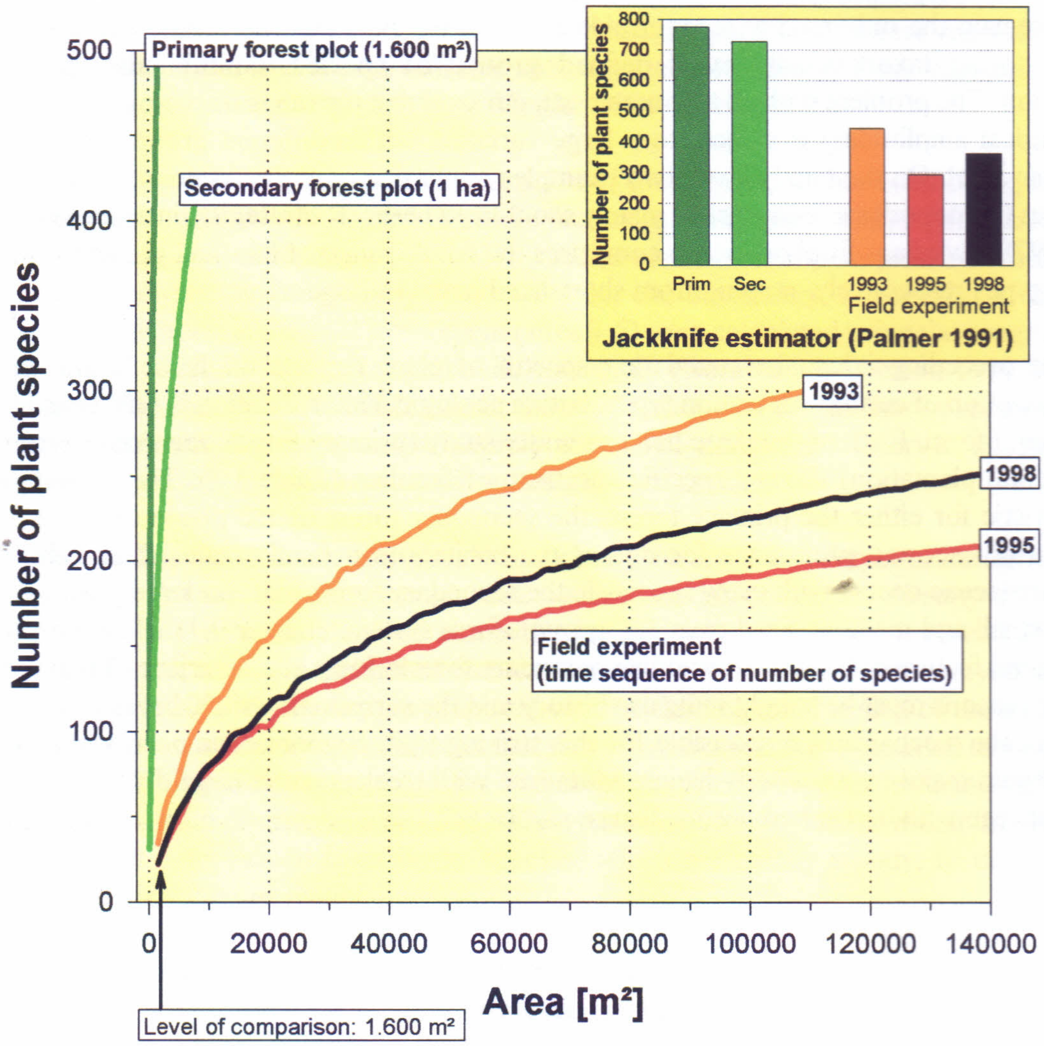

Fig. 3.2:
Comparision and estimation of species richness in a primary forest plot, a secondary forest plot and the SHIFT field experiment, with the help of species-area curves and the second-order jackknife estimator (inset).

Table 3.2:
Spectra of the plant families with the most species occurring in the sample areas of the primary forest, the secondary forest and the experimental plantation in 1995. Set off: families within the displayed selection which occur in all of the three habitats.

	Primary forest	Secondary forest	lantation
total no. of species	490	409	182
total no. of families	72	72	44
area surveyed [m²]	1.600	7.700	140.000
Order of the 12 plant families with the most species (in brackets: number of species)	1 Sapotaceae (30) 2 Chrysobalanaceae (28) 3 Burseraceae (26) 4 Annonaceae (21) 5 **Rubiaceae** (20) 6 Caesalpiniaceae (20) 7 Mimosaceae (19) 8 **Moraceae** (19) 9 Lauraceae (16) 10 Araceae (16) 11 **Bignoniaceae** (14) 12 Meliaceae (12)	1 Melastomataceae (33) 2 **Moraceae** (26) 3 **Rubiaceae** (24) 4 **Bignoniaceae** (23) 5 Fabaceae (17) 6 Sapindaceae (15) 7 Burseraceae (12) 8 Annonaceae (12) 9 Arecaceae (12) 10 Flacourtiaceae (11) 11 Menispermaceae (9) 12 Euphorbiaceae (8)	1 Poaceae (7) 2 **Bignoniaceae** (7) 3 **Rubiaceae** (6) 4 Melastomataceae (5) 5 Fabaceae (5) 6 Mimosaceae (5) 7 Malpighiaceae (4) 8 **Moraceae** (4) 9 Asteraceae (4) 10 Euphorbiaceae (4) 11 Verbenaceae (3) 12 Solanaceae (3)

3.4 Structural analysis of vegetation

3.4.1 Definitions

"Structure" in vegetation science can be defined as the organisation of the plant individuals in space which compose a site[3]. This general definition is close to the one given by Dansereau (1957)[4]. The term "vegetation structure" can be seen as complementary to "floristic composition" and comprises the arangement of morphological elements of plant individuals in a stand[5]. This includes growth-form, stratification and vegetation cover and also "functional groups" or "strategy types" in accordance with Grime 1979 (cf. Preisinger 1991). Within the present comparative vegetation studies, structural analyses are part of the search for morpho-physiological traits and functional groups in the different successional stages of the Central Amazonian vegetation. "Morpho-physiological traits" are morphological characteristics of plants and groups of plants which play a key role for their ecological behaviour in different environments (see also chapter 4).

3.4.2 Methods

The 10 x 10 m forest plots were surveyed once in 1994. All the tree individuals with stem diameters > 1 cm had been listed, the diameters measured (in 30 cm in height above ground), sampled and identified. The plant individuals with diameters < 1 cm were sampled, identified and the species listed as presence-absence data per plot.

The vegetation in the 90 plots of the experiment had been surveyed three times (6 months after slashing and burning in 1993, 1995 and 1998, wth an additional survey of growth-form composition in 2000). We found it necessary to analyse the whole range of vegetation occurring in all the plots of the experimental area of 14 ha. It was therefore necessary to develop a methodology which permitted to carry out the vegetation survey in this large area with an acceptable effort in labor and time on the one hand and to accumulate ecologically meaningful, quantitative data on the other. The solution was to work out and combine two different data sets, the first being presence-absence data of flora for all the plots and the second quantitative data of cover of the growth-form types. For the survey of the cover of growth-form types in the agricultural plots, a simplified version of the growth-form system (chapter 9.1) was used, consisting of 7 types: T = trees and treelets, SH = shrubs, WT/WH = woody and herbaceous lianas, GR/GT = rhizomatous and tussock grasses, GS = stolon grasses, UT = herbs and forbs.

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3 The term "site" is understood here in the (abstract) meaning of the German word "Standort", which is defined as "the totality of all site factors which effect the plant cover in a certain locality" (Rübel 1930), cf. also Billings (1952), Müller-Dombois & Ellenberg(1967) and Wiegleb (1986).

4 "Structure is the organization in space of the individuals composing a vegetation type or association" (Dansereau 1957).

5 "stand" is a real locality in the landscape where an assemblage of plant individuals is growing.

3.4.3 Comparative analysis of the growth-form composition in three different habitats

The analysis of growth-form composition and strata in the primary forest plot, the secondary forest plot and the experimental plantation is based on the same data sets than the floristic analysis (chapter 3.3). In this approach, the number of species belonging to the 16 growth-form types had been calculated for the three habitats, separately for three strata (epiphyte layer, tree layer and shrub/herb layer). The shrub/herb layer covers the woody plant individuals with stem diameter < 1 cm and herbaceous species, whereas the tree layer covers the plants with stem diameters > 1 cm. The growth-form spectra in the three strata of the three habitats, which represent a sequence with an increasing effect of past disturbance events, are presented as grouped bar charts (Fig. 3.3).

The sequence reveals in which way the different growth-form types respond to an increasing intensity and frequency of disturbance. The number of tree species (TT, MT, LT) declines drastically even after the first slashing and burning, but the relatively high numbers of tree species still found as saplings and young plants in that stage of the secondary forest,i.e. in the shrub/herb layer, indicates that a succession towards the mature forest would be possible at long date, provided that there will be an undisturbed development in future. Though the treelets (ST) do not play an outstanding role in non of the habitats in terms of absolute number of species, it is obvious that the number of species for that growth-form type reaches its maximum in the secondary forest. However, in terms of biomass and number of individuals, treelets are often dominant in secondary forests (see following chapter). It is not surprising that the dicotyledonous herbs (UH), the grasses (GS, GT) and the shrubs (SH) gain more importance in the plantation than in the other habitats, because the majority of the species belonging to this group are mostly invasive plants of cultivated areas, often with a wide, pantropic or even cosmopolitan distribution (e.g. *Pteridium aquilinum*[6]).

The most interesting group within the compared habitats are the woody lianas (WT), because their number of species does not change much in the sequence of habitats in comparison to the other groups. They obviously show a very flexible response even to severe and frequently occurring disturbances. Nevertheless, the group of "woody lianas" comprises species of a wide range of ecological behaviour and it might therefore be argued that the species composition within the group is different in the three habitats. This is partially true, but the floristic analysis also reveals that there are many species belonging to the woody lianas which occur as well in the disturbed primary forest as in the secondary forest and in the plantation (examples: *Machaerium hoehnearum* - Fabaceae; *Memora adenophora, M. flaviflora, M. moringifolia* - Bignoniaceae).

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[6] For the complete plant names with authors see species list (chapter 9.2).

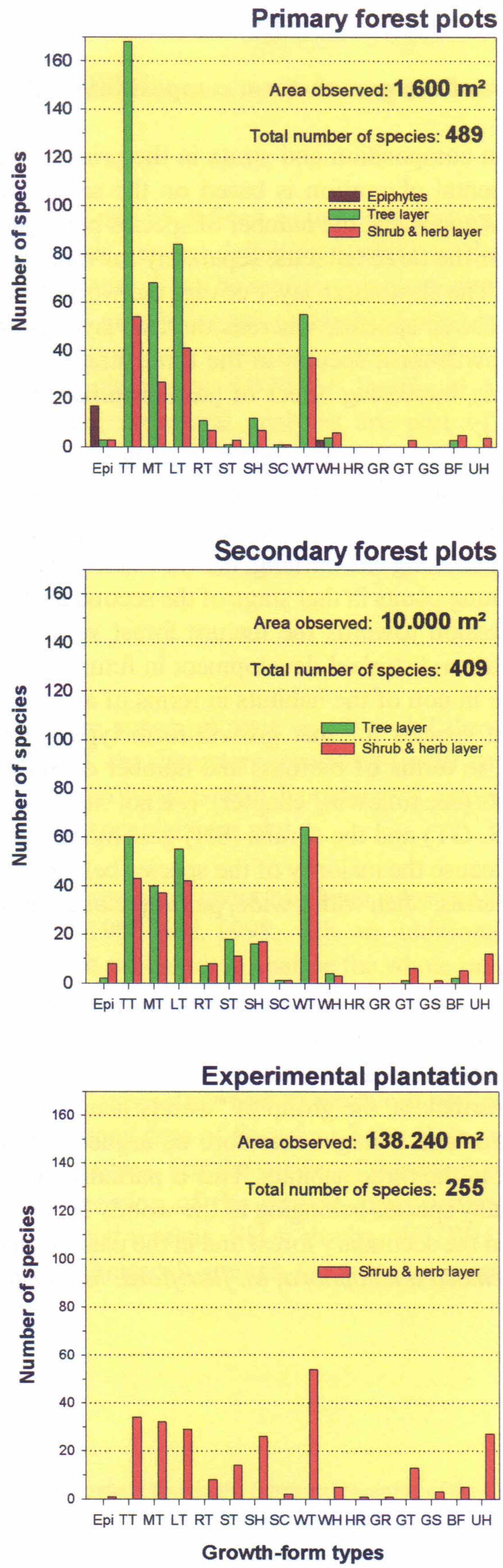


Fig. 3.3:
Spectra of growth-form types in the primary forest plot, the secondary forest plot and the experimental plantation (after five years of plantation management in 1998). Abbreviations for growth-form types see chapter 10.1 and text.

3.4.4 The secondary forest plot of reference

Methods

The secondary forest plot of reference is an 8 year old secondary forest plot of 1 ha (cf. chapter 3.2). Gradients in the floristic composition of the site were analysed, applying (centred) Principal Component Analysis (PCA), on a presence-absence data set (= floristic composition in the tree and herb layer separately for each of the plots). The program used was CANOCO 4.0 win (ter Braak & Šmilauer 1998). In an additional plot of 10x10 m, lying apart from the others, the plant biomass was measured, separate for all the individuals with stem diameters > 1cm.

Spatial patterns and gradients

The vegetation survey carried out in 1994 revealed a total number of 409 species in the study area. The tree layer was dominated by *Vismia guianensis*, and this species was also the most frequently occurring tree species in the experimental site. The most frequently occurring species in the tree and the shrub/herb layer of the plots reveal that the floristic composition in the strata are quite different (Table 3.3). The growth-form spectra of the herb and the tree layer are similar (Fig. 3.3). Only the growth-form types with herbaceous species ("WH" to "UH" in the graph) are absent in the tree layer or represented by only few species. The one species of "Tussock Grasses" (GT) occurring in the tree layer is a giant sedge (*Diplasium karataefolium*, Cyperaceae) of 2,50 m in height.

The fact that the most frequently occurring species in the two layers are quite different, whereas their growth-form compositions show similarities, requires a closer look at the floristic similarities of the 10 x 10 m plots, divided into "tree" and "herb layer". Fig. 3.4 shows an ordination model (PCA) of the presence-absence data set of the experimental site. The data set consists of 74 plots and 409 species, and each plot is divided into "shrub/herb" and "tree layer", resulting in a matrix of 148 x 409 fields. The site scores of the ordination model show two main abstract gradients:

- Two distinct groups of samples in the model, displayed along the first ordination axis, one of the herb and one of the tree layer. This confirms that the floristic composition of the two layers differ significantly from each other.
- A gradient along the second ordination axis, showing a floristic continuum, observed both in the herb and the tree layer.

The species mainly responsible for the variation in the data set are shown in the plot of the species scores. There are tree species which occur only as saplings and young plants in the herb layer (e.g. GUA GUI = *Guatteria guianensis*), species which dominate the tree layer of nearly all plots (e.g. VIS GUI = *Vismia guianensis*), species which occur in the "upper" extreme of the gradient in the tree layer (e.g. AMP SUR = *Amphirrhox surinamensis*) and species which occur mainly in the "lower" extreme of the gradient (e.g. VOC VIS = *Vochysia vismaefolia*). The abstract floristic gradient along the second ordination axis has its causes in the spatial patterns of the 409 species in the plots of the study area. Examples for such patterns can be seen in the contour diagrams (Fig. 3.5 and 3.6):

1. The number of species in the tree layer of the plots varies between 14 and 35 (Fig. 3.5,

above). The spatial patterns of "number of species" and "*Bellucia dichotoma*" are linked so that were *B. dichotoma* (Fig. 3.5, below) is present with large trees, the number of species is low. This can be explained by the large, dark leaves which shade the understorey and the litter which prevents other species from coming up (Richter 1999; see also chapter 9.3, Photo 6).

2. Two of the most frequently occurring species in the experimental site, *Miconia tomentosa* and *Goupia glabra*, show independent patterns that cannot be explained from the data sets available.

There are obviously no environmental gradients or bounderies in the experimental site, e.g. of soil qualitities. The floristic gradients and spatial patterns must therefore be interpreted as the result of the history of the sites (= use history, mainly former disturbance events), plant distributions by chance and the result of interactions and interspecific competition of the species. The analysed data set represents a moment in the progressive secondary succession of the tropical secondary forest. Comparative studies of different sites combined with long-term studies would be the only reliable way to accumulate knowledge on the paths of succession, the coordinated variance of the species and the autecological behaviour of single species in the successional sequence. Nevertheless, the analysis of the strata for all plots of the sites permits views into the past and the near future of the vegetation under study. Examples: In the tree layer, *Miconia tomentosa* spreads by seeds which were mainly imported by birds, whereas *Goupia glabra* is a remain of the primary forest which survived the slashing and burning as roots and stumps and regenerated vegetatively afterwards. In the herb layer, the gras *Homolepis aturensis* invaded the site after slashing and burning, whereas the tree species *Guatteria guianensis* and the palm tree *Oenocarpus bacaba* are part of future stages of succession. The distinct species composition in the two strata leads to the conclusion that succession might not necessarily proceed step by step and continuously, but discontinuously, i.e. with periods of stagnation and rapid progression.

Structure of dominance

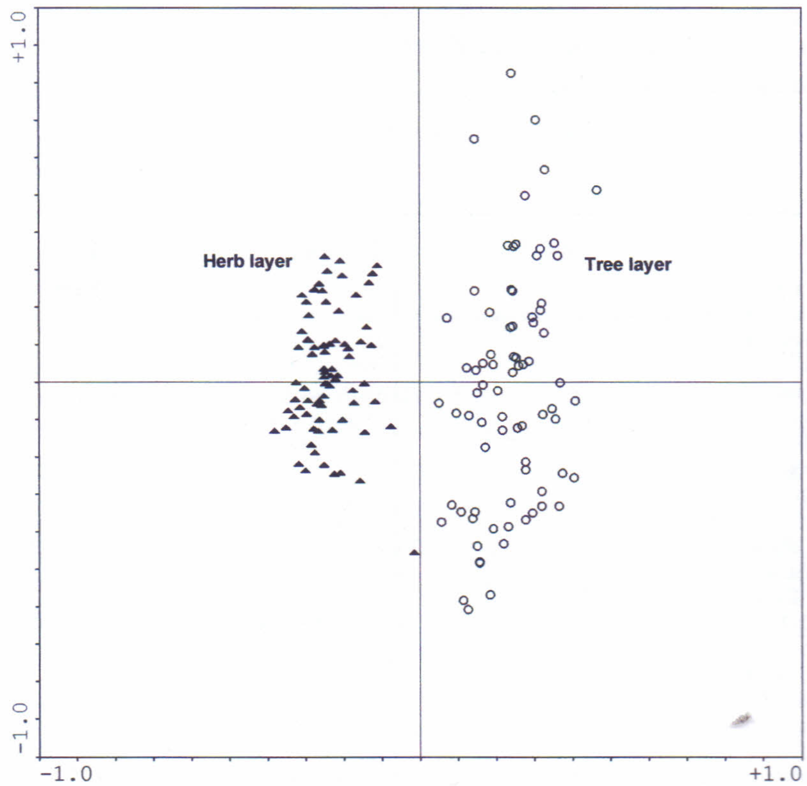
The "structure of dominance" is an important ecological parameter in animal and plant communities (cf. Renkonen 1938, Haeupler 1982, Preisinger 1991). It comprises the number of the participating entities (e.g. morphological elements, species) and their quantities (e.g. number of individuals, cover, biomass), which can be represented as bar charts with descending quantities. For vegetation analyses, the most reliable parameter for the quantities of the individuals and species growing in a stand is the plant biomass. However, biomass can only be analysed in small areas because of the heavy investment of time, labour and cost.

The plant biomass was measured in a plot of 10 x 10 m, separate for all the individuals with stem diameters > 1 cm. The plot can serve here as an example for the structure of dominance in the predominating stage of succession in the experimental site. However, it cannot be representative for the whole secondary forest, which forms irregular patterns (cf. Figs. 3.5 and 3.6). The analysed plot is dominated by *Bellucia grossularioides*, in terms of biomass and number of individuals (Fig. 3.7), and the medium sized trees are therefore the dominating growth-form type in the plot. Low trees are represented by few species (*Vismia cayennensis*, *V. guianensis*, *Amphirrox surinamensis*), but with a high biomass.The treelets (*Cecropia concolor*, *Miconia gratissima*) are underrepresented compared to the majority of the other plots. Lianas and shrubs represent the majority of the species, but play a minor role in terms of biomass.

Table 3.3:
Most frequently occurring plant species in the shrub/herb layer (above) and the tree layer (below) of the secondary forest plot of reference.
freq. = frequency

Species (shrub/herb layer)	**Family**	**Growth-form type**	**freq. [%]**
Homolepis aturensis (Kunth) Chase	Poaceae	GS	84,4
Oenocarpus bacaba Mart.	Arecaceae	RT	76,6
Irlbachia alata (Aubl.) Maas	Gentianaceae	UH	54,5
Clidemia hirta (L.) D. Don	Melastomataceae	SH	48,1
Guatteria guianensis (Aubl.) R.E. Fries	Annonaceae	MT	48,1
Psychotria adderleyi Steyerm.	Rubiaceae	SH	48,1
Passiflora auriculata Kunth	Passifloraceae	WT	45,5
Miconia tomentosa (Rich.) D. Don ex DC.	Melastomataceae	ST	40,3
Heliconia acuminata L.C. Rich.	Heliconiaceae	BF	36,4
Pleurostachys pauciflora Steud.	Cyperaceae	GT	36,4
Amphirrhox surinamensis Eichl.	Violaceae	LT	32,5
Miconia alata (Aubl.) DC.	Melastomataceae	ST	32,5
Miconia pyrifolia Naud.	Melastomataceae	LT	29,9
Bellucia grossularioides (L.) Triana	Melastomataceae	LT	27,3
Leandra micropetala (Naud.) Cogn.	Melastomataceae	SH	26,0
Mendoncia sprucei Lindau	Mendonciaceae	WT	24,7
Piper spp.	Piperaceae	SH	23,4
Vochysia vismaefolia Spruce ex Warm.	Vochysiaceae	MT	23,4
Virola theiodora (Benth.) Warb.	Myristicaceae	TT	22,1
Bocageopsis multiflora (Mart.) R.E. Fries	Annonaceae	MT	20,8
Miconia astrophocama Donn. Smith	Melastomataceae	ST	20,8
Psychotria iodotricha Muell. Arg	Rubiaceae	SH	20,8
Andropogon leucostachyus Kunth	Poaceae	GT	18,2
Clidemia novemnervia (DC.) Triana	Melastomataceae	SH	18,2

Species (tree layer)	**Family**	**Growth-form type**	**Freq. [%]**
Vismia guianensis (Aubl.) Choisy	Clusiaceae	LT	98,7
Miconia pyrifolia Naud.	Melastomataceae	LT	93,5
Bellucia grossularioides (L.) Triana	Melastomataceae	LT	92,2
Hevea brasiliensis (Adr.Juss.) Muell. Arg.	Euphorbiaceae	TT	84,4
Miconia tomentosa (Rich.) D. Don ex DC.	Melastomataceae	ST	74,0
Doliocarpus dentatus (Aubl.) Standl.	Dilleniaceae	WT	54,5
Passiflora auriculata Kunth	Passifloraceae	WT	54,5
Bocageopsis multiflora (Mart.) R.E. Fries	Annonaceae	MT	53,2
Memora adenophora Sandw.	Bignoniaceae	WT	53,2
Amphirrhox surinamensis Eichl.	Violaceae	LT	49,4
Goupia glabra Aubl.	Celastraceae	TT	49,4
Clidemia hirta (L.) D. Don	Melastomataceae	SH	44,2
Miconia alata (Aubl.) DC.	Melastomataceae	ST	44,2
Adenocalymna subincanum Huber	Bignoniaceae	WT	40,3
Palicourea grandifolia (Willd. ex R.&S.) Standl	Rubiaceae	MT	40,3
Miconia dispar Benth.	Melastomataceae	ST	39,0
Memora longilinea A. Samp	Bignoniaceae	WT	37,7
Miconia phanerostila Pilger	Melastomataceae	ST	37,7
Pogonophora schomburgkiana Miers. ex Benth.	Euphorbiaceae	TT	37,7
Bellucia dichotoma Cogn.	Melastomataceae	LT	36,4
Machaerium madeirense Pittier	Fabaceae	WT	36,4
Vismia cayennensis (Jacq.) Pers.	Clusiaceae	LT	36,4
Humirianthera rupestris Ducke	Icacinaceae	WT	33,8
Ryania speciosa Vahl	Flacourtiaceae	LT	33,8



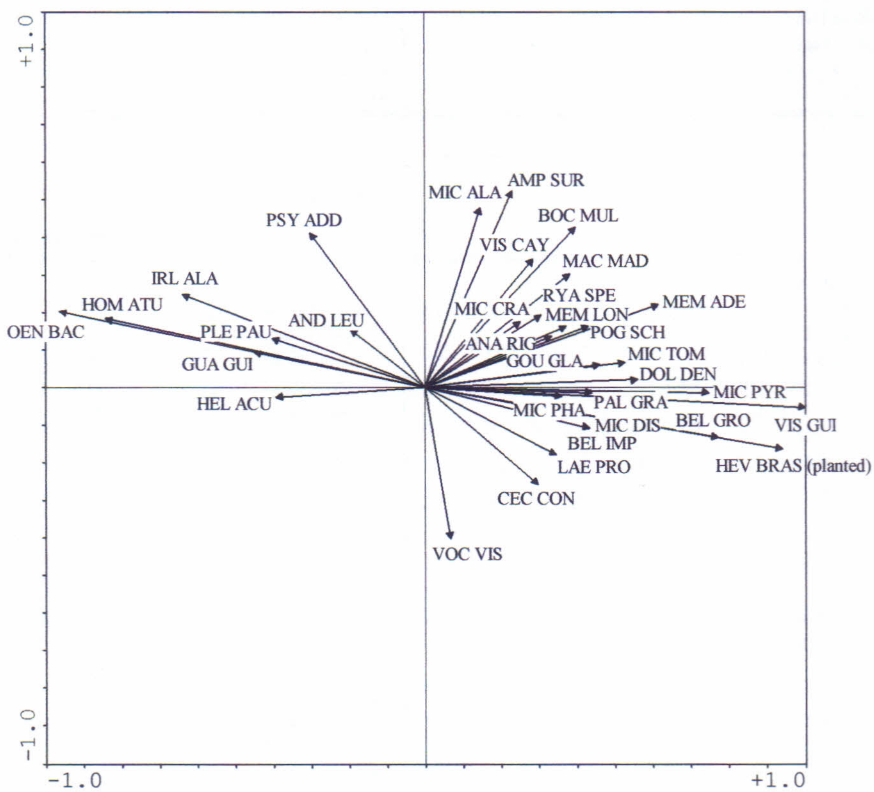
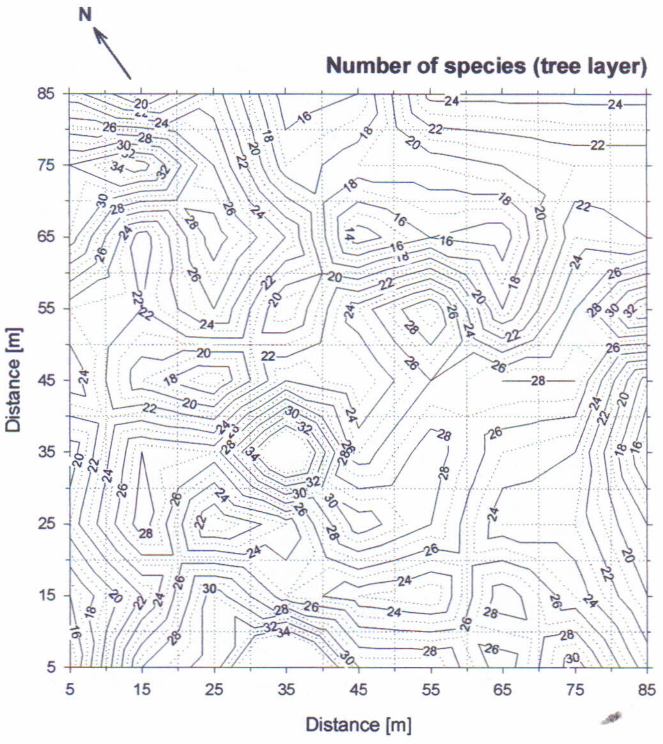


Fig. 3.4:
Ordination model (PCA) of the secondary forest plot of reference, the plots divided into "shrub/herb" and "tree layer". Above: sample scores, below: species scores.



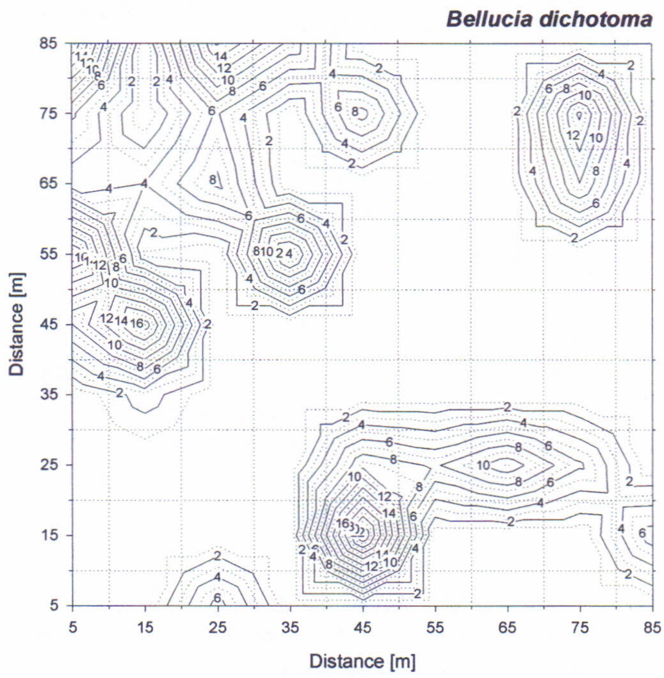


Fig. 3.5:
Spatial patterns in the secondary forest plot of reference, displayed as contour diagrams.
<u>Above:</u> pattern of species richness (contours: number of species);
<u>Below:</u> occurrance of *Bellucia dichotoma* (contours: sums of trunk diameters [cm]).

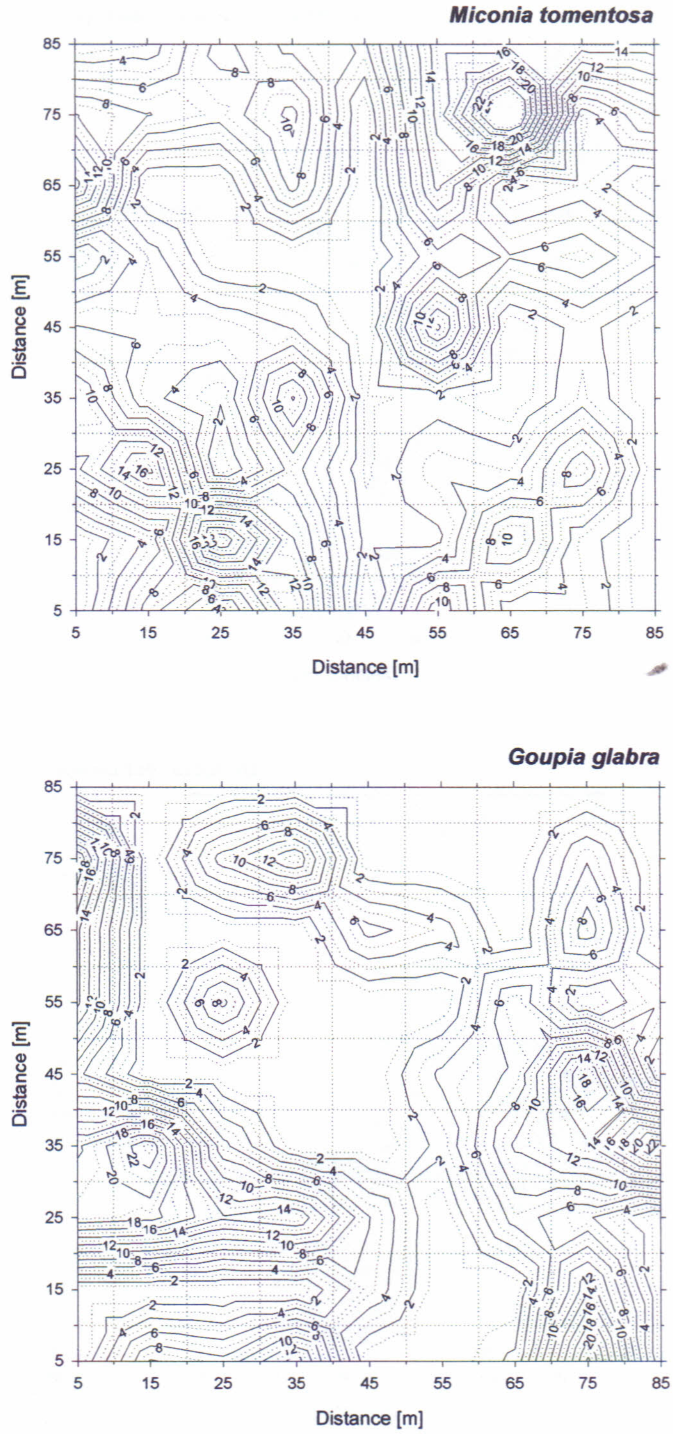


Fig. 3.6:
Spatial patterns in the secondary forest plot of reference, displayed as contour diagrams.
Above: occurrance of *Miconia tomentosa* (contours: sums of trunk diameters [cm]);
Below: occurrance of *Goupia glabra* (contours: sums of trunk diameters [cm]).

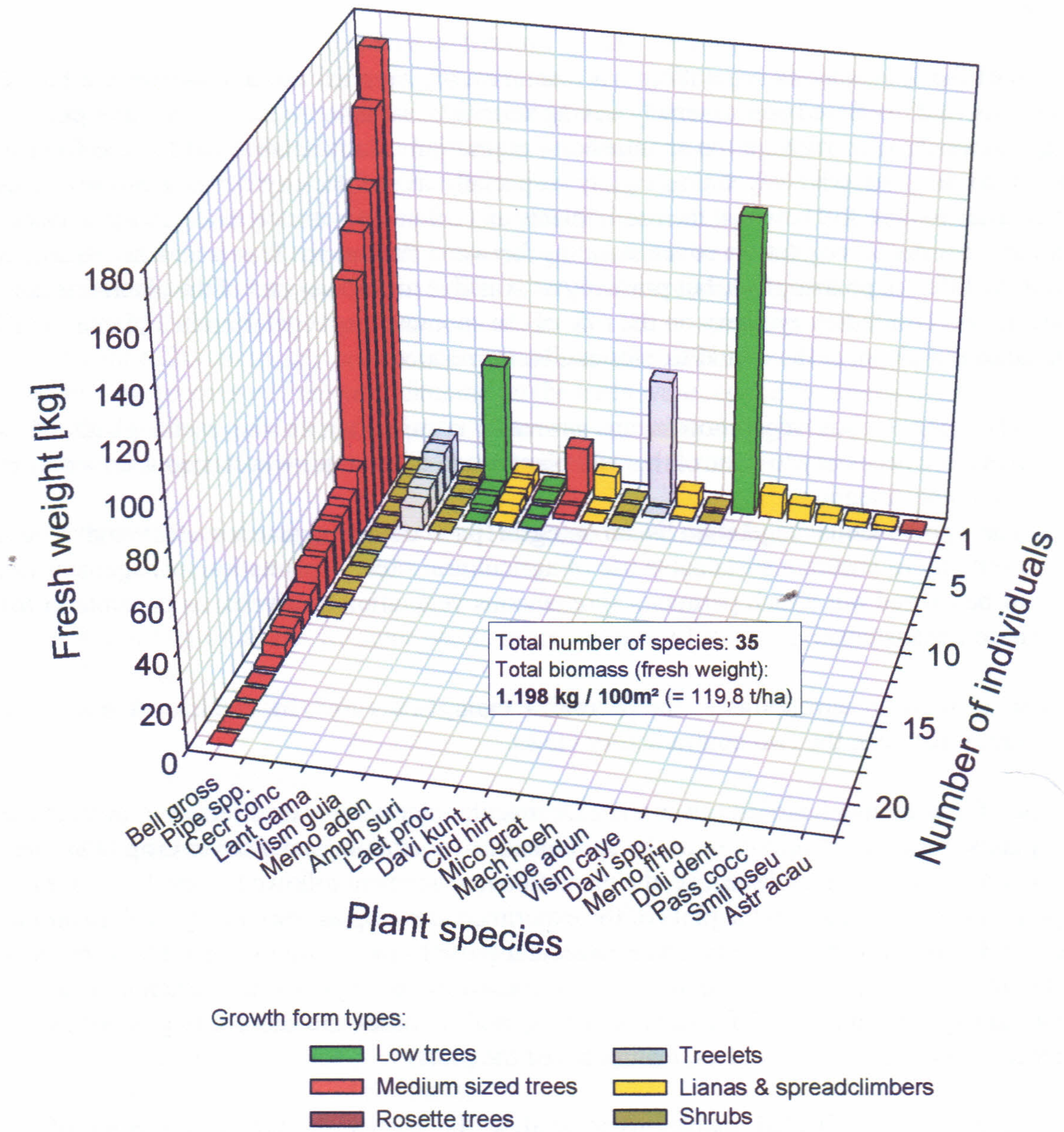


Fig. 3.7:
Structure of dominance in a 10x10 m plot of an eight year old secondary forest in the experimental site (cf. Fig. 3.1): Plant biomass (fresh weight) of the individuals of the 20 most dominant species, classified with regard to their growth-form types, and arranged with decreasing biomass of the individuals and decreasing number of individuals.

Abbreviations for species:
Bell gross = *Bellucia grossularioides*, Pipe spp. = *Piper spp.*, Cecr conc = *Cecropia concolor*, Lant cama = *Lantana camara*, Vism guia = *Vismia guianensis*, Memo aden = *Memora adenophora*, Amph suri = *Amphirrhox surinamensis*, Laet proc = *Laetia procera*, Davi kunt = *Davilla kunthii*, Clid hirt = *Clidemia hirta*, Mico grat = *Miconia gratissima*, Mach hoeh = *Machaerium hoehnearum*, Pipe adun = *Piper aduncum*, Vism caye = *Vismia cayennensis*, Davi spp. = *Davilla spp.*, Memo fl'flo = *Memora flaviflora*, Doli dent = *Doliocarpus dentatus*, Pass cocc = *Passiflora coccinea*, Smil pseu = *Smilax pseudosyphilitica*, Astr acau = *Astrocaryum acaule*.

3.4.5 Spatial and temporal change of vegetation in the SHIFT experiment

Introduction

The role of the spontaneous vegetation in a plantation of perennial useful plants in the humid tropics is as well discussed controversely among scientists, as there is also no common practise among farmers how to manage the spontaneous vegetation. Many smallholders in the Central Amazon control the wild vegetation rigidly, especially in the vicinity of their houses. This practice leads to bare soil between the useful plants and often, as a consequence, to soil erosion. Others leave a dense vegetation cover standing between the crops. This is not necessarily a question of different philosophies, but primarily of available manpower and of the plantation size. However, two contradictory views on the role of the spontaneous vegetation in a plantation of perennial useful plants in the humid tropics can be formulated:

1. The spontaneous vegetation means primarily competition to the useful plants. It is therefore necessary to control the wild plants and/or introduce a herbaceous cover crop, preferably a legume.
2. The spontaneous vegetation is an integral part of the agro-ecosystem and serves primarily to ensure a sustainable use of agricultural sites. A plantation management has to be carried out which permits a spontaneous vegetation as diverse as possible in the agro-ecosystem.

The first is often an agronomist's, the second a biologist's view. In practice, it has to be compromised between the two contradictory views.

The type of management carried out in the experimental plantation was directed to protect the useful plants from the competition of the spontaneous vegetation, and a cover crop (*Pueraria phaseoloides*) had been established, i.e. the plantation management followed "view 1". However, the spontaneous vegetation in the plots of the experiment developped differently, with regard to floristic and structural characteristics (like cover and growth-form composition). This is because of different ecological conditions in the 90 plots, caused by the experimental varients (5 blocks, 5 plantation systems and the 2 fertilization levels) and by other site factors (e.g. site history, differences in chemical soil qualities, inclination of the plots).

The vegetation data collected enables us to analyse the spatial and temporal change of the vegetation, together with biometric and harvest data of the useful plants. This permits the development of hypotheses on the factors controlling the spontaneous vegetation and on the role of the different types of spontaneous vegetation on the development of the useful plants.

In the following text, the term "vegetation" means the spontaneous vegetation of wild plant species growing between and under the useful plants, the latter being trees only. "Vegetation" includes the cover crop Kudzu (*Pueraria phaseoloides*), which was formerly introduced, but then grew spontaneously together with the other wild plant species.

Fourteen species of mainly perennial useful plants were planted in the experimental field. Four different mixed cultivation systems (systems 1-4, see Table 2) and four conventional monocultures (systems 6-9) were to be compared in the field trial. System 5 is land which was prepared in the same way as the other systems and then left to follow its own course. Perennials, short-term crops for planting between the rows and cover plants are being used in the systems. The choice of crops was based largely on current marketing prospects.

System 1 is a comparatively intensive cultivation system with little space left between the rows. More space was left between rows in systems 2 and 3, which can be used for growing short-term crops in the first year. In practice, this would help farmers survive the first years after establishment of the plantation, during which the longer-lived species are not generating any income. System 4 is the most "extensive" of the test systems. The species planted produce timber. Secondary vegetation is tolerated between the trees. In systems 1-3 and in monocultures 6-8, on the other hand, a cover plant (*Pueraria phaseoloides*) was sown. The nine plantation systems described were established in different fertilization variants which include zero fertilizer, 30 % and 100 % of the recommended dose for the respective species. The plantation management followed mainly conventional practices of EMBRAPA. The vegetation around the trunks and the tendrils of *Pueraria* climbing on the trees were regularily removed, and from time to time the whole vegetation cover in the plots was cut using a machete. The intervals between the measures largely depend on the season (approx. every 2 to 3 months).

In this chapter, the following parameters of vegetation and useful plants will be analysed:

Flora

- Recording of all the vascular plants in the 90 plot of the experiment (presence-absence data set);
- Number of species in the plots (species diversity);

Structural traits of vegetation

- Cover of the 7 growth-form types in the 90 plots (quantitative data set).
- Total cover of the vegetation in the plots [%];

Substitutes for environmental variables

- Plantation systems (systems no. 1-9), which are the summarized effects of the planted trees to the vegetation;
- Position of the plots in one of the 5 experimental blocks;
- Nearest distance of the plots to the forest margin;
- Maximum inclination of the plots.

Biometric and harvest data of the useful plants

- Tree heights, trunk diameters and weight of fruits of *Theobroma grandiflorum* (Cupuaçu).

The parameters presented above permit a large number of analyses and comparisions. In this report, we present

- a comparision between the number of species per plot in the 5 blocks and the 9 plantation systems in 1998,
- the temporal change of the overall growth-form composition in the plantation from 1993 to 2000,
- the spatial and temporal change of flora and growth-form types in the plots of the polyculture systems, and

- an analysis of the complex interactions between one of the useful plants (Cupuaçu (*Theobroma grandiflorum*, Sterculiaceae), the vegetation and key environmental factors in the polyculture plantation systems 1, 2, 3 and the monoculture system 7 with the help of a multivarite analysis.

Variation of species richness

The number of species in the experimental plots varies roughly between 10 and 50 (survey in 1998). Quantitative data on the structure of dominance in the experimental plots (e.g. expressed as Evenness [%], see Haeupler 1980, 1982) are not available because it was not possible to estimate the cover of the single plant species in the plots (see methodology). We found only few among the 196 species in the experimental plots capable to form single-species stands or to reach dominance under the site conditions of frequently occurring disturbances. Examples:

Pueraria phaseoloides, Fabaceae (sown out as a cover crop)
Clidemia hirta, *C. rubra*, Melastomataceae
Rolandra fruticosa, Rubiaceae
Borreria verticillata, Rubiaceae
Homolepis aturensis, Poaceae (and some other grasses)

The spatial variation of the number of species in the plots shows differences with regard to the mean values in the blocks, indicating differences in the site conditions along the elongated shape of the experimental site (Fig. 3.8, above). The causes have to be sought in differences in the pre-use of the sites. The differences in the number of species with regard to the plantation systems is more obvious, because the different combinations of useful plant species in the plots are strongly responsible for the site conditions of the vegetation (Fig. 3.8, below). The forestry system (S4), being the most extensive of the plantation systems, is the one with the highest species diversity (median value) in the experiment. It is the only system where a low frequency of disturbance permits many secondary forest and some primary forest species to regenerate. The plantation system with the lowest number of species is the peach palm system (S8). There is little space left between the useful plants and the ground is shaded, which leads to a sparse cover of vegetation of mainly herbaceous plants. The number of species in the polyculture systems S1, S2 and S3 is higher than in the peach palm system, and there are no significant differences between them. Rubber tree, Cupuaçu and orange tree monoculture systems permit considerably more wild plant species to grow because more space was left between the trees than in the polyculture systems and the management intensity - or the intensity of disturbance for the wild plants, respectively - is lower than in the polyculture systems.

The fallow plots (S5) were slashed and burned in the same way than all the other plots, but then left unattended. The vegetation could therefore follow its own course without any intermediate disturbance. The results show that the number of species in the fallow plots is lower than in the (extensive) forestry system S4.

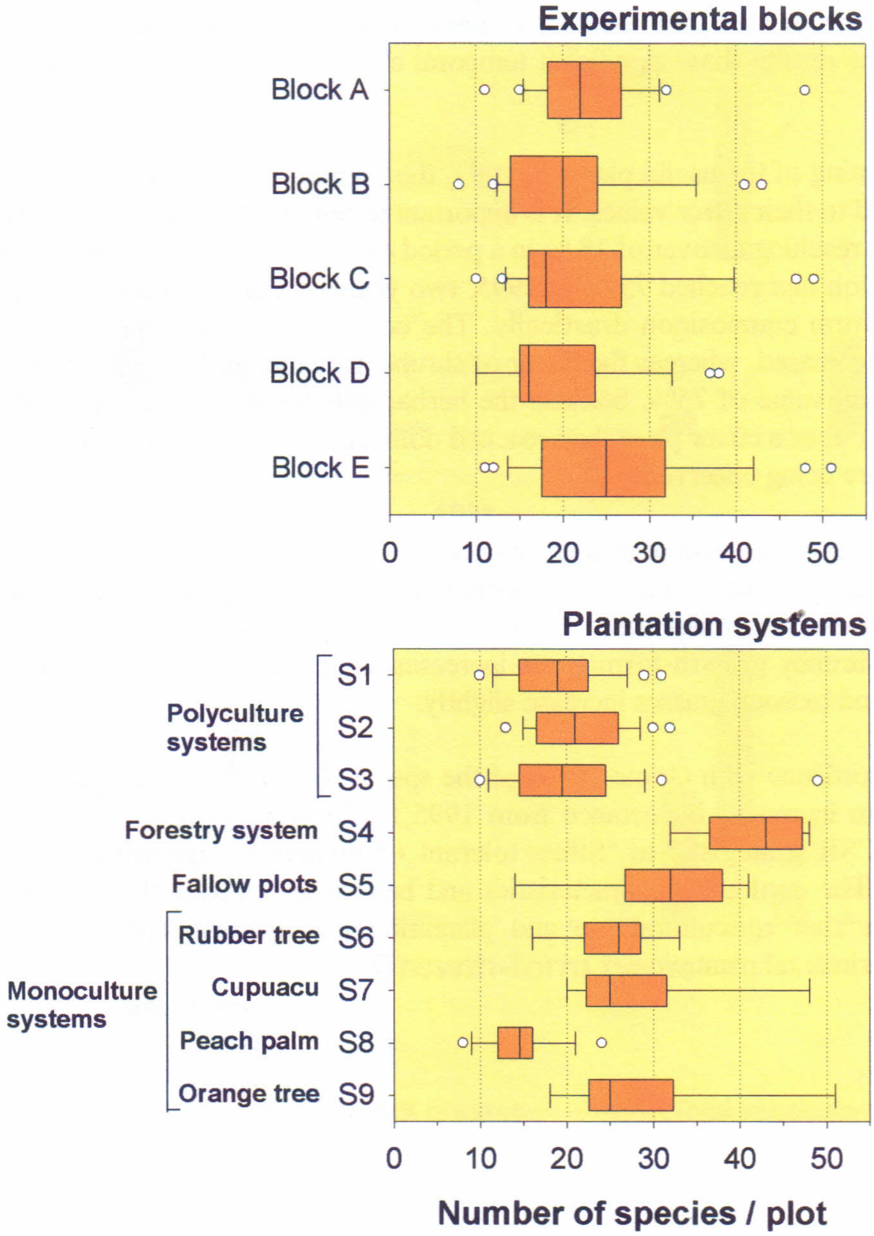


Fig. 3.8:
Variation of species richness in the experimental plantation (1998).

Above: Spatial variation with regard to experimental blocks (cf. Fig. 3.1);
Below: Variation with regard to the different plantation systems.

Temporal change of growth-form composition

The survey of the growth-form composition in the plantation had been carried out four times within 7 years, that is from 1993, the moment of installation (= 6 months after slashing and burning), to 2000. The results show significant temporal changes which can be interpreted as follows (Fig. 3.9):

In the moment of planting of the useful plants in 1993, the 7 growth-form types were ± evenly distributed with regard to their cover values. It is important to note that the recovery of the tree layer went on rapidly, reaching a cover of 18 % in a period of 7 months (median value), and the total cover of vegetation had reached 75%. In 1995, two years of plantation management had changed the growth-form composition drastically. The cover of trees and rhizomatous and tussock grasses had decreased, whereas the cover of shrubs had increased. The cover of lianas had rushed to a median value of 75%, because the herbaceous liana *Pueraria phaseoloides*, which had been sown out as a cover plant, had reached dominance. From 1995 to 2000, mainly the following trends are being observed:

1. The total cover of vegetation decreases slightly,
2. the cover of lianas (mainly *Pueraria phaseoloides*) and the stolon grasses (mainly *Homolepis aturensis*) also decrease,
3. the cover of shrubby growth-form types increases significantly, and the cover of the rhizomatous and tussock grasses increase slightly.

The strategies (in accordance with Grime 1979) of the species belonging to the growth-form types which gained an increased importance from 1995 to 2000, range from "Competitive Ruderal (CR)" and "CSR strategists" to "Stress tolerant - Competitive strategists (SC)" (see Tables 9.1 and 9.2). The ecological characteristics and behaviour linked with SC strategists permit the hypothesis that agricultural use and plantation management lead to drier site conditions in the experimental plantation.

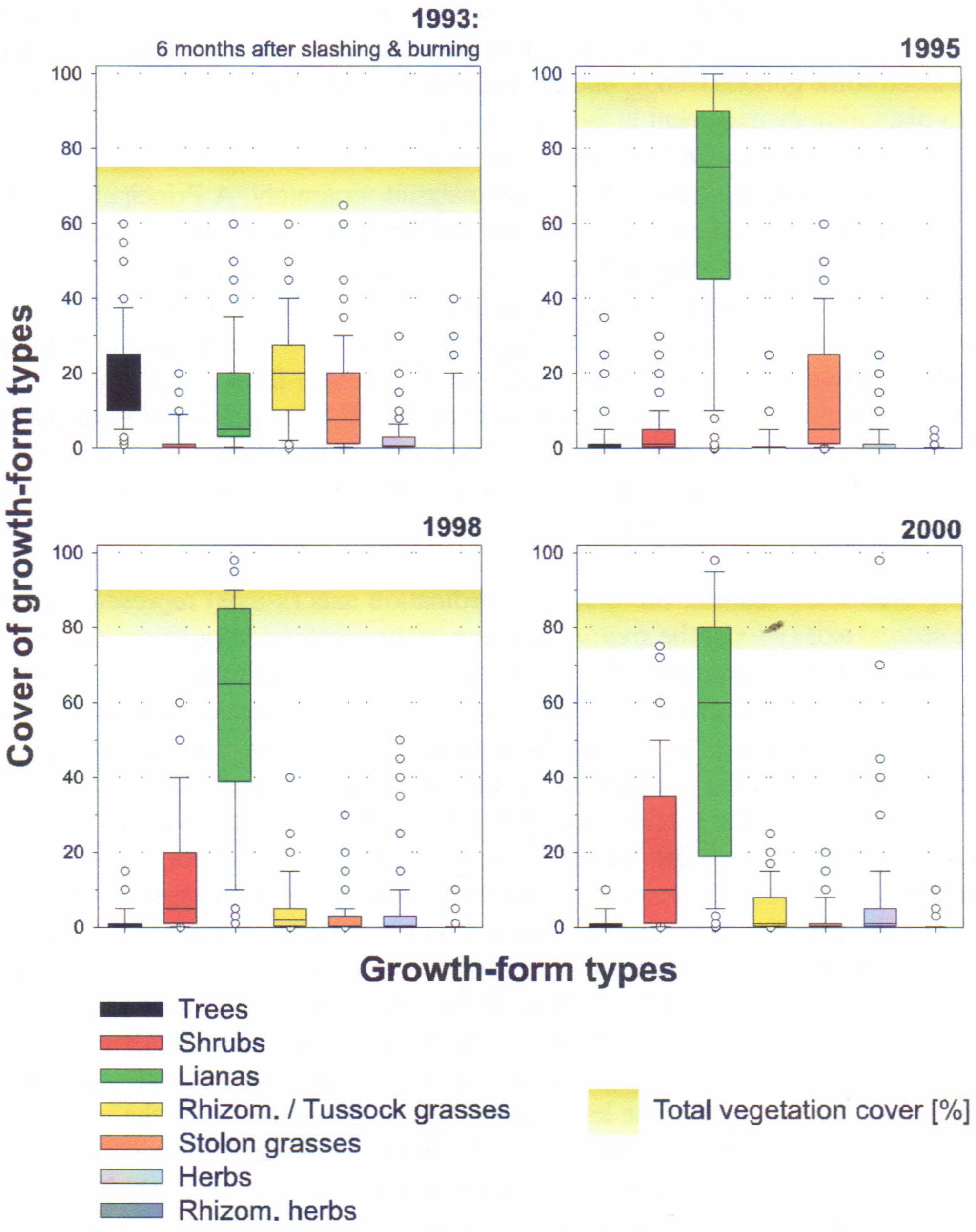


Fig. 3.9:
Temporal change of growth-form composition and vegetation cover in the experimental plantation from 1993 to 2000, presented as median values, 5th and 95th percentiles and outliers of the cover of growth-form types.

Spatial and temporal change of the spontaneous vegetation in the polyculture systems

The previous analysis was focussed on the average temporal change of growth-form composition and cover in the plantation, without differentiating between the blocks, plantation systems and plots.This revealed some general trends, but ignored existing differences in space and differences with regard to plantation management in the plantation systems. More sophisticated approaches have to make use of multivariate ordination techniques. For that reason, the spontaneous vegetation of the three polyculture systems were analysed separately. A Principal Component Analysis (PCA) had been carried out with the flora of all the plots belonging to system 1, 2, and 3, and for three moments in the temporal sequence. The main matrix consists of the species (= lines) occurring in the plots of one of the plantation system in the moments 1993, 1995 and 1998. In a second step a second matrix, consisting of the growth-form composition of the plots, had been correlated passively with the main matrix, i.e. the growth-form composition is used as a substitute for environmental variables. The results of the PCA are presented graphically as a covariance biplot (Corsten & Gabriel 1976). The diagrams can be superimposed on each other but are shown here, for more clearity, as separate diagrams. The rules for the interpretation of the biplot are laid down in Jongman et al. (1987).

In the resulting ordination models, the first PCA ordination axis (x-axis) represent mainly the *temporal*, the second axis (y-axis) the *spatial* variation of the species composition (see Fig. 3.10, for plantation system 3, as an example). The sample scores the plots of plantation system 3 (Fig. 3.10, above) show that six months after slashing and burning, the spatial variation within the species composition is high, due to historical differences in the sites, and caused e.g. by the former vegetation patterns of the primary forest and by differences in the use history (see Fig. 3.10, above: sample scores in the 1. and 2. quadrant). It is obvious that the plots of block E (red symbols) show a characteristic species composition different from the others, forming a cluster in the 2. quadrant. After two and five years of plantation management, the species composition had changed *and* the variation between the sites had reduced, i.e. the scores in the diagram lie closer together. There are only few species which were promoted by the disturbance caused by plantation management (see Fig. 3.10, below, arrows pointing to the left), e.g. *Cecropia concolor* (CEC CON), *Piper hispidum* (PIP HIS), *Paspalum paniculatum* (PAS PAN) and the cover crop *Pueraria phaseoloides* (PUE PHA). The species richness decreases roughly with the first ordination axis from the right to the left in the diagram. The centroids of the sample scores belonging to the five experimental blocks (Fig. 3.11, above) are a summarization of Fig. 3.10, above, showing that even after five years of plantation management the plots of block E remain different from the others, with regard to species composition. Fig. 3.11, below, reveals that there is not only a spatial-temporal pattern of flora, but also of growth-form composition: In 1993, tree species (T) are more abundant in the plots of block A and B than in block E, and blocks C and D occupy an intermediate position, whereas herbs (UH), shrubs (SH), rhizomatous herbs (HR, mainly bracken) and rhizomatous and tussock grasses (GT) tend to be more abundant in block E than in the others (cf. the "spatial gradient" postulated by Preisinger et al. 1994). From 1993 to 1995/98, the importance of lianas (WT/WH, mainly *Pueraria phaseoloides*) increased and the importance of tress and rhizomatous/tussock grasses decreased. - The analysis of the plantation systems 1 and 2 show similar trends as in system 3, but the reduction of floristic variation between the plots from 1993 to 1995/98 is not as distinct as in system 3. The reason might be that in system 3 the root systems of mainly the tress had been disturbed more intensively in the beginning of the experiment by planting and cultivating short-lived useful plants (maize, beans, cassava).

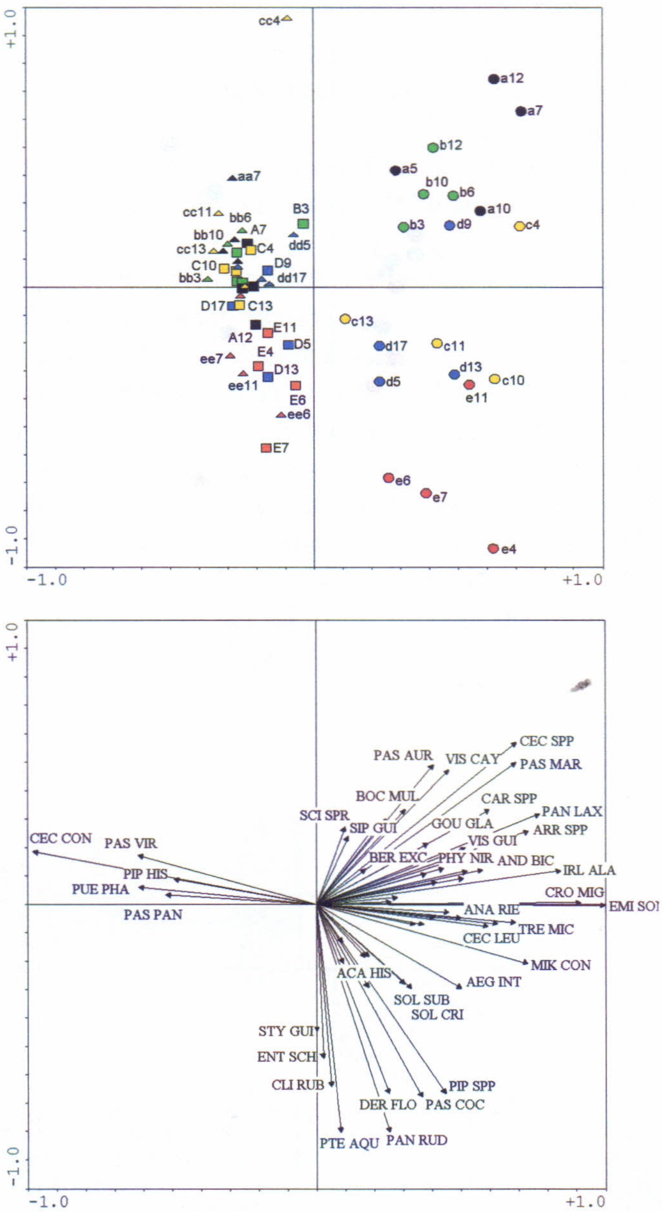
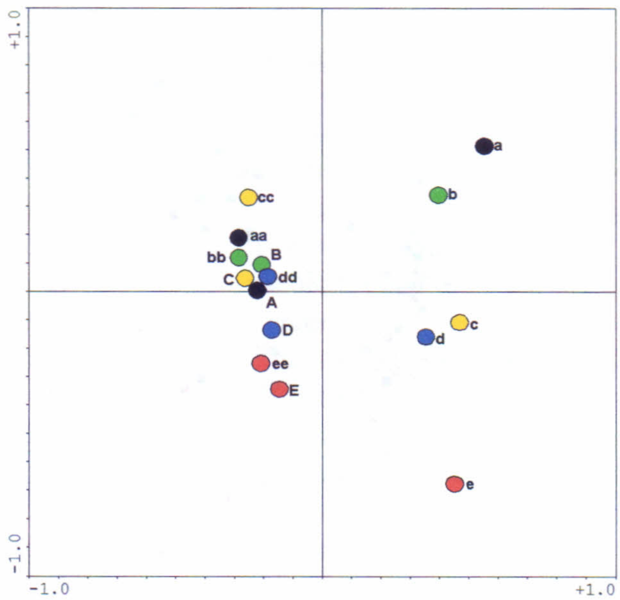


Fig. 3.10:
Spatial variation and temporal change of the spontaneous vegetation in the plots of plantation system 3, displayed as an ordination biplot (Principal Component Analysis), I:

Above - sample scores:
Symbols (= temporal change): *Circle* = 6 months after slashing and burning of the secondary forest in 1993; *Square* = 2 years after plantation management in 1995; *up triangle* = after 5 years of plantation management in 1998. Colours (experimental blocks = substitutes for spatial variation): *black* = block A; *green* = block B; *yellow* = block C; *blue* = block D; *red* = block E.

Below - species scores:
In the diagram, a selecton of species is displayed only, representing a minimum cumulated fit of 15% with regard to the first two axes. - See text for further explanations!



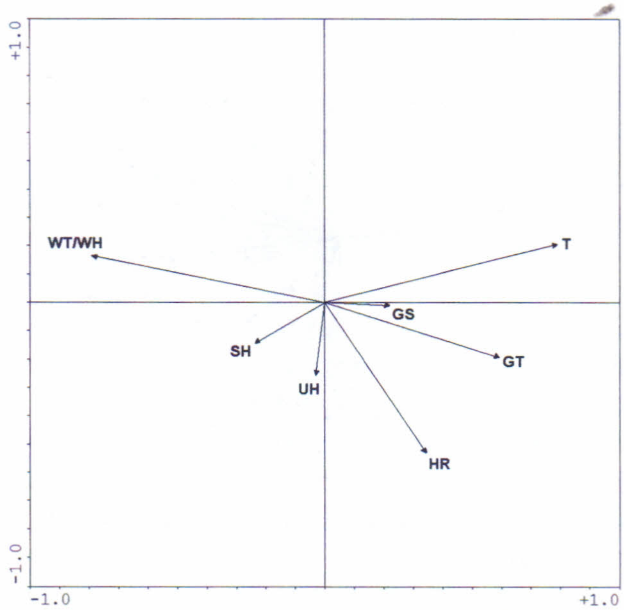


Fig. 3.11:
Spatial variation and temporal change of the spontaneous vegetation in the plots of plantation system 3, displayed as an ordination biplot (Principal Component Analysis), II:

Above - centroids of experimental blocks: For legend see Fig. 3.10!
Below - growth-form types (= substitutes for environmental variables).

See text for further explanations!

Interactions between vegetation, useful plants and environmental factors

This analysis focusses on possible interactions between the vegetation and planted trees in the experimental plantation, the latter forming in part the ecological conditions for the spontaneous vegetation. Cupuaçu (*Theobroma grandiflorum*, Sterculiaceae) is used here as an example for a useful tree species, which is locally important in the Central Amazon for the production of juice, desserts, sweets and ice cream. It is planted in four of the nine plantation systems.

The analysis of the complex interactions between the vegetation, the useful plant and key environmental factors in the experimental plantation requires also a multivariate analysis. It starts from the floristic composition of the experimental plots, i.e. from a presence-absence data set of 196 species and 65 plots ("primary matrix", cf. Fig. 3.12). A second matrix concerns the substitutes for environmental factors available which seem to be of importance for the development of the vegetation, and additionally, harvest and biometric parameters of Cupuaçu. The primary and the secondary matrix were analysed together applying Redundancy Analysis (RDA), the canonical form of Principal Component Analysis (PCA) (cf. Jongman et al. 1987). In a second step, a third matrix, concerned with the composition of the growth-form types in the plots (= quantitative data set), was correlated passively with the result of the RDA. All results were displayed graphically as covariance biplots in accordance with Corsten and Gabriel (1976).

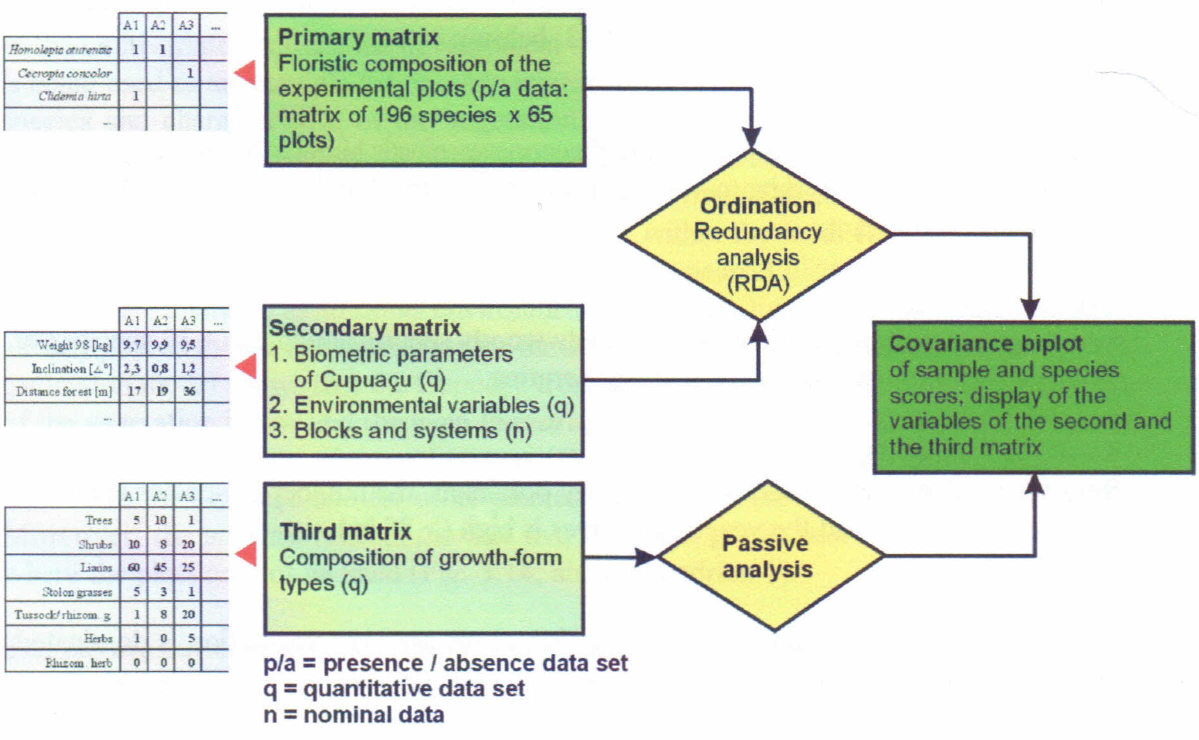


Fig. 3.12:
Interactions between vegetation, useful plants and environmental factors: Data set and procedure of data analysis; on the left: structures of the matrices used for the analysis.

Tests with the primary matrix (= floristic composition of the experimental plots, cf. Fig. 1) and of similar types of data had shown that Principal Component Analysis (PCA), which relates to a linear response model (see Jongman et al. 1987, Ter Braak & Šmilauer 1998), resulted in ordination models which were ecologically better interpretable than those obtained by Correspondance Analysis (CA). We therefore applied Redundancy Analysis (RDA), the canonical - or constrained - form of Principal Component Analysis (PCA) for the detection of patterns of variation in the species data that can be explained by the environmental variables available.

The resulting ordination model , displayed in Figs. 3.13 and 3.14, shows the sample and the species scores and environmental variables which are supposed to be responsible for the composition of the wild flora. They are substitutes for environmental factors which are in part not available by measurement, e.g.

- differences in past disturbance events (including plantation management);
- differences in competition of the useful plants to the wild plants (depending on the species planted, or the plantation system, respectively) for light, space and nutrients;
- differences in soil qualities (physical and chemical).

Additionally, the seven growth-form types and the number of species are displayed in Fig. 3.14, below, as a result of a passive correlation analysis with the main matrix. The ordination model shows that there is a continuum in the species composition of the analysed plots. Within the continuum, four extreme types can be classifed which are linked to one of the four quadrants of the coordination system of the model (see Fig. 3.13, below):

<u>Type 1 (quadrant 1):</u>
Sites where the number of woody and herbaceous species is high (> 20 species per plot), and were tussock and rhizomatous grasses dominate; locally bracken (*Pteridium aquilinum*) is abundant.

<u>Type 2 (quadrant 2):</u>
Sites where there is a high diversity of mainly woody species abundant (> 30 species per plot) and were forest species are still regenerating.

<u>Type 3 (quadrant 3):</u>
Sites where *Pueraria phaseoloides* is highly dominant, the number of species is low (< 20 species per plot) and the vegetation cover is high (> 85 %).

<u>Type 4 (quadrant 4):</u>
Sites where number of species and vegetation cover are low; vegetation is dominated mainly by lianas and grasses.

The classification of the plots with regard to the experimental blocks (see sample scores, Fig. 3.13, above) shows that the vegetation types are not evenly distributed within the five blocks, e.g. vegetation type 1 is mainly restricted to block E and type 4 mainly to block D. The position of the centroids of the experimental blocks in the ordination plain (Fig. 3.14, above) represents a summarization of this fact. The result reveals that the floristic pattern which was found in the experimental site five months after slashing and burning of the secondary forest in 1993 (see

Preisinger et al. 1994) was still present in 1998, after five years of plantation management. The causes of these patterns have to be sought in the history of the sites, which are in particular the vegetation pattern of the former primary forest and different intensities and durations of agricultural use (= rubber plantation) after the first slashing and burning.

The four plantation systems provide different environmental conditions for the vegetation, because the tree species planted together form different structural patterns, and therefore the practice of management is slightly different. Hence, the positions of the centroids of the plantation systems S1, S2, S3 and S7 in the ordination plain differ significantly from each other (Fig. 3.14, above), representing different combinations of wild plant species. The plots of system 1, being the most intensive plantation system with little space left between the trees, tend towards "vegetation type 4", whereas the plots of the Cupuaçu monoculture system (S7), being a more extensive plantation system with more space left between the trees, tend towards "type 2". The average number of wild plant species increases from S1 to S7 (see Fig. 3.14, below). We suggest that the intensity of disturbance caused by the plantation management increases from S7 to S1. It can be concluded that "intensive" cultivation systems mean higher intensities of disturbance and stress to the vegetation than "extensive" cultivation systems. High intensities of disturbance lead to a vegetation poor in number of species and where regenerating trees and other long-lived forest species are absent, and which are dominated by short lived herbs, e.g. *Alternathera tenella* (ALT TEN) and *Commelina nudiflora* (COM NUD), lianas, e.g. *Mascagnia* spp. (MAS SPP), sedges, e.g. *Cyperus* spp. (CYP SPP) and few grasses, e.g. *Paspalum paniculatum* (PAS PAN), as can be seen in the 2. quadrant of Fig. 3.14 (below).

In the multivariate analysis, the development of Cupuaçu in the different plots of the experiment is being used as an example for possible interactions between the development of a planted tree species and characteristics of the vegetation. This parameter, serving as a substitute for the development of the trees, are the weights of the fruits, which show a close correlation to other growth partameters like trunk diameter and height of the trees. The main objective of the approach is an identification of indicator species within the local flora which can be used in agriculture. The mean inclination of the plots and the nearest distance of the plots to the forest margin were analysed as aditional environmental variables. Especially the second parameter has already proved to be a relevant factor for the development of Cupuaçu (see Reisdorff 1998). The ordination model shows that the Cupuaçu trees are best developped in plots where the diversity of the vegetation is low and the liana *Pueraria phaseoloides* reaches dominance (= quadrant 3, see Fig. 3.13, below), whereas bracken (*Pteridium aquilinum*) indicates unfavourable site conditions for Cupuaçu and for other planted tree species (see Fig. 3.13, below, quadrant 1). Moreover, the analysis reflects the fact that Cupuaçu grows best near the forest margin and where the plots are not inclined (Fig. 3.14, above, quadrant 1).

The passive correlation of the proportions of the growth-form types of the experimental plots with the existing ordination model (Fig. 3.14, below) supports some of the interpretations made above: The poportions of the trees and the shrubs (and the number of species) are negatively correlated to the proportion of the lianas. The proportions of tussock and rhizome grasses show weak positive correlations to the poportions of trees and shrubs, and strong negative correlations to the weight of the fruits of Cupuaçu.

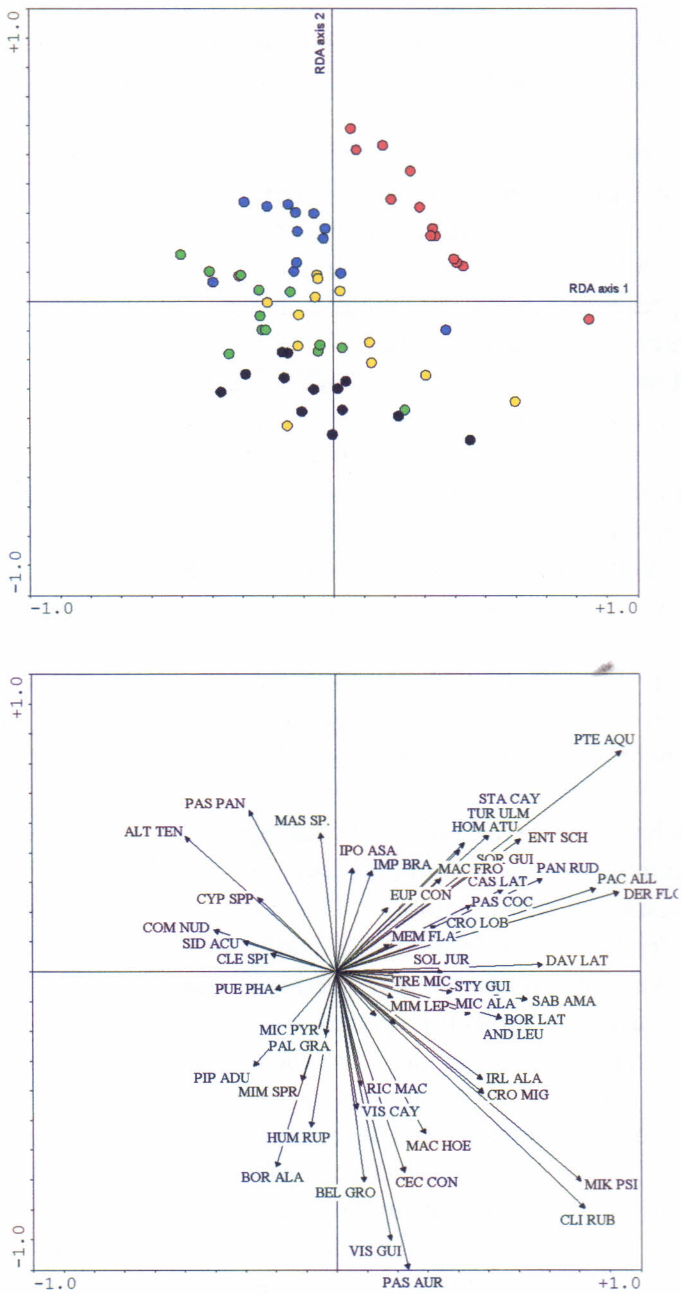


Fig. 3.13:
Ordination biplot (Redundancy Analysis - RDA), showing the variation of the spontaneous vegetation and of the weight of fruits of Cupuaçu in the plots of plantation systems 1, 2, 3 and 7, I:

Above: Sample scores (symbols: black = block A, green = block B, yellow = block C, blue = block D, red = block E);
Below: Species scores. In the diagram, only a selecton of species is displayed, representing a minimum cumulated fit of 15% with regard to the first two axes. - See text for further explanations!

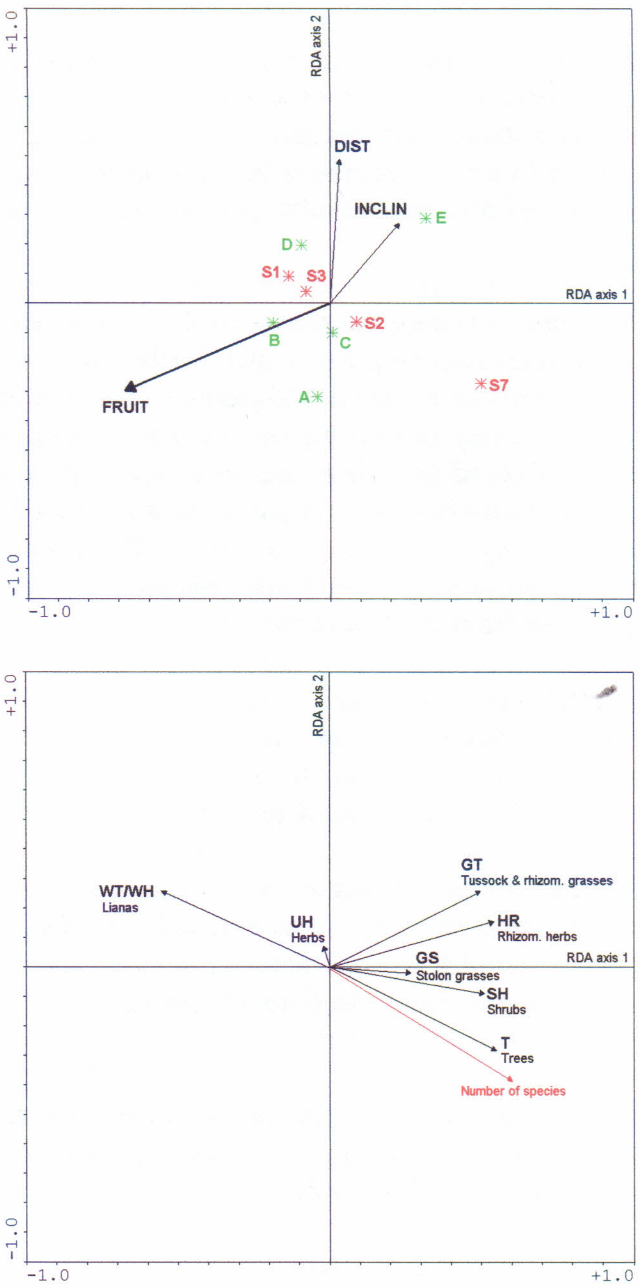


Fig. 3.14:
Ordination biplot (Redundancy Analysis - RDA), showing the variation of the spontaneous vegetation and of the weight of fruits of Cupuaçu in the plots of plantation systems 1, 2, 3 and 7, II:

Above: Substitutes for environmental variables.
Arrows (cardinal variables): FRUIT = weight of fruits per plot in 1998; DIST = minimal distance of the plots from the forest margin; INCLIN = maximal inclination of the plots;
Asterisk (nominal variables): Centroids of experimental blocks (green) and plantation systems (red);
Below: Passive variables of growth-form types, species richness and vegetation cover. - See text for further explanations!

Conclusions

The results of the study imply that species richness, species composition and growth-form structure of the spontaneous vegetation in the experimental plantation depend primarily on duration, type and intensity of plantation management, or disturbance, respectively. The number of wild plant species in the polyculture systems is lower than in the monoculture systems, because intensity and frequency of disturbance in the polyculture systems is higher than in the monoculture systems.

For a short-term agricultural use (7 years), the results of the analysis supports the view that spontaneous vegetation means primarily competition, and that *Pueraria phaseoloides* as a cover crop creates favourable site conditions for the useful plants. More than that, a dense cover of *Pueraria* prevents the soil from drying out during the dry season. However, the analysis and observations in the field also showed that there are sites where *Pueraria* could not reach dominance. There is evidence that these sites were subject to a higher intensity of past disturbance than the others, leading to drier site conditions. The plantation management (= cutting and hoeing), carried out for 7 years, lead to the following changes in the spontaneous vegetation of the field experiment from 1995 to 2000:

- a slight decrease in total vegetation cover;
- a drastic decrease in the number of tree species;
- a deminishing importance of *Pueraria* and the stolon grasses;
- a growing importance of shrubs and tussock grasses.

These temporal changes of structural parameters of the vegetation indicate drier conditions and a decrease of site fertility at long date. From the ordination model, a number of wild plant species and certain growth-form types (shrubs, tussock and rhizomatous herbs and grasses) can be identified which indicate unfavourable site conditions for perennial useful plants, or unfertile sites, respectively.

This is also shift from species and growth-form types native to the rain forest to elements which are disturbance-tolerant and show a wide-spread or even pantropic distribution in the experimental plantation (see chapter 9.1, Table 9.2).

4 Autecological studies

4.1 Overview

Prognoses on vegetation development after severe disturbance events like slashing and burning require a good knowledge of the autecological behaviour of the plant species involved in the successional processes. This is not yet available for Amazonian plant species.

Thirteen common secondary forest tree species of Terra Firme sites near Manaus, Amazonas, Brazil, covering a wide range of growth-form types and of ecological behaviour in the succcessional sequence, were selected for a comparative study designed to develop basic knowledge of their autecology. Growth-form, biometric traits and the morphological and anatomical characteristics of leaves and wood were compared. Plant biomass and the mineral nutrient content of different organs were analysed in individual plants (see Preisinger et al. 1999). In addition, the life history of individual twigs and leaves was recorded.

The aim of the study was to identify functional traits for plant species in the secondary forest and to derive "plant functional types" for different successional stages at a *regional scale*, in contrast to the *global scale* (cf. Box 1981, Box 1996, Díaz & Cabido 1997). The present work searches for causal links between growth-form, leaf characteristics and behaviour of thirteen species of Central Amazonian secondary forests, called "sample species".

The studies on autecology of secondary forest species started with six species of only *one plant family* (Melastomataceae). This promised an ecologically meaningful comparison of the results. The studies were later extended to other common species of *different taxonomic groups* representing morphological types which are thought to be of major importance in secondary forests of the Central Amazon. Fundamental results from morphological-anatomical studies which were made from the Brazilian side of the project, in particular on the leaves and the wood of the sample species, were already laid down in detailed reports and are therefore not presented here (Morais 1998, Aguiar 2000).

4.2 Sample species

The sample species and the individuals for study were selected from the 1 ha secondary forest site or from adjacent areas. Important criteria for the subjective choices were:

- availability of a large number of plant individuals of the species,
- availability of some ecological information on the species, either from literature or from own observations, and
- the species represent examples of a certain morphological and ecological type in the secondary forest.

The 13 sample species show a large range of leaf types, in particular in leaf size (Fig. 4.4). The species were classified with regard to their growth form types, applying the growth form system designed for the vegetation of the study area (see Table 9.1). The roles of the sample species in the secondary forest for reference, with regard to the spectra of plant families, vascular plant species and growth-form types, is displayed in Figs. 4.1 to 4.3.

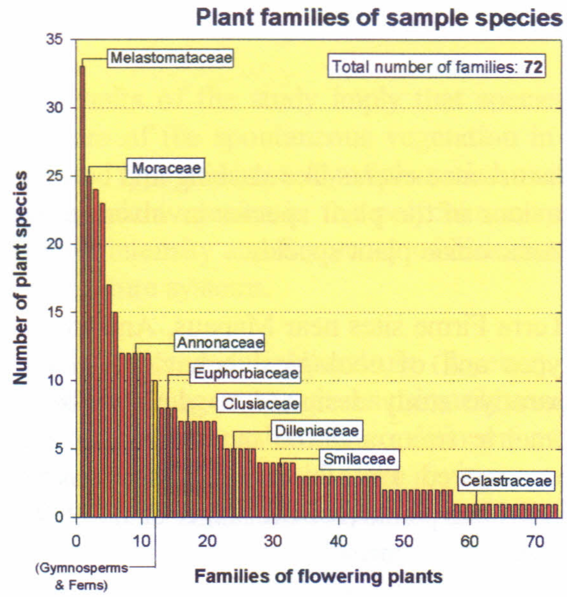


Fig. 4.1:
Number of plant species of the 72 plant families in the 1 ha secondary forest of reference, and plant families of the 13 sample species.

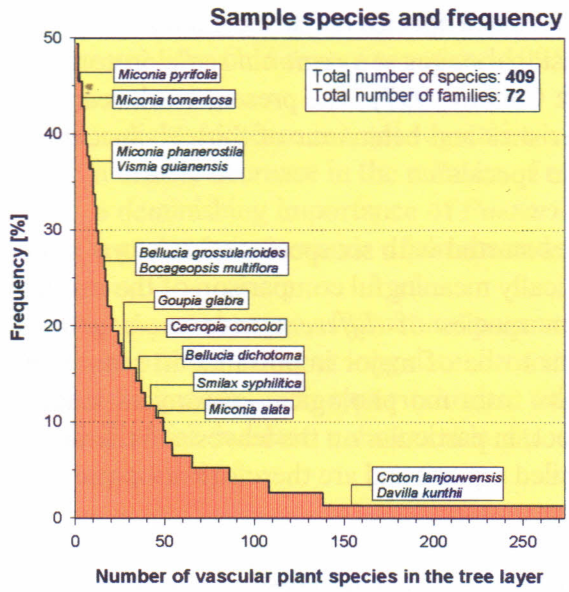


Fig. 4.2:
Frequency of the 409 vascular plant species in the secondary forest of reference, and frequency of the sample species.

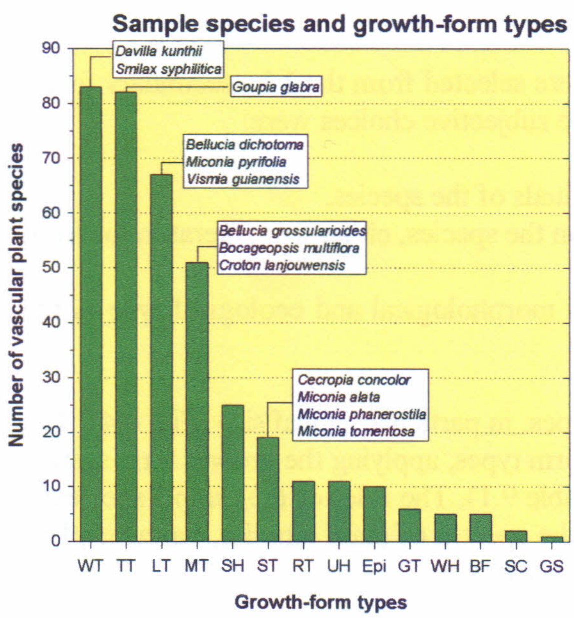


Fig. 4.3:
Number of vascular plant species belonging to the different growth-form types present in the secondary forest of reference, and sample species belonging to certain growth-form types. WT = Lianas, TT = Tall Trees, LT = Low Trees, MT = Medium sized Trees, ST = Treelets.

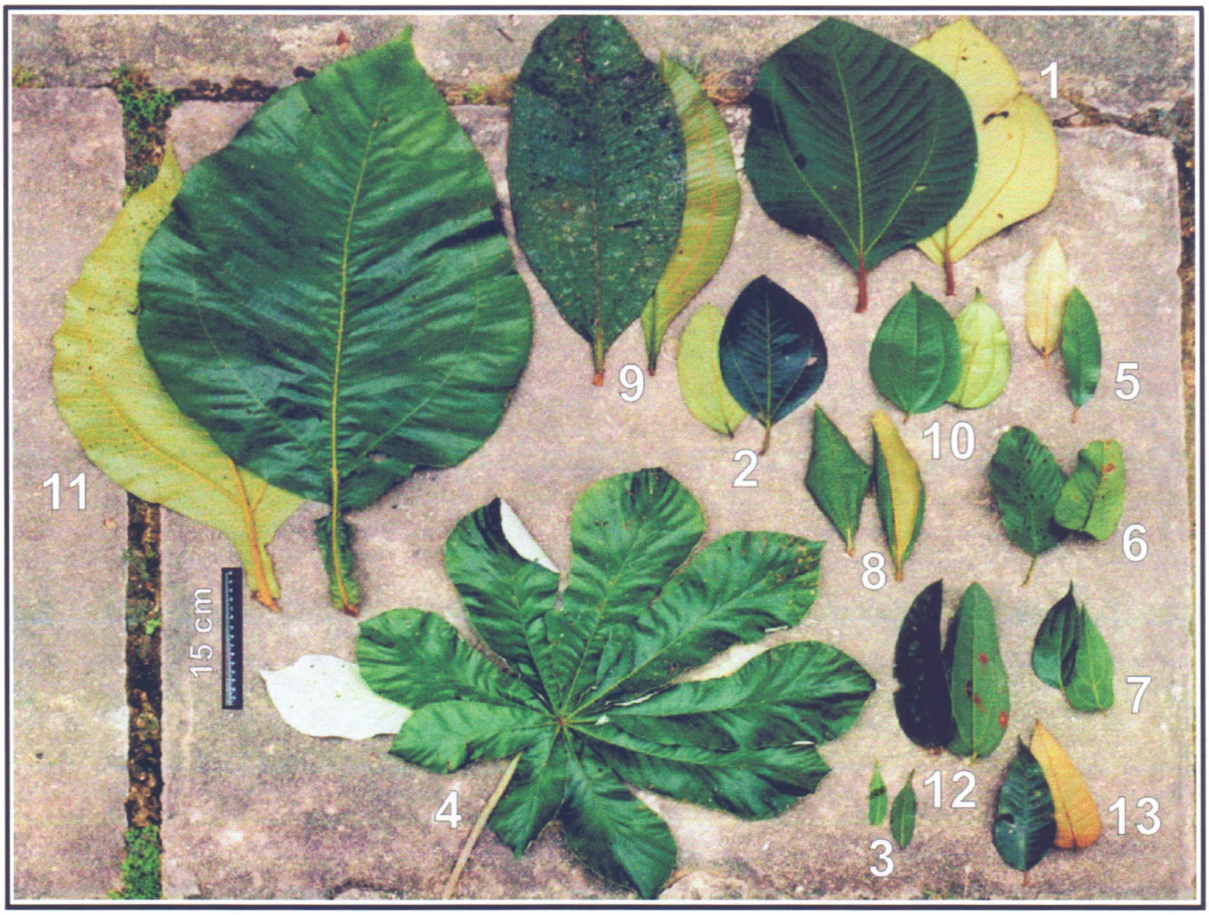


Fig. 4.4:
The sample species and their leaves.

1	*Bellucia dichotoma* Cogn. (Melastomataceae)
2	*Bellucia grossularioides* (L.) Triana (Melastomataceae)
3	*Bocageopsis multiflora* (Mart.) R.E. Fries (Annonaceae)
4	*Cecropia concolor* Willd. (Cecropiaceae)
5	*Croton lanjouwensis* Jablonski (Euphorbiaceae)
6	*Davilla kunthii* A. St. Hil. (Dilleniaceae)
7	*Goupia glabra* Aubl. (Celastraceae)
8	*Miconia alata* (Aubl.) DC. (Melastomataceae)
9	*Miconia phanerostila* Pilger (Melastomataceae)
10	*Miconia pyrifolia* Naud. (Melastomataceae)
11	*Miconia tomentosa* (Rich.) D. Don ex DC. (Melastomataceae)
12	*Smilax syphilitica* Willd. (Smilacaceae)
13	*Vismia guianensis* (Aubl.) Choisy (Clusiaceae)

See also chapter 9.3, Photos 3-9!

4.3 Morpho-physiological traits

Methods

For the analyses of plant biomass, morphological and anatomical parameters and pattern of nutritional elements, three individuals of each of the sample species typical of the secondary forest of reference were cut. The main root was dug out, but it was not possible to excavate the whole roots system because of the need to conserve the study area for further experiments. The plants were separated into root, trunk, twigs and leaves and the fresh weight was determined in the field. Parts of the plant material were pre-dried in a sun drier (secador solar), and dried in a drying oven at 103 °C until constant weight, and water content and dry matter calculated. The total area of assimilation of a plant was calculated from the mean values of dry matter, the leaf area of one leaf and the total dry matter of leaves.

The following morphological parameters, which can be easily measured and recorded, were considered in the analysis:

- Total height of the plant [m];
- Trunk diameter (BHD) [cm];
- Length and width of leaves [cm] and leaf areas [cm²], taking into account up to 50 well developed leaves per tree. The leaf areas were measured using an optical leaf area analyser (Optical Area Meter, LI-Cor, Nebraska, USA);
- Type and extent of leaf hairiness;
- Arrangement and density of stomata.

The proportions (length:width) and shapes of the leaves are characteristics not suited to differentiate between the selected plant species and were therefore not taken into account.

Morphological traits of leaves

The majority of the plant species occurring in the secondary forest shows a large uniformity in leaf shape, having simple, ovate or lanceolate leaves. However, in detail there is a high diversity in leaf shape, concerning the leaf apex (e.g. obtuse, acuminate, aristate) and the leaf margins (e.g. entire, dentate, serrate). Some species have lobed, palmate or digitate leaves (e.g. *Pouroma* spp., *Cecropia* spp., *Schefflera* spp.). Even more striking than the diversity in leaf shape are the differences in leaf size (leaf areas of the sample species between approx.10 cm² and 1.400 cm², cf. Fig. 4.4) and the diversity in the structure of leaf surfaces (glabrous, papillose, ± hairy, felty, cf. Table 4.1 and Fig. 4.5).

4.3 Morpho-physiological traits

Methods

For the analyses of plant biomass, morphological and anatomical parameters and pattern of nutritional elements, three individuals of each of the sample species typical of the secondary forest of reference were cut. The main root was dug out, but it was not possible to excavate the whole roots system because of the need to conserve the study area for further experiments. The plants were separated into root, trunk, twigs and leaves and the fresh weight was determined in the field. Parts of the plant material were pre-dried in a sun drier (secador solar), and dried in a drying oven at 103 °C until constant weight, and water content and dry matter calculated. The total area of assimilation of a plant was calculated from the mean values of dry matter, the leaf area of one leaf and the total dry matter of leaves.

The following morphological parameters, which can be easily measured and recorded, were considered in the analysis:

- Total height of the plant [m];
- Trunk diameter (BHD) [cm];
- Length and width of leaves [cm] and leaf areas [cm²], taking into account up to 50 well developed leaves per tree. The leaf areas were measured using an optical leaf area analyser (Optical Area Meter, LI-Cor, Nebraska, USA);
- Type and extent of leaf hairiness;
- Arrangement and density of stomata.

The proportions (length:width) and shapes of the leaves are characteristics not suited to differentiate between the selected plant species and were therefore not taken into account.

Morphological traits of leaves

The majority of the plant species occurring in the secondary forest shows a large uniformity in leaf shape, having simple, ovate or lanceolate leaves. However, in detail there is a high diversity in leaf shape, concerning the leaf apex (e.g. obtuse, acuminate, aristate) and the leaf margins (e.g. entire, dentate, serrate). Some species have lobed, palmate or digitate leaves (e.g. *Pouroma* spp., *Cecropia* spp., *Schefflera* spp.). Even more striking than the diversity in leaf shape are the differences in leaf size (leaf areas of the sample species between approx.10 cm² and 1.400 cm², cf. Fig. 4.4) and the diversity in the structure of leaf surfaces (glabrous, papillose, ± hairy, felty, cf. Table 4.1 and Fig. 4.5).

Table 4.1:
Sample species and characteristics of leaves (see also Fig. 4.5).

Growth-form type	***Species*** Common Braz. name	**Description of leaf surfaces**	**no. of stomata per mm²**
Tall Trees (TT)	***Goupia glabra*** Cupiúba	Youngest leaves sparsely haired, later glabrous; dark green adaxially; abaxially also glabrous, but with papillae; leaf surfaces shiny	220
Medium sized trees (MT)	***Bocageopsis multiflora*** Envira preta	Dark green and glabrous, adaxially suface shiny, abaxially surface papillary	?
	Miconia pyrifolia	Youngest leaves sparsely haired, later glabrous, remaining slightly hairy on the main nerves; abaxially shiny	100
	Croton lanjouwensis Dima	Glabrous, dark green and shiny on the adaxial side; abaxially whitish - greenish - brownish and coverd with scaly hairs	396
	Bellucia grossularioides Goiaba de anta branca	Young leaves with very light, velvety brownish hairs abaxially, almost glabrous adaxially; turning glabrous and only main nerves hairy or completely glabrous; smooth and shining adaxially	284
Low Trees (LT)	***Vismia guianensis*** Lacre branco	Adaxially sparsely covered with stellate hairs, surface dark green and shiny, abaxially covered with dense, felty stellate hairs, varying in density and colour (light brown to dark brown)	?
	Bellucia dichotoma Goiaba de anta preta	Young leaves with white to brown hairs, especially on the nerves (long stellate hairs), lightly haired adaxially, densely abaxially; turning glabrous, smooth and somewhat shining adaxially (only short, simple hairs)	221
Treelets (ST)	***Miconia alata***	Dense cover of white, soft-velvety hairs (stellate and glandular hairs), turning glabrous adaxially (only short glandular hairs)	80
	Miconia phanerostila	Similar to *M. tomentosa*, but less hairy, stellate hairs reddish, also thicker and longer than in *M. tomentosa*; adaxially surface shiny	150
	Cecropia concolor Imbaúba branca	Upper surface nearly glabrous or sparsely haired (simple, long and adjacent hairs); lower surface densely white-felty haired (long stellate hairs, on the veins also simple, long and adjacent hairs)	?
	Miconia tomentosa	Young leaves with dense brown, velvety hairs, older leaves turning glabrous adaxially; all nerves remaining densely covered with stellate hairs	142
Woody lianas (WT)	***Davilla kunthii*** Cipó de fogo	Glabrous and dark green adaxially; pale-green and hairy, especially on the prominent veins (both simple long and adjacent hairs as shorter stellate hairs)	389
	Smilax syphilitica	Glabrous on both sides; dark green and shiny on the upper and light green on the lower surface	96

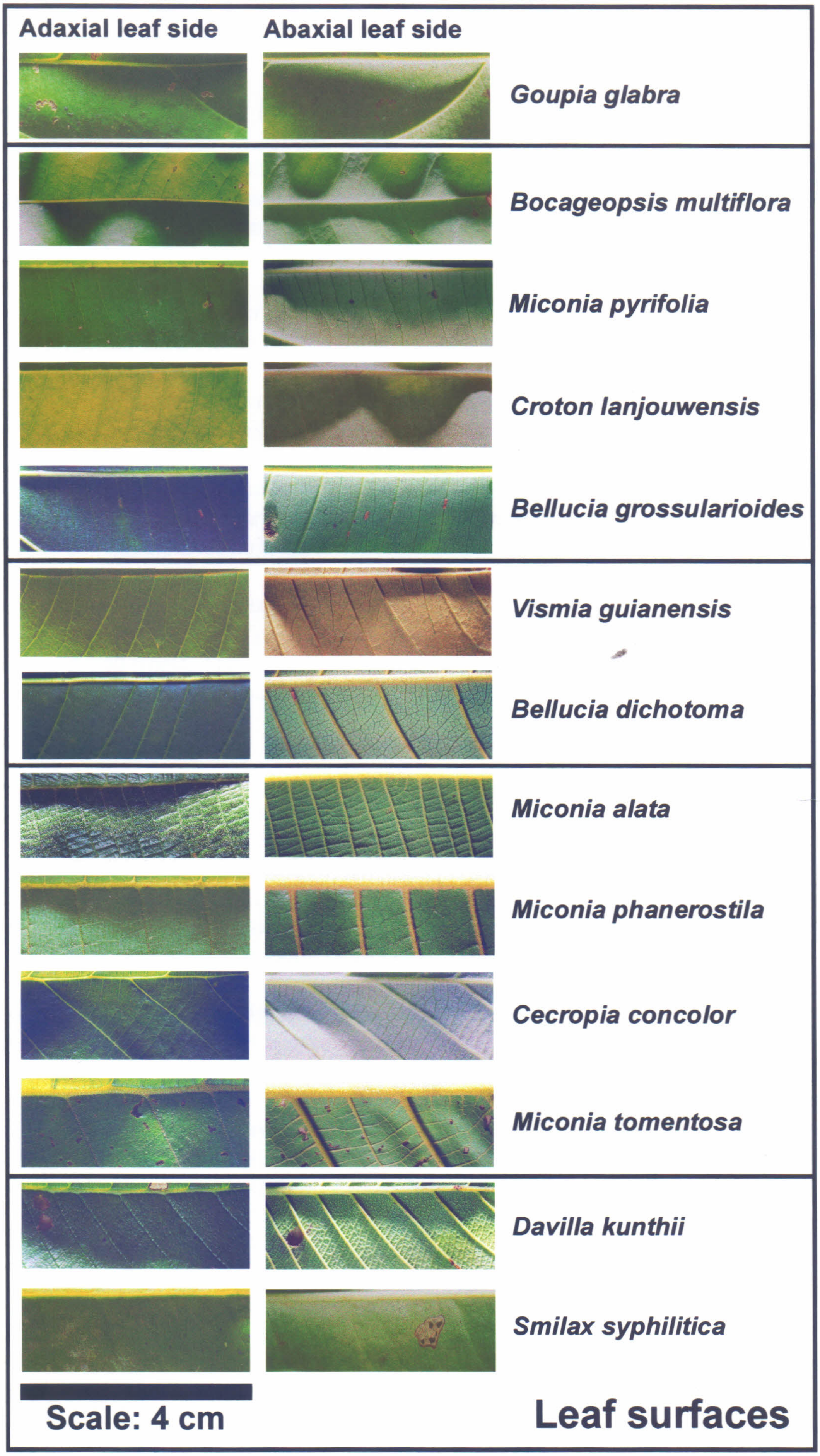


Fig. 4.5:
The leaf surfaces of the sample species

Morphological traits of leaves, biomass and ecological behaviour

The connections between growth-form, overground plant biomass (dry matter), leaf biomass per plant, mean values of leaf areas and specific leaf area weight of three plant individuals of the thirteen sample species were analysed . The resulting two ordination diagrams of the individuals of the sample species reveal the following trends (Figs. 4.6 and 4.7):

- The proportion of leaf biomass on overground biomass decreases with growing overground plant biomass.
- There are large-leaved species with high and with low specific leaf area weights (*Bellucia* spp. vs. *Miconia tomentosa* and *Cecropia concolor*) in the analysis. The small-leaved species *Bocageopsis multiflora* and *Goupia glabra* have low leaf area weights. *Miconia alata*, a plant species with medium-sized leaves, has a low leaf area weight. All the other species occupy intermediate positions in the diagram.
- The large leaves are hairy, and the small leaves tend to be glabrous.
- The combinations of traits mentioned are linked to certain growth-form types.

The progressive succession of secondary forest tree species commences with the large-leaved, short lived sample species (Treelets) and progresses to small-leaved, longer-lived species (Medium and Tall trees). The many liana species present in the experimental area show a high plasticity with regard to the analysed traits and are therefore abundant in a large spectrum of sites.

Duration of life of individual leaves

Five twigs of individuals of eight of the sample species were marked. Growth and development of the leaves were measured (length x width) every four weeks and leaves damaged or fallen off were recorded. The measurements had been carried out for 18 months, starting with the beginning of the rainy season in October 1997 and ending in March 1999.

The spectra of age-classes (Fig. 4.8) show that the leaves of the majority of the species can survive for one year or more. However, the differences in the duration of life between the leaves of the sample species, being morphologically quite different, are not as large as expected. Leaves of *Goupia glabra* and *Miconia pyrifolia*, belonging to the small-leaved species, reached a maximal duration of life of more than 18 months. From observation we know that the majority of the leaves does not die because of senescence but because they were eaten up or cut off by insects. The high death rate in the two first months is primarily caused by phytophages.

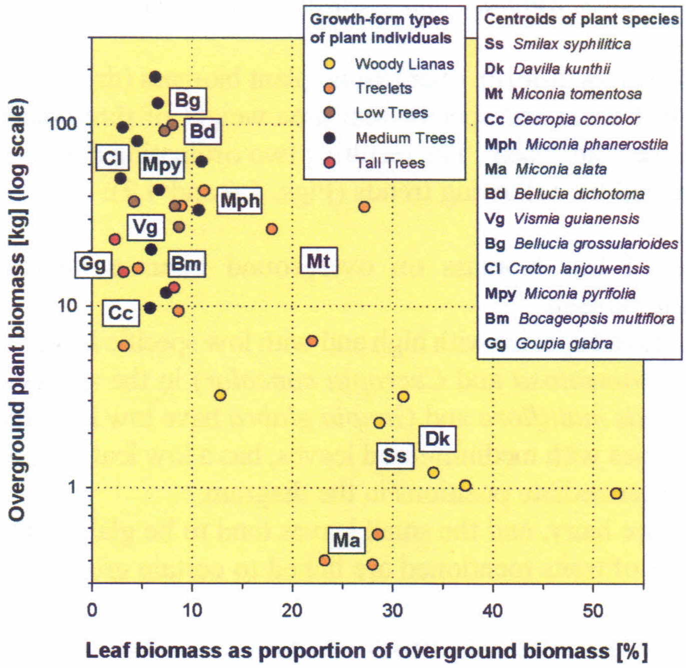


Fig. 4.6:
Ordination of sample species and individuals with regard to overground plant biomass and leaf biomass as proportion of overground biomass, and the species and their growth-form types indicated (insets).

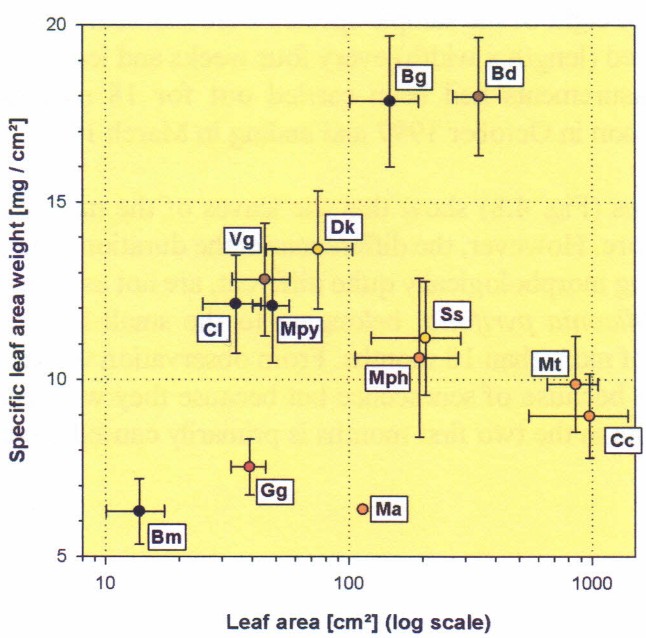


Fig. 4.7:
Ordination of sample species with regard to specific leaf area weight (weight per leaf area = reciprocal value of leaf area index) and leaf area; abbreviations for plant species and growth-form types see Fig. 4.6 (insets).

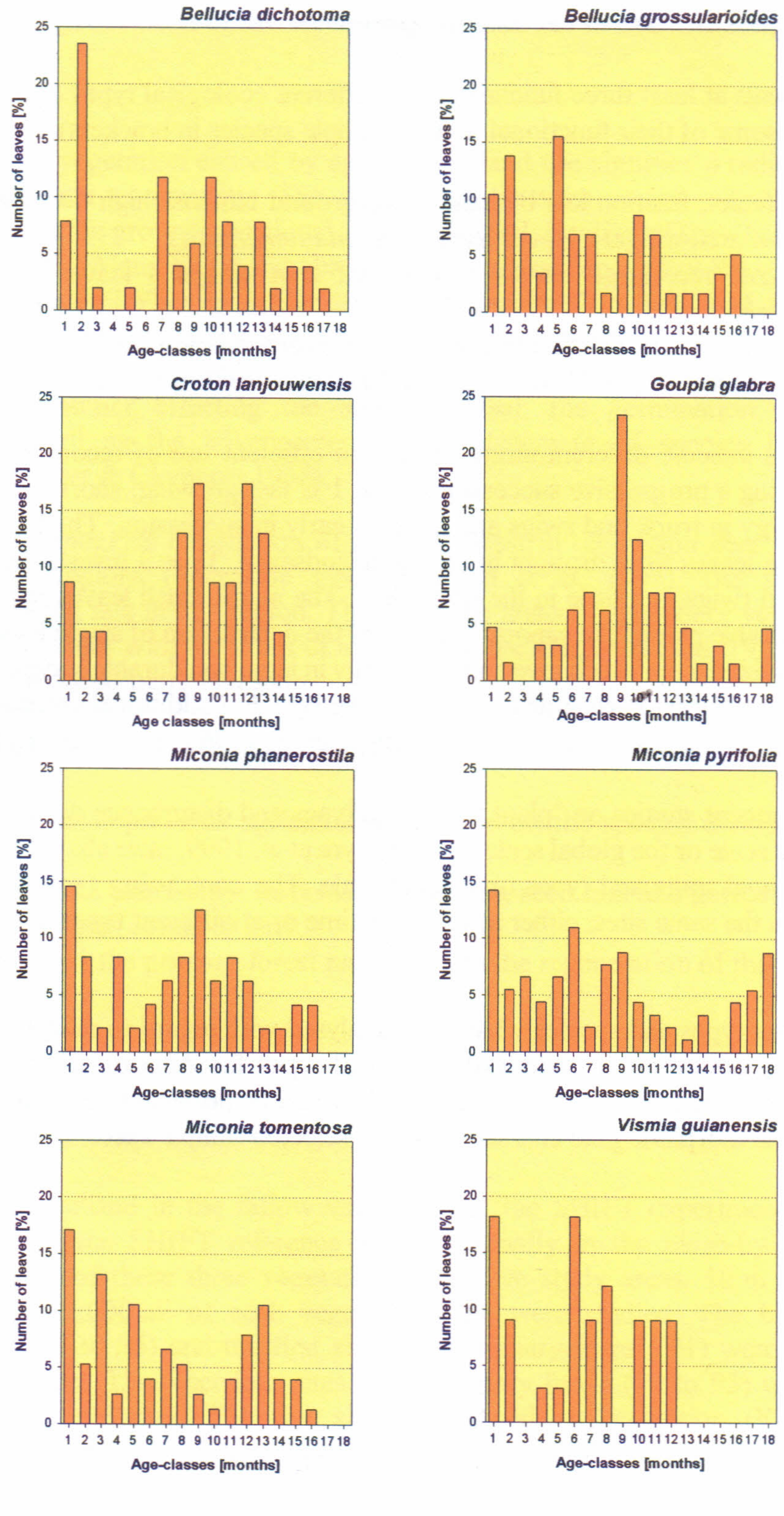


Fig. 4.8:
Duration of life of individual leaves for eight of the sample species, presented as spectra of age-classes (from October 1997 to March 1999).

4.4 Functional classification of the sample species

The analysis reveals at least three fundamentally different ecological types of secondary forest tree species and some of their functional traits (example species in brackets):

Type 1:	Treelet, fraction leaf biomass / overground biomass high - ± large leaves - low leaf area weight - leaves hairy (*Miconia tomentosa*);
Type 2:	Low tree, large leaves - high leaf area weight - leaves ± hairy (*Bellucia dichotoma*);
Type 3:	Medium tree, fraction leaf biomass / overground biomass low - small leaves - low leaf area weight - leaves glabrous (*Bocageopsis multiflora*).

The sets of traits indicate different strategies for an efficient use of recources in a changing environment during a progressive succession. Type 1 is fast growing, short lived (± 10 years), invests little energy in trunk and twigs and appears early in succession. The hairy leaf surface might protect the leaves from drought in the open landscape. Type 3 invests much energy in a durable trunk and twigs, but little in the single leaf. The many, small leaves reduce the risk of loosing a considerable part of the canopy because of the destruction of single leaves. Type 2 are low and medium sized trees which invest much energy in large and durable leaves. The leaves are well protected against phytophages and mechanical damage. For additional aspects on the sample species belonging to Melastomataceae see Preisinger et. al. (1999) and Richter (1999).

The majority of recent studies on "plant functional types and disturbance dynamics" refers to a large geographic scale or the global scale (cf. McIntyre et al. 1999, inter alia). The present study identified functional traits and types on a local scale. The contrasting types identified in the example occur in the same sites, either at the same time or at different times in the successional sequence.

The range of plant types and species which was analysed with regard to morphological traits is not wide enough to develop a system of functional types for Amazonian secondary forests. However, the examples given above indicate that it would be possible to develop such a system by analying simple morphological characteristics of selected sample species.

5 Studies on the regeneration of the secondary vegetation

5.1 Introduction

The disturbance of vegetation caused by agricultural land use signifies a radical interference into the natural plant community. The differences between source vegetation and later regenerating vegetation grow proportional to intensity and duration of the disturbance activity (Fujisaka et al. 1998). Many biotic and abiotic factors interact and effect the succession of the regenerating vegetation (Wheaver & Clements 1938, Janzen 1975, Uhl et al. 1981, Uhl 1987, Aarssen 1992). During succession vegetation types with species composition emerge, that does not occur in the natural habitat (Janzen 1975). Simultaneously, single parameters change in characteristic manner effecting the seed dispersal, the germination, the vegetative propagation, as well as the advancement and replacement of species by interspecific competition (Wheaver & Clements 1938).

There is less anthropogenic destruction of primary forest in the region near Manaus than in other Amazonian regions (Fearnside 1993, Nepstad et al. 1997). But the pressure of settlement is growing fast in this region. Therefore the areas of secondary vegetation expand without control together with the areas of agricultural use (Nepstad et al. 1997). The original primary forest is reduced more and more.

Therefore this study analyzes following problems concerning the Manaus region:

1. Which effects show previous agricultural land use on the species diversity and species composition?
2. How do the species phenology, dispersal syndromes, seed rain and germination alter with the change of species composition?
3. In which way does the primary forest participate in the regeneration of the vegetation?

5.2 Methods

Selection of the study sites

The studies were realized in the fallow vegetation of the SHIFT experimental area, in the secondary forest of the SHIFT reference area and finally in the close-by primary forest (fig. 5.5.1). In each of these three vegetation types five study areas, 10 m by 20 m, were marked. Therefore 1.000 m² of each vegetation type were studied. The five sites in the secondary forest (S1 to S5) and the first site in the primary forest (P1) were established by Preisinger in 1993 yet. The other four sites of the primary forest (P2 to P5) were established along the experimental area. The five sites of the fallow vegetation (F1 to F5) were established in the treatment 5 of the experimental area, a control site without land use.

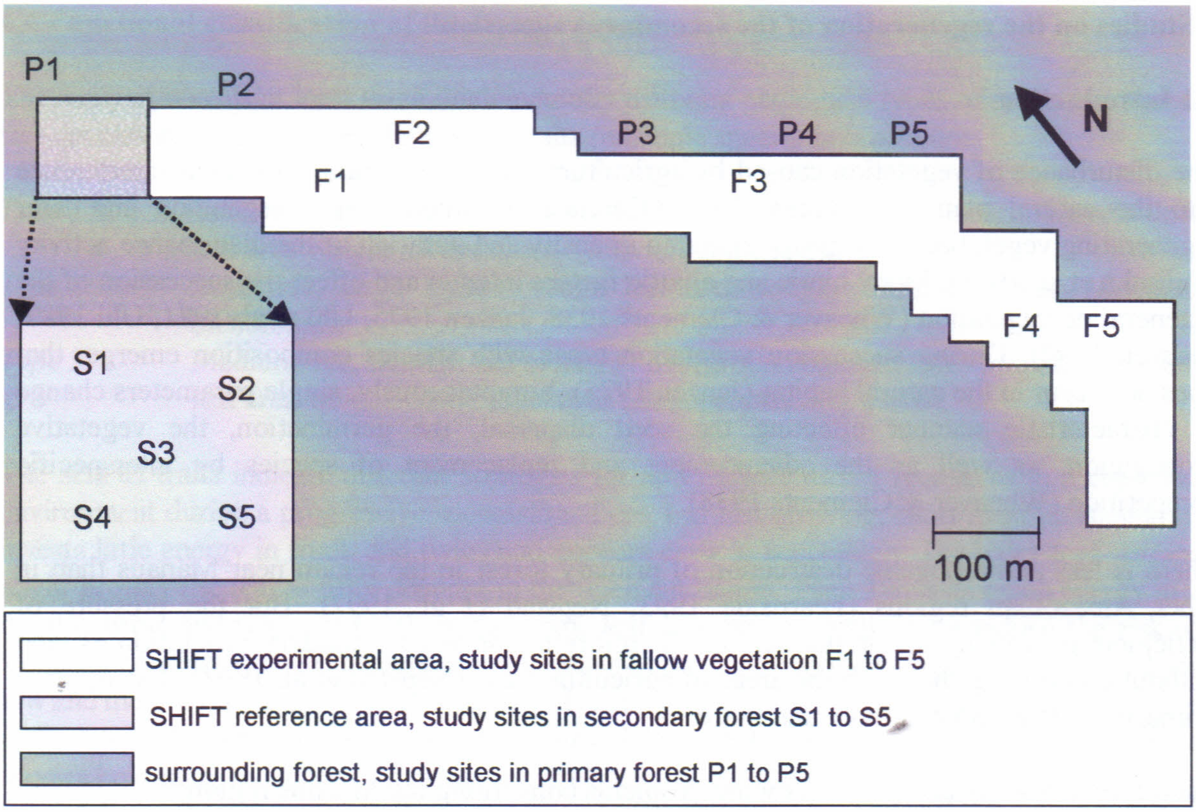


Figure 5.1:
Position of the fifteen study sites in the vegetation types fallow vegetation, secondary and primary forest.

Identification of the plant species

A list of the plant species was made for all study sites. In 1996 all plant individuals with an stem diameter ≥ 1 cm (in 30 cm stem height) were marked in the new sites F1 to F5 and P2 to P5. The plants were labeled and a twig with leaves, if it was possible with flowers or fruits, were taken for species identification. Individuals with several shoots per rootstock were labeled only once. From the smaller herbaceous and wooden plants with a stem diameter < 1 cm one sample of each species was collected in each study site. In the sites P1 and S1 to S5, already installed by Preisinger in 1993, all labeled plant individuals were listed. In addition new grown plants with stem diameter ≥ 1 cm were marked and a sample for identification was taken. For the plants with a stem diameter < 1 cm one sample was collected for each species of the site. In 1998 all sites were analyzed in the same way again.

The collected plant samples, were identified to genus level by literature (among others Silva et al. 1977, Gentry 1996) and with assistance of the mateiro Luiz F. Coelho. Lateron the samples were compared with the collection in the herbarium of the Instituto National de Pesquisas da Amazônia (INPA). The nomenclature corresponds with the "Checklist of the plants of the Guianas" (Boggan et al. 1992).

Estimation of the above ground plant biomass

The above ground plant biomass was estimated according to Kira (1978). This method calculates the approximate plant biomass using the stem diameter in breast hight (dbh = diameter at 1.3 m stem height) as a factor. In this study the stem diameter was measured at 0.3 m height (d) to include also smaller plants. Therefore an adjustment factor was determined measuring the diameter at 0.3 m (d) and 1.3 m (dbh) stem height of 200 plants in each vegetation type. The proportional ratio of the two diameters is:

$$dbh = 0.89 \cdot d$$

Because of the numerous stemless palms on the study sites, these could not be included into the estimation, thus their above ground biomass was estimated separately. Three plants of different sizes from *Astrocaryum sciophilum* as well as from *Attalea attaleoides* were cut at soil level. The plant material was oven dried at 65 °C for five days and the dry weight was determined for each plant individual. The average dry weight per plant was calculated and the biomass of all palms in the study sites was extrapolated.

Realization of the phenology studies

From September 1995 until August 1998 the development of flowers and fruits was investigated monthly. All labeled plants with open flowers and / or mature fruits were noted. Referring to the smaller, non-labeled plants the plant species was noted for each study site, when one plant of this species had open flowers or mature fruits.

The frequency and duration of flower and fruit periods is very variable and can differ according to habitat and climatic oscillations within the same species. In order to achieve an overview about the time of seed production of the species, the plant species were classified by the number of months with fruits, according to Newstrom et al. (1994), modified:

- supra-annual fructification, fructification not every year;
- annual fructification, one great fructification every year;
- sub-annual fructification, several fructifications per year or one great fructification with sporadic, short interruptions.

This classification is rough enough to disregard shorter climatic and habitat differences and counts as species characteristic. The number of month with fructification shows how far seeds of a species are available for the vegetation development.

Investigation of seed dispersal

Information about the seed dispersal of the plant species with fruits were taken from literature (e. g. ROOSMALEN 1985, GENTRY 1996, RIBEIRO ET AL. 1999). For some plant species no information about the seed dispersal was found, but information about the dispersal characteristics of their plant genus or family was given. If the genus or family has only one type of seed dispersal, this indication was evaluated as an explicit character in this genus or family, and was adopted as species character. If in literature no information about the seed dispersal could be found, the dispersal syndrome was determined by fruit or seed characteristics according to Pijl (1982).

Measurement of the seed rain

In order to measure the seed rain in the study areas, three seed traps per each of the fifteen study sites were installed. Each of these 45 seed traps covered an area of 1 m². From March 1996 until August 1998 the fallen litter and seeds were collected twice a month and oven dried at 65 °C. After five days the seeds were separated from the litter and were sorted according to color, shape, surface structure and size and counted. Additionally seeds were collected out of fruits of known species and a diaspore collection was generated. For identification the seeds found in the traps were compared with this diaspore collection. Anemochorous diaspores could be identified also by figures in common field guides (Roosmalen 1985, Gentry 1996).

Determination of the original vegetation type of the collected seeds

The origin of seeds of plant species was defined by the occurrence of the adult plants in the study site. The common habitat of plant species, that do not occur in the study sites, was determined by literature (Roosmalen 1985, Gentry 1996, Ribeiro et al. 1999). It was supposed that the species occur near the study areas in the same vegetation type, if the plant species do not occur in the study sites, but are typical plants of the vegetation type according to literature. For further succession only those seeds are important, that are brought in from other vegetation types, because only species that do not occur as adult plants in a vegetation type lead to a long-term development of the vegetation.

Examination of the seedling stocks

Two areas of 2 m² were established in each of the fifteen study sites. The seedlings in these areas were labeled and identified. All plants smaller than 30 cm and definitively not grown vegetatively from roots were classified as "seedlings". Between 1995 and 1998 the seedlings were examined once a year, because only the long term development of the seedling populations are of interest for the regeneration of the vegetation. All new germinated seedlings were checked as well as the seedlings, that survived the previous year.

Survey of the root collar shoots

The occurrence of several shoots at the same rootstock is not always caused by previous plant destruction and later vegetative regeneration but can emerge spontaneously. Though the number of plants with several shoots inclines after destruction of the vegetation and can therefore be an indicator of vegetative regeneration after destruction. The number of shoots per rootstock were counted in 1996 and 1998 together with the labeling and identification of the plants (see above).

5.3 Vegetation types

5.3.1 Floristic compositions in the fallow vegetation, secondary and primary forest

All together 3764 plant individuals with a stem diameter ≥ 1 cm were found. From these individuals 86.3 % could be identified on species level, 12 % on genus level and 1.4 % only on family level. A part of 0.3 % could not be identified, not even on family level. A lot of the samples of smaller plants with stem diameter < 1 cm, especially samples of young trees, could not be identified. Therefore only those samples of smaller plants were taken into account, that could be identified on species or genus level. These are 957 samples, 72.6 % identified on species level, and 27.4 % identified on genus level. Due to the limited size of the established study sites, the species spectra described here show only a part of the local species spectra of the vegetation types.

During the whole study period 660 species of spermatophytes were identified belonging to 271 genera and 84 families. The species spectra of the fallow vegetation, secondary and primary forest differ generally (fig. 5.2).

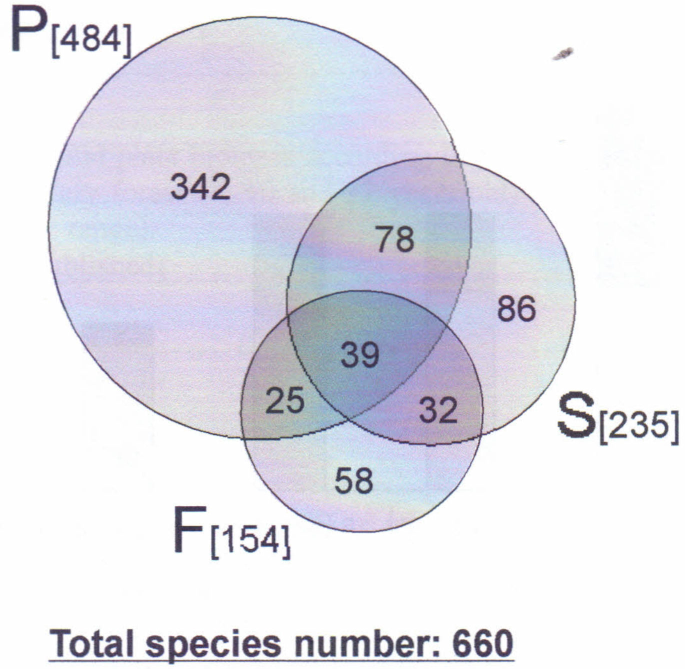


Figure 5.2:
Taxonomic similarity of the species spectra in fallow vegetation (F), secondary forest (S) and primary forest (P), illustrated by an intersection diagram.
Numbers in the intersections of the cycles = number of collective species
Number in [ ] = species number of the vegetation type

More than 50 % of the total species number (342 species) were found exclusively in the primary forest, 13 % (86 species) exclusively in the secondary forest and 9 % (58 species) exclusively in the fallow vegetation (fig. 5.52). The primary forest has the highest species number with 484 species (73 % of total species number). In the secondary forest 235 species (36 % of total species number) were identified, in the fallow vegetation only 154 species (23 % of total species number).

All three vegetation types share only 39 species or 6 % of the total species number (fig. 5.2). Few species occured only in two of the three studied vegetation types. The concordance between secondary forest and fallow vegetation is much lower than between secondary and primary forest. Primary forest and fallow vegetation have the least amount of species in common.

5.3.2 Plant density

The density of plant individuals in the 4 year old fallow vegetation with 1,123 plant individuals (stem diameter ≥ 1 cm) per 1,000 m² is nearly as high as in the primary forest with an average of 1,205 plant individuals (fig. 5..3). Nearly half of the plants in the fallow vegetation were *Vismia guianensis* (Clusiaceae). During further succession the density of plant individuals in the fallow vegetation and secondary forest declined to half due to the die-off of *V. guianensis*. Only in the twelve year old secondary forest the density of plant individuals increased again.

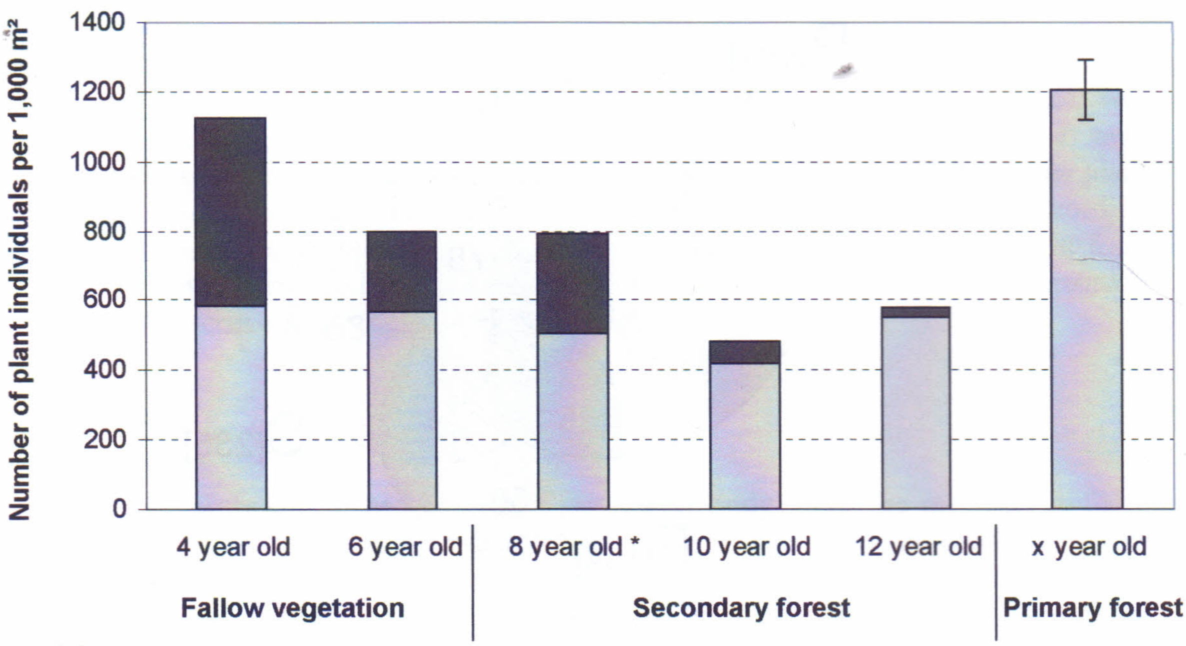
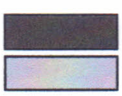


Figure 5.3:
Number of plant individuals (stem diameter ≥ 1 cm) per 1,000 m² in fallow vegetation (4 and 6 years old), secondary forest (8, 10 and 12 years old) and primary forest (average from two different years, T : range).
* data from Preisinger (unpublished)


Plant individuals of *Vismia guianensis* (Clusiaceae)
Plant individuals of the other species

5.3.3 Development of the above ground plant biomass

Fallow vegetation, secondary and primary forest show an continuous increase of above ground plant biomass (fig. 5.4). The estimated plant biomass of the 4 year old fallow vegetation amounts to 32 t/ha dry weight and increases after two year to 40 t/ha. The eight year old secondary forest has an estimated above ground plant biomass of 80 t/ha dry weight. In the following two years the plant biomass increased to 124 t/ha, and after further two years the biomass increased to 142 t/ha. Due to storm induced downfalls of big trees, the above ground plant biomass of the primary forest ranges between 336 and 314 t/ha.

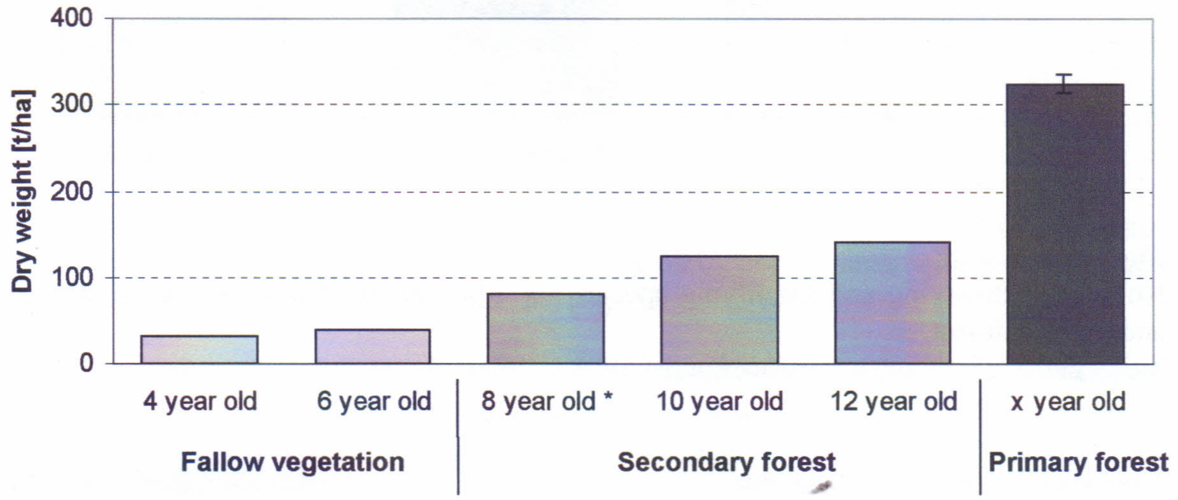


Figure 5.4:
Estimation of the above ground plant biomass according to Kira (1987) in fallow vegetation (4 and 6 years old), secondary forest (8, 10 and 12 years old) and primary forest (average from two different years, T : range).
* data from Preisinger (unpublished)

5.4 Fructification

5.4.1 Flower and fruit phenology

Only 34 to 49 plant species flourish on the 1,000 m² of each vegetation type within the three years of study (fig. 5.5). In consideration of the found species diversity it is obvious that less than 25 % of the species flourish in each vegetation type. A share of 24 % of the found 154 species in the fallow vegetation produced flowers. In the secondary forest these were 14 % of the 235 species and in the primary forest only 10 % of the 484 species.

Not all plant species, that flourished in the years 1995 to 1998, produced mature fruits (fig. 5.5). Thus 2 species of the fallow vegetation produced flowers but not mature fruits. In the secondary forest this occurred in 10 species and in the primary forest in 18 species. Consequently the quota of species with fruits decreases in relation to the number of species in the vegetation types. A share of 23 % of the species in the fallow vegetation produced mature fruits. In the secondary forest these were 10 % and in the primary forest 7 % of the species.

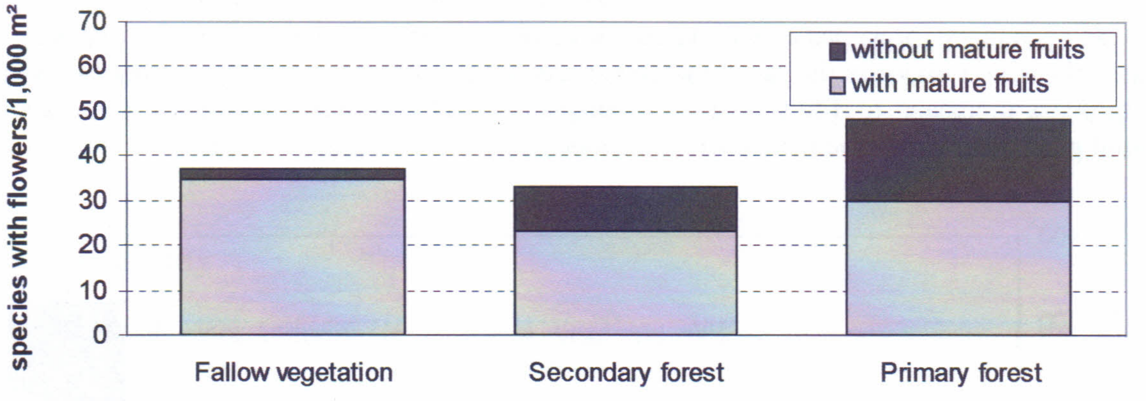


Figure 5.5:
Number of flowering and fructifying species per 1,000 m² in fallow vegetation, secondary and primary forest.
Study period: September 1995 to August 1998

5.4.2 Rhythm of fruit phenology

The fruit phenology is primarily a consequence of the rhythm of the flower phenology. Due to the different flowering rhythms of the species, the number of plants with mature fruits show seasonal fluctuations (fig. 5.6).

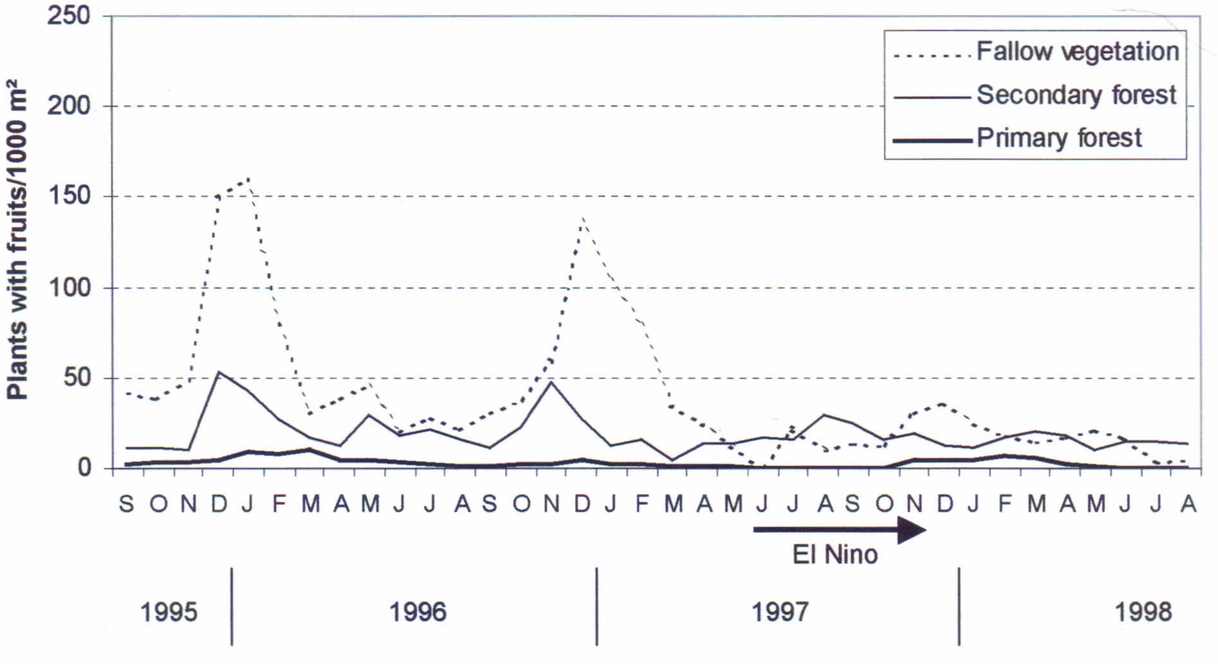


Figure 5.6:
Seasonal fluctuation of the number of plants (stem diameter ≥ 1 cm) with mature fruits per 1,000 m² in fallow vegetation, secondary and primary forest.
The period of the "El Niño" phenomenon is marked because of the heavy and persistent climatic changes. Study period: September 1995 to August 1998.

In the fallow vegetation most plants produced mature fruits during the rainy months December to February (fig. 5.6). Nearly 150 plant individuals (stem diameter ≥1cm) per 1,000 m² showed mature fruits. The fruit maximum failed during the period of "El Niño", due to the lack of flower production. In the secondary forest 40 to 50 plant individuals per month produced fruits during the observed fructifying maxima in the months November to January. As in the fallow vegetation the lack of flower production during "El Niño" lead to a failure of a fruit maximum in the secondary forest. Only about 10 plant individuals per 1,000 m² and month produced fruits in the primary forest. There were two slight fruit maxima in the month January to March of 1996 and 1998. Because of the generally very low number of fructifying plants, the lack of fructifying plants during July to September of 1997 cannot be attributed to the "El Niño"-phenomenon.

In the fallow vegetation and secondary forest, the two vegetation types with the most fructifying plants during the study period, more than 60 % of the plants with fruits have an annual fructification with one great fruit period (fig. 5.7).

In the fallow vegetation a part of 35 % of the fructifying plants have a sub-annual fructification about most time of the year (fig. 5.7). With the quota of 1 % the number of fructifying plants with supra-annual fructification was negligible in the fallow vegetation. In the secondary forest the number of fructifying plants with sub-annual fructification decreased as the number of fructifying plants with supra-annual fructification increased. About 15 % of the fructifying plants in the secondary forest had a supra-annual fructification and produced fruits only every other year or rarer. In the primary forest nearly 85 % of the plants with fruits have a supra-annual fructification and only 15 % of the plants show an annual fructification.

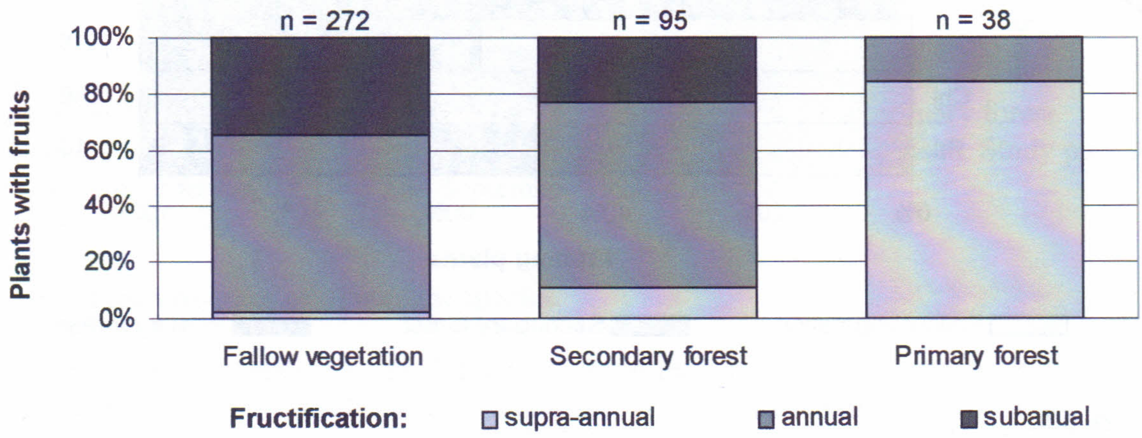


Figure 5.7:
Regularity of fructification of the plants with fruits (stem diameter ≥ 1 cm) in fallow vegetation, secondary and primary forest.
Study period: September 1995 to August 1998

5.4.3 Fructifying plants and their seed dispersal types

During the study period of three years 405 plants (stem diameter ≥ 1 cm) produced fruits. 186 plants disperse their seed by bats and 175 plants by birds (fig. 5.8). These adds to 91 % of all plants with fruits. Only 44 plants disperse their seeds in an other way.

The majority of the plants with bat and bird dispersal grow in the fallow vegetation (fig. 5.8), where the high number of fructifying *Vismia guianensis* (Clusiaceae) causes the high number of plants with bat dispersal. Hydrochorous and epizoochorous dispersal are restricted to the fallow vegetation. In the secondary forest the high number of plants with ornithochorous seed dispersal are Melastomataceae of the genera *Bellucia* and *Miconia*. As *V guianensis* persists in the secondary forest, the number of plants with bat dispersal is also high. Uncommon are fructifying plants with anemochorous and autochorous seed dispersal. In the primary forest 19 fructifying plants disperse their seeds by birds. So ornithochory is the most common seed dispersal there. Restricted to the primary forest are synchorous and primatochorous seed dispersal.

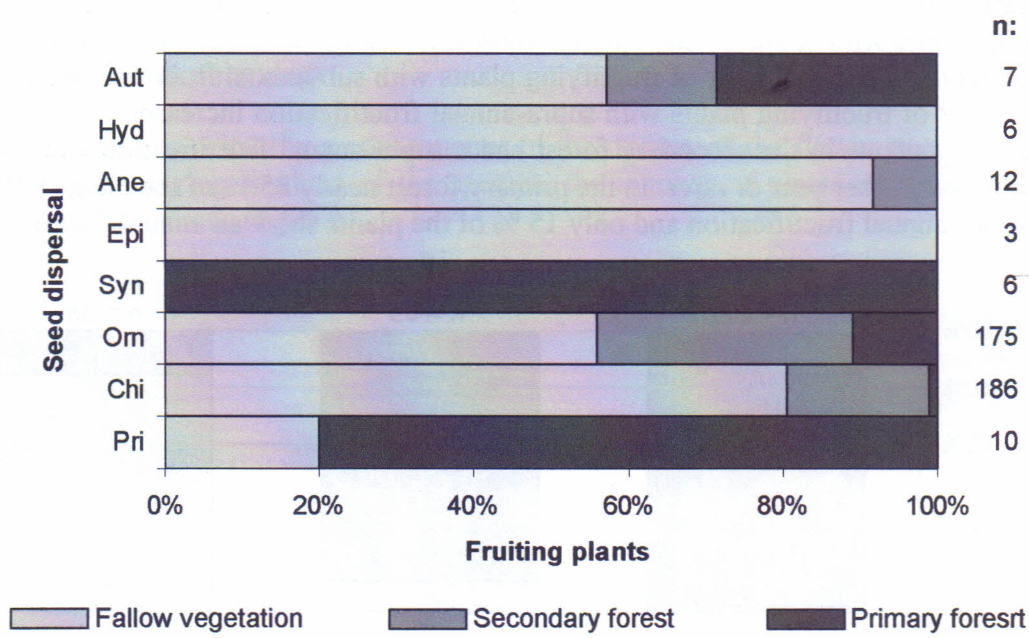


Figure 5.8.
Percentage distribution of the different dispersal agents upon the plants with fruits of fallow vegetation, secondary and primary forest.
Study period: September 1995 to August 1998

<u>Seed dispersal:</u>

Aut: autochorous (plant mechanisms)
Ane: anemochorous (wind)
Chi: chiropterochorous (bats)
Epi: epizoochorous (adhered in skin / feathers)
Hyd: hydrochorous (water or rain)
Orn: ornithochorous (birds)
Pri: primatochorous (monkeys)
Syn: synchor (carried off, buried, mostly rodents)

5.5 Seed dispersal

5.5.1 Seed rain

The seed rain of a vegetation contains seeds of the own plants and seeds, that are brought in from other vegetation types. Overall 807,446 seeds were collected within 2½ years of study. According to external characteristics 226 different seed types could be distinguished. 126 of these seed types, accounting for only 0.2 % of all collected seeds, could not be identified taxonomically. From the remainders 100 seed types 33 types could be identified to family level, 29 types to genus level and 38 types to species level.

The average seed rain per m² and year between the three vegetation types differs within dimensions (fig. 5.9). The annual seed rain consists of 4,800 to 6,400 seeds per m² in the fallow vegetation, of 16,800 to 29,700 seeds per m² in the secondary forest and of 100 to 150 seeds per m² in the primary forest.

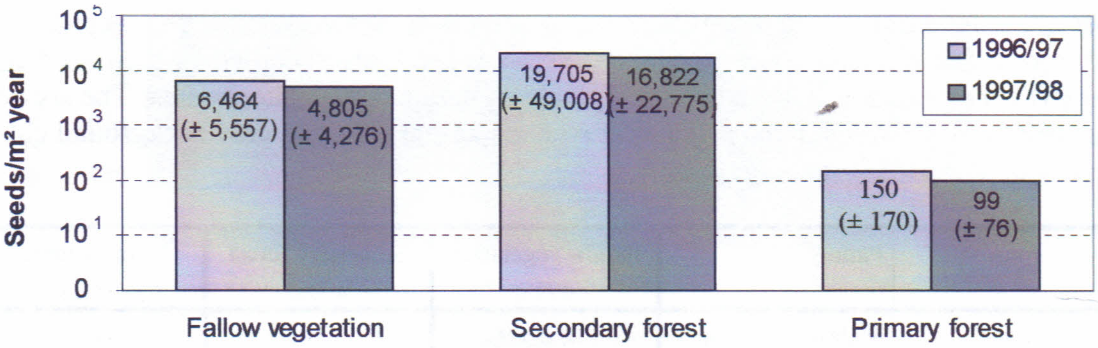


Figure 5.9:
Average seed rain per m² and year in fallow vegetation, secondary and primary forest. Because the values differ within dimensions the logarithmic scale was chosen. Study periods: 1996 September to August 1997 and September 1997 to August 1998.

5.5.2 Seed introduction of new plant species

Because the three vegetation types differ strongly in their floristic composition the probable origin of the seeds in the seed rain can be detected by their affiliation to plant family, genus or species. A precise detection of the origin could not be done for all seeds. For example seeds of the plant family Euphorbiaceae are very similar in shape, surface structure, color and size and this plant family occurs in all three studied vegetation types.

7,007 seeds of new species, genera or plant families, which do not occur as adult plant in the respective vegetation type, were found in the seed traps during the study period from March 1996 to August 1998. This is a quote of 0.9 % of the total seed rain of 807,446 seeds. Especially species with fruits rich of seed are brought into other vegetation types, e. g. *Bellucia dichotoma* (Melastomataceae) from the secondary forest into the fallow vegetation or *Cecropia concolor* (Cecropiaceae) from the fallow vegetation into the secondary and primary forest (tab. 5.5.1).

In the fallow vegetation 531 seeds of new species were found in the seed rain (tab. 5.5.1). These are 35 seeds per m² in 2½ years, extremely few in comparison to the high total seed rain (fig. 5.9). Mainly seeds from the genus *Miconia* (Melastomataceae) are brought in beside the seeds of *Bellucia dichotoma*. In the secondary forest 2621 seeds were found in 2½ years, equivalent to 174.7 seeds per m². *Cecropia concolor* alone has a part of 94 % of these seeds. 2,069 seeds of *C. concolor* occurred in feces in one single seed trap in January and February 1997. These seeds constitute the main input of seeds of new species in the secondary forest. Most of the other introduced new species are common species of the fallow vegetation. Only one new palm species from the primary forest was introduced often into the secondary forest. The primary forest has the highest introduction of new species by seeds. During the study period of 2½ years 3555 seeds or 237 seeds per m² reached the primary forest from other vegetation types. Consequently the seed rain of the primary forest is composed more by seeds from other vegetation types than by its own. The main newly introduced species, besides of *Cecropia concolor* (Clusiaceae) are Melastomataceae of the genera *Bellucia*, *Clidemia* and *Miconia* and the Clusiaceae *Vismia guianensis*.

Table 5.1:
Number of seeds introducing a new plant species into the fallow vegetation, the secondary or primary forest. Seeds, that are not identified on species level, are specified by their seed type number (ST). The number of seeds in the original vegetation (OV) is not named. The six new species with the most seeds in the vegetation type are accented with a gray background color. Study period: March 1996 to August 1998.

Species	Family	Fallow vegetation n (%)	Secondary forest n (%)	Primary forest n (%)
Bellucia dichotoma	Melastomataceae	**371 (69.9)**	OV	43 (1.2)
Miconia sp. (ST 76)	Melastomataceae	43 (8.1)	OV	-
Miconia sp. (ST 153)	Melastomataceae	15 (2.8)	-	OV
ST 101	Rubiaceae	17 (3.2)	OV	1 (0.03)
Miconia tomentosa	Melastomataceae	14 (2.6)	OV	393 (11.1)
Miconia sp. (ST 57)	Melastomataceae	48 (9.1)	OV	410 (11.5)
Vismia guianensis	Clusiaceae	OV	OV	238 (6.7)
Bellucia grossularioides	Melastomataceae	OV	OV	208 (5.9)
Cecropia concolor	Cecropiaceae	OV	**2,414 (94.0)**	**1,180 (33.2)**
Clidemia hirta	Melastomataceae	OV	45 (1.7)	500 (14.19
Solanum sp. (ST 3)	Solanaceae	OV	36 (1.4)	7 (0.2)
Piper hispidum	Piperaceae	OV	22 (0.9)	91 (2.6)
ST 13	Arecaceae	-	17 (0.7)	OV
Cecropia ulei	Cecropiaceae	OV	15 (0.6)	17 (0.5)
remaining species		23 (4,3)	63 (2.4)	384 (10.7)
total number of seeds		531 (100)	2,621 (100)	3,555 (100)
seeds per m²		35,1	171,7	237

In the fallow vegetation 531 seeds of new species were found in the seed rain (tab. 5.5.1). These are 35 seeds per m² in 2½ years, extremely few in comparison to the high total seed rain (fig. 5.9). Mainly seeds from the genus *Miconia* (Melastomataceae) are brought in beside the seeds of *Bellucia dichotoma*. In the secondary forest 2621 seeds were found in 2½ years, equivalent to 174.7 seeds per m². *Cecropia concolor* alone has a part of 94 % of these seeds. 2,069 seeds of *C. concolor* occurred in feces in one single seed trap in January and February 1997. These seeds constitute the main input of seeds of new species in the secondary forest. Most of the other introduced new species are common species of the fallow vegetation. Only one new palm species from the primary forest was introduced often into the secondary forest. The primary forest has the highest introduction of new species by seeds. During the study period of 2½ years 3555 seeds or 237 seeds per m² reached the primary forest from other vegetation types. Consequently the seed rain of the primary forest is composed more by seeds from other vegetation types than by its own. The main newly introduced species, besides of *Cecropia concolor* (Clusiaceae) are Melastomataceae of the genera *Bellucia*, *Clidemia* and *Miconia* and the Clusiaceae *Vismia guianensis*.

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total number of seeds		531 (100)	2,621 (100)	3,555 (100)
seeds per m²		35,1	171,7	237

5.5.3 Dependency of species exchange on dispersal agents

Principally new plant species with bat and bird dispersed seeds are introduced into another vegetation type. 3,097 seeds of new, bird dispersed plant species and 3,852 seeds of new, bat dispersed plant species were found in the seed traps (fig. 5.10).

531 seeds of new plant species are introduced into the fallow vegetation, all with bird dispersed seeds (fig. 5.10). 2,465 seeds of new plant species with bat dispersed seeds are found in the seed traps of the secondary forest. Dispersal by birds and wind are of less importance. Only 5 epizoochorous and 1 primatochorous seed are also found. In the primary forest 2,143 seeds of bird dispersed species were collected. This is the major part of all new species with bird dispersed seeds. The number of seeds of species with bat dispersal is only half as high. The third dispersal agent that takes seeds of new species into the primary forest is the wind. 31 Seeds of wind dispersed seeds are found in the seed traps of the primary forest.

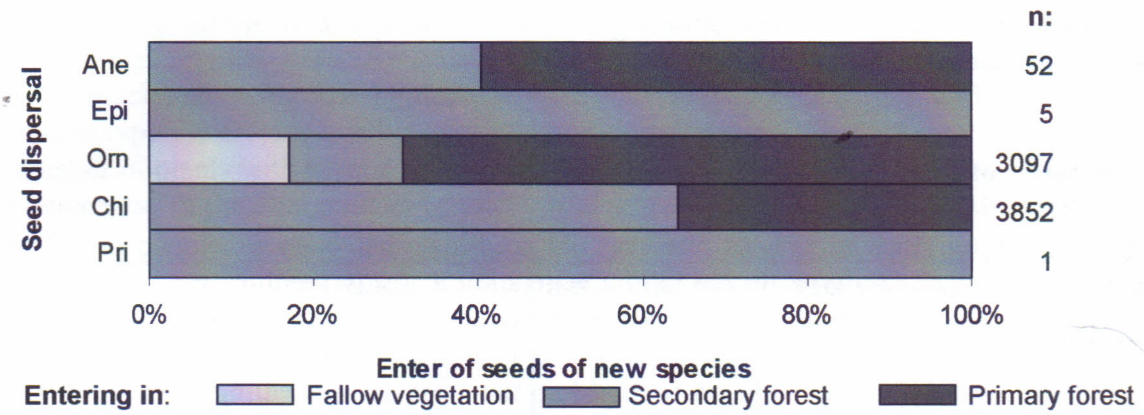

Figure 5.10:
Dispersal direction of the seeds of new species with different dispersal agents into the fallow vegetation, secondary and primary forest.
Study period: March 1996 to August 1998

Seed dispersal:
Ane: anemochorous (wind)
Chi: chiropterochorous (bats)
Epi: epizoochorous (adhered in skin / feathers)
Orn: ornithochorous (birds)
Pri: primatochorous (monkeys)

5.5.4 Number of seedlings in the seedling stock

The average number of new seedlings ranges from 1 seedling per m² in 1997 to 15 seedlings per m² in 1996 (fig. 5.11). These variation in time come along with high variation of seedling number in space identifiable by the high range of standard deviation. In the secondary forest the temporary variation in seedling number is low, with 1 to 3 new seedlings per m². But the relatively high standard deviations demonstrate the high spatial variation of new seedlings. The number of new seedlings in the primary forest is equal to the one in the secondary forest. But in the primary forest the number of new seedlings show high constancy in time and space.

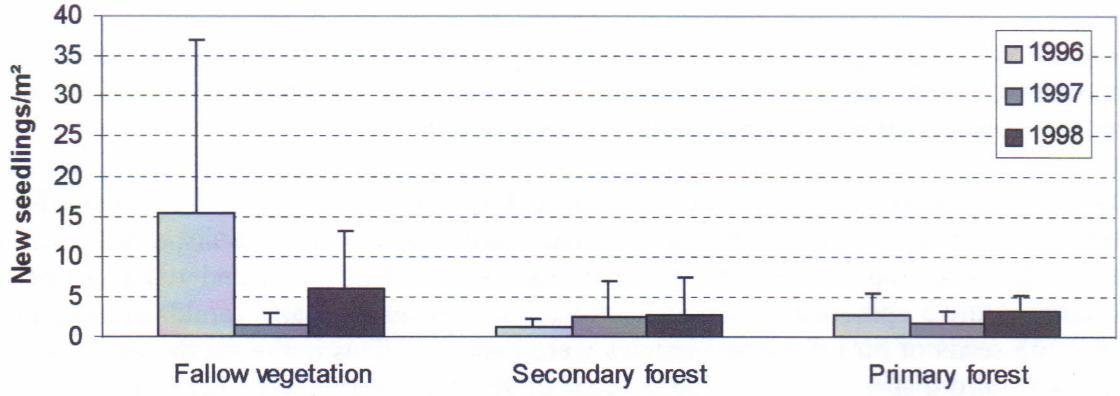

Figure 5.11:
Number of new germinated seedlings per m² in the fallow vegetation, secondary and primary forest in the years 1996 to 1998.
The data basis are annual surveys of new germinated seedlings in 20 m² in each vegetation type. (T: standard deviation)

5.5.5 Density of the steady seedling stock

A steady seedling stock of at least one year old seedlings, has been developed in different stages in each vegetation type. In the fallow vegetation a steady seedling stock has scarcely developed, because a seedling rarely survives one year or more (fig. 5.12). In the secondary forest a steady seedling stock is formed up by 2 to 4 at least one year old seedlings per m². In the primary forest 4 to 6 seedlings per m² build up the most dense seedling stock of the three vegetation types.

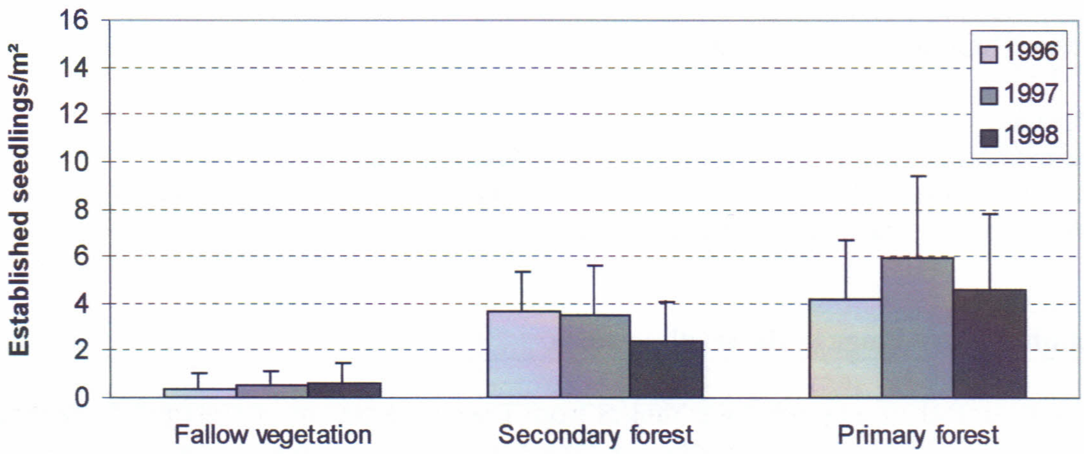

Figure 5.12:
Density of long-term established, at least one year old seedlings in the fallow vegetation, secondary and primary forest in the years 1996 to 1998.
The data basis are annul surveys of at least one year old seedlings in 20 m² in each vegetation type. (T: standard deviation)

5.5.6 Vegetative regeneration

Overall 385 plants with several shoots per rootstock were found in all study areas. 351 plants of them were identified to species level, 28 plants to genus level and 4 plants only to family level. 2 plants could not be identified taxonomically. Altogether 94 species, 61 genera and 35 plant families were found with several shoots per rootstock.

266 plants in 1,000 m² of fallow vegetation have several shoots per rootstock, mostly plants of *Vismia guianensis* and *V. cayennensis* (Clusiaceae) (tab. 5.5.2). Both tree species together account for 37 % of plants with several shoots per rootstock. Other species, that frequently show several shoots per rootstock, are the liana *Davilla latifolia* (Dilleniaceae), and the shrubs *Clidemia hirta* (Melastomataceae), *Piper hispidum* (Piperaceae) as well as the pioneer tree *Cecropia concolor* (Cecropiaceae). According to Gentry (1996) and Ribeiro et al. (1999) all six species are common species in the secondary vegetation.

Table 5.2:
Number of plants with several shoots per rootstock in the fallow vegetation, secondary and primary forest.
The six species showing the highest frequency of several shoots per rootstock in each vegetation type are accented with a gray background color.
n = number of plants with several shoots per rootstock
% = percentage of the total number of plants with several shoots in each vegetation type

Species	**Family**	**Fallow vegetation n (%)**	**Secondary forest n (%)**	**Primary forest n (%)**
Goupia glabra	Celastraceae	1 (0.4)	**9 (10)**	-
Memora adenophora	Bignoniaceae	1 (0.4)	**9 (10)**	-
Amphirrhox surinamensis	Violaceae	5 (1.9)	6 (6.6)	-
Pogonophora schomburgkiana	Euphorbiaceae	9 (3.4)	5 (5.6)	-
Ryania speciosa	Flacourtiaceae	2 (0.7)	5 (5.6)	-
Vismia guianensis	Clusiaceae	**60 (22.4)**	5 (5.6)	-
Vismia cayennensis	Clusiaceae	39 (14.6)	1 (1.1)	-
Davilla latifolia	Dilleniaceae	30 (11.2)	-	-
Clidemia hirta	Melastomataceae	29 (10.8)	-	-
Piper hispidum	Piperaceae	19 (7.1)	-	-
Cecropia concolor	Cecropiaceae	18 (6.7)	-	-
Siparuna guianensis	Monimiaceae	-	-	**3 (11.1)**
Rinorea racemosa	Violaceae	2 (0.7)	2 (2.2)	2 (7.4)
remaining species		53 (19.9)	48 (53.3)	22 (81.5)
total number of plants		266 (100)	90 (100)	27 (100)

In the secondary forest the number of plants with several shoots per rootstock is much lower than in the fallow vegetation (tab. 5.5.2). 90 plants with several shoots per rootstock are found in 1,000 m². The tree species *Goupia glabra* (Celastraceae) and the liana species *Memora adenophora* (Bignoniaceae) have a part of 10 % respectively. Other species with high frequency of several sprouts per root stock are the tree species *Amphirrhox surinamensis* (Violaceae), *Ryania speciosa* (Flacourtiaceae), *Pogonophora schomburgkiana* (Euphorbiaceae) and also *Vismia guianensis* (Clusiaceae). According to Gentry (1996) and

Ribeiro et al. (1999) only *V. guianensis* is a common tree in the secondary forest. *G. glabra* is found in the primary forest and in the older secondary forest. The other four species are common primary forest species. All six species show also several shoots per rootstock in the fallow vegetation but not in the primary forest.

Having several shoots per rootstock is still less common in the primary forest (tab. 5.5.2). Only 27 plants show several shoots per rootstock in the study site, three times *Siparuna guianensis* (Monimiaceae) and twice *Rinorea racemosa* (Violaceae). For the other 22 species only one plant was found with several shoots per rootstock within the 1,000 m² study site.

5.6 Discussion

5.6.1 Species diversity and above ground biomass

Successive alterations occur with increasing age of the vegetation leading over from one vegetation type to the other. In doing so the species number increases from 154 species per 1,000 m² in the fallow vegetation up to 235 species in the secondary forest and 484 species in the primary forest (fig. 5.2). At the same time the species spectra changes successively. In the study sites of 1,000 m² each in the fallow vegetation, secondary and primary forest 660 species of higher plants were found. This species diversity shows, in spite of the relatively small study sites, a good overview of the local species spectra. In the Reserva Ducke, a protected reserve of 100 km², only 2 km away from our study area, herbar samples of 1,199 species of vascular plants were identified during all botanical studies of several decades (Ribeiro et al. 1994). The Reserva Ducke contains, besides of a different secondary vegetation, also different types of primary forest.

The above ground plant biomass cumulates with increasing age of the vegetation from a dry weight of 32 t/ha in the 4 year old fallow vegetation to 142 t/ha in the 12 year old secondary forest (fig. 5.4). However, after 12 years of succession the above ground plant biomass does not reach the half of the above ground plant biomass of the primary forest, that accounts to about 325 t/ha dry weight. According to Uhl et al. (1988) an above ground plant biomass similar to the primary forest can only be reached during succession following shifting cultivation after 200 years. In comparison to biomass data of about 500 t /h dry weight for a primary forest near Manaus (Klinge 1976), the above ground plant biomass estimated for the primary forest here is rather low. Therefore it must be suggested, that big trees providing a lot of above ground biomass were extracted. This can bi presumed because of the nearby city of Manaus.

In spite of increasing above ground plant biomass the plant density regress continuously during the first 10 years of succession (fig. 5.3). Similar developments during succession after agricultural use are shown in studies at the Upper Rio Negro (Uhl 1987), in the semi-decidious rainforest in Acre (Fujisaka et al. 1998) and wet and dry tropical forests in Costa Rica (Opler et al. 1980).

The biomass, the species composition and plant density show a successive development from the fallow vegetation to the secondary forest. A transition from the secondary to the primary forest can only be found rudimentarily with these parameters. In contrary to the succession in the temperate climates the succession in the tropics pass through more stages including basic changes of the species spectra and the composition of life forms, especially in the early successional stages (Janzen 1975). After 50 years at the best typical primary forest species have an important portion in the species spectra of secondary forests (Uhl 1987). Even though studies of older secondary forests are missed as links, the parallel realized short-time studies in the three vegetation types stand for a long-time analyze of the succession of the vegetation in the Central Amazon.

5.6.2 Succession

The succession of the tree and shrub vegetation begins after the last slash and burn activity with vegetative regeneration from rootstocks. Especially the pioneer trees *Vismia guianensis*, *V. cayennensis* (Clusiaceae) and *Cecropia concolor* (Clusiaceae) are able to regenerate vegetatively as well as many shrubs and lianas (tab. 5.2). Starting from vegetatively regenerated plants *V. guianensis* expands into the surrounding area sprouting from lateral roots (fig. 5.13). During the first 10 years of succession many shoots of *V. guianensis* die in the dense thickest (fig. 5.3), a phenomenon observed also in other Amazonian regions (Uhl 1987). Notwithstanding the previous slash and burn activities some typical species of the original primary forest are found in the fallow vegetation and secondary forest (tab. 5.2). These plants survived each slash and burn and each weeding activity during the cultivation. This wastes the energy reserves of the plants. In consequence many plants die (Prance 1975, Uhl et al. 1981, Uhl 1987, Uhl et al. 1988). Therefore the density of vegetatively regenerated plants of *Goupia glabra* (Celastraceae) and *Memora adenophora* (Bignoniaceae) is higher in the secondary forest than in the fallow vegetation, that grew up after cutting the secondary forest. Other primary forest species, as *Amphirrhox surinamensis* (Violaceae), *Pogonophora schomburgkiana* (Euphorbiaceae) and *Rinorea racemosa* (Violaceae) tolerate also several slash and burn activities. Regenerated plants of these species can be found in similar number in the fallow vegetation and the secondary forest. Due to the repeated slash and burn activity plant species occur, that do not have their natural distribution in this region. Herbs, as cosmopolitan and anthropophilous species, were introduced by men and play more and more an important role during cultivation and early succession (Pires 1992).

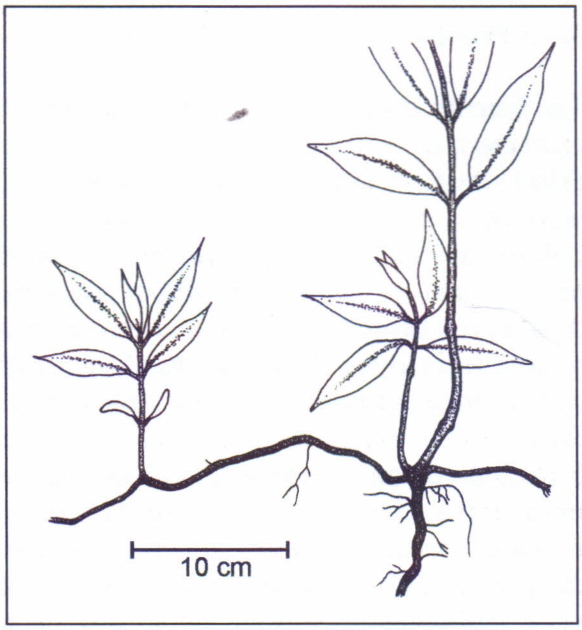

Figure 5.13:
Sprouting from lateral roots by *Vismia guianensis* (Clusiaceae).

The generative regeneration, in contrast to the vegetative regeneration, has no importance for the development of the vegetation during the early succession. The germination of pioneer plants is induced by light with an high near-red/far-red ratio and increasing soil temperatures (Murray 1986). These conditions are given in the open areas of the fallow vegetation, outside of the dense *Vismia*-thickets and explain the high number of germinating seedlings, that are mostly pioneer species (fig. 5.11). But the seedlings seldom outlive a year (fig. 5.12), so that only few germinated plants participate in the regeneration of the younger fallow vegetation. Nepstad et al. (1991) observed, that 80 to 99 % of the seedlings of pioneer species do not survive the first year and die mostly during the dry season. In the secondary forest 2 to 4 seedlings per m^2 survive the first year (fig. 5.13), because the dense vegetation equalizes the seasonal climatic oscillations. Additionally these seedlings belong to species of older secondary and primary forests, that are not susceptible to the climatic oscillations (Nepstad et al. 1991). In the primary forest the density of older seedlings increases to 4 to 6 seedlings per m^2. The few germinating seedlings, in average less than 3 seedlings per m^2 and year (fig. 5.12), find good conditions to survive in the secondary and primary forest. In the secondary and primary forest the seedlings build up the regeneration pool facilitating rapid growth after local destruction of the vegetation (Pijl 1982). The capability of primary forest species to pause in the seedling stadium substitutes the missing seed dormancy. The seed dormancy allows pioneer species to outlive in the soil seed bank until good germination conditions are given.

5.6.3 Fructification and seed dispersal

The fructification differs in the three vegetation types enormously. The fallow vegetation is characterized by a high and frequent fructification (fig. 5.6 and 7). According to Uhl et al. (1981) the first herbaceous species flourish 4 month after the slash and burn activity, the first wooden species flourish 6 month later. The pollination by wind and insects as much as self pollination enable a high fertilization (Opler et al. 1980). The continuous fructifying over many months of 35 % of the fructifying plants allows a permanent fructification year-round. A similar situation can be found in the secondary forest, where the total number of plants with fruits is lower. Nearly 25 % of the fructifying plants show a continuous fruit production and ensure a permanent fructification also in the secondary forest. The primary forest has the lowest fructification. One-third of the flowering species do not produce mature fruits (fig. 5.5). One reason for the failure of mature fruits is the dioeciousness of many primary forest trees (Bawa et al. 1990) meaning that fruits are produced only from the plants with female flowers. Specialized pollinators as birds or bats and the inability of self-pollination minimize the pollination rate of flowers in the primary forest. Additionally it can be observed, that many pollinated flowers die before fruit maturing (Bawa et al. 1990). In this case the flowers serve only as pollen source (Baker et al. 1983). More than 80 % of the plants with mature fruits produce fruits only within an interval of several years (fig. 5.7). On the study site of 1.000 m^2 several months without mature fruits in the primary forest were observed (fig. 5.6). Therefore the frugivore animals need a great forage area. The fructifying maxima in the fallow vegetation and secondary forest lack during the El-Niño period in 1997, because most of the plants did not flourish.

In all three vegetation types most plants have chiropterocorous or ornithocorous seed dispersal (fig. 5.8). Especially the fallow vegetation and the primary forest differ in their dispersal syndromes of the fructifying plants. In the fallow vegetation fructifying plants show also epizoochorous, anemochorous and hydrochorous seed dispersal. Synchory and primatochory exist predominantly in fructifying plants of the primary forest, that shows therefore a higher dependency on particular animals as dispersal agents.
The determination of the dispersal agent can be done only with field observation. In spite of special plant-animal interactions the shape, size and color of the fruits are often systematic

characters, that are similar within a plant family, regardless of different ecological conditions and different spectra of dispersal agents (Herrera 1986). The low occurrence of potential seed dispersal agents in the primary forest (Lovejoy & Bierregard 1990, Göckler 2000) requires separate and time-consuming faunistic studies, that could not be realized in this work. Therefore it had to be reverted to data from literature.

The number of fructifying plants and the dispersal type affect strongly the seed rain, that is composed of seeds of the own vegetation type and of seeds brought in from other vegetation types. The very high seed rain in the fallow vegetation, consisting of 5.000 seeds per m² and year, and in the secondary forest, consisting of 18.000 seeds per m² and year, are build up by seeds of the own vegetation (fig. 5.9, tab. 5.1). In the primary forest the seed rain of about 100 seeds per m² and year is mainly brought in from the other vegetation types. The introduction of new plant species by seed dispersal is highest in the primary forest and lowest in the fallow vegetation. This difference is caused by the habitat preferences of the dispersal agents (Stiles & White 1986). Many dispersal agents avoid e. g. open areas in vegetation (Uhl et al. 1988, Willson &Whelan 1990). Primates, important dispersal agents of primary forest plants, are more restrictively in their habitat preferences and only one seed of a primatochorous species got out of the primary forest.

Mainly Melastomataceae seeds of the genera *Bellucia*, *Clidemia* and *Miconia* as well as different *Cecropia* species (Cecropiaceae) are dispersed as new plant species into the vegetation types (fig. 5.10). These species, representing more than 99 % of the seeds of newly introduced species, show a chiropterochorous or ornithochorous dispersal syndrome. The ornithochorous seeds are dispersed principally into the primary forest. But ornithochory is also the dispersal syndrome of all seeds of newly introduced species in the fallow vegetation. Most seeds of species with chiropterochorous dispersal syndrome attain the secondary forest, coming from the fallow vegetation. The darkness protects bats, when they visit the open areas of the fallow vegetation in the twilight (Charles-Dominique 1986).

The different habitat preferences of the dispersal agents vary in space and time and with them varies the seed rain. 2069 seeds of *Cecropia concolor* (Cecropiaceae) reached within feces one seed trap of the secondary forest in January and February 1997. These seeds count for 79 % of the total collected seed rain of the secondary forest in 2½ years. As the average seed number per fecal deposition of vertebrates amounts to 4 to 15 seeds (Willson & Whelan 1990), a small group of animals frequented the tree above the seed trap for 8 weeks.

5.6.4 Conclusions

Repeated slash and burn activity reduces more and more the species diversity of the spontaneous vegetation. Especially the number of primary forest species declines due to the exhausting of the energy reserves of the plants by repeated resprouting, and due to the lack of primary forest seedlings in the secondary vegetation. In contrast the number of anthropophilous plant species increases. If small herbaceous and wooden plants are included in the study, the area size of 1,000 m² is sufficient to give a good overview of the local species spectrum of the vegetation, even in the primary forest.

The plants of the three vegetation types analyzed here differ in their regeneration strategies:

- The fallow vegetation is characterized by plants with high potential of generative regeneration, ensured by self pollination or wind and insect pollination, by high and frequent fructification, as well as by seed dispersal using generalized agents like bats and small birds. Thus seeds from *Cecropia concolor* (Cecropiaceae), *Clidemia hirta* (Melastomataceae) and *Vismia guianensis* (Clusiaceae) are dispersed into the secondary and primary forest. Seeds of these plant species need open areas to germinate but few seedlings outlive a year. The first closed thickets are build by *V. guianensis*, that regenerates after cutting by a resprouting rootstock and expands to the surrounding area sprouting form lateral roots.

- The plants of the secondary forest show similar regeneration strategies as the fallow vegetation. The *V. guianensis* dominated thickets are replaced mainly by plants of the Melastomataceae-genera *Bellucia* and *Miconia*. The seed dispersal agent of these plants are small birds. Bat dispersed plants species as *C. concolor* or *V. guianensis* are missing or decreasing in number. The seeds are dispersed into the two neighboring vegetation types.

- Primary forest species show an extremely different regeneration strategy. The primary forest species are often dioecious plants, have special pollinators as birds and bats, produce seeds only every other year or rarer, and depend on certain dispersal agents particularly greater birds, primates and rodents. The seeds are rarely dispersed into long distance from the parent tree. The seeds germinate in the shadow of other trees. The seedlings outlive some years waiting for an opening of the vegetation. The plants show a relatively low vegetative regeneration ability, which causes a great loss of many species after slash and burn activity.

The seed dispersal, especially from the primary forest into the secondary forest and fallow vegetation, is supposed to be the major decelerating factor of the succession of spontaneous vegetation. The primary forest, though in direct neighborhood of the fallow vegetation and the secondary forest, contributes little to the vegetation development during early successional stages. An adjacent primary forest as a seed pool for the succession is insufficient for a spontaneous regeneration of areas with previous land use. To accelerate the succession of the spontaneous vegetation and to enrich the secondary vegetation soon with primary forest species, the seeds must be introduced by man. The thickets build by *V. guianensis* can be a good habitat for their germination.

6 Valuation and summarization of the results

Basis of the present study is a vegetation survey of example sites of Terra Firme in the Central Amazon, which were altered by former or actual agricultural use. The interest is focussed mainly on the SHIFT experimental site, situated in the area of EMBRAPA Amazônia Ocidental in the north of Manaus, Amazonas. The vegetation science approach is based both on *flora* and *structural traits* of the example sites. In this context, structure is the organization in space of the plant individuals composing a vegetation stand, and the elements of vegetation structure are all the morphological elements composing the vegetation cover. The aim of the study is an indication of site conditions from the vascular plants present in a site. It is therefore necessary to be informed on their ecological behaviour, which can be in part predicted from certain morphological traits of the plants. Hence, the identification of morphological traits which play a functional role for the plants are of major imortance for the approach. Such characteristics are as well superior entities like growth-form, stratification and cover as morphological elements in the strict meaning of the word, like e.g. the surface structure of leaves. The analysis of such "morpho-physiological traits" is part of the autecological approach carried out in the project.

As a first step for a functional description of the *Terra Firme* vegetation altered by man in the Central Amazon, a growth-form system had been developped, and the species occurring in the experimental area were classified into the system (see chapters 9.1 and 9.2). The system is adapted to the anthropogenic vegetation under study and kept as simple as possible. The classification of flora of a number of vegetation types revealed that the system in its present form is suited to differentiate between different stages of succession. More than that, the results show that it is possible to draw conclusions from the growth-form structure with regard to environmental conditions, e.g. like different durations and intensities of pre-use of a site. In the present state the classification of the branched out trees in "Low", "Medium sized" and "Tall tress" is preliminary. This classification was the only one available because of the limited ecological knowledge on that subject. Because the three classes do not necessarily cover uniform functional types, they have to be changed later in favour of a simple, but proven functional classification. That is also true for the category "Woody lianas", comprising species with a wide range of ecological behaviour. The first large data sets analysed with the help of the growth-form system were eight sites of different use histories from the Central and Eastern Amazon (Preisinger, Baar & Denich 1998). The evaluation of the data sets, applying Principal Component Analysis (PCA), resulted in an ordination model showing different directions for progressive and regressive successional processes. The corresponding vegetation types were characterized by specific growth-form spectra. However, the results showed also that the classification of the branched-out trees limited the potential of interpretation.

A comparative analysis of the growth-form spectra of the experimental plots in an extensively used primary forest, an eight year old secondary forest and in the experimental plantation, carried out separately for the tree layer and the shrub/herb layer, revealed in which way the forest vegetation responds to increasing intensities and frequencies of disturbance events (like trampling, cutting and hoeing, slashing and burning). The number of "Tall trees" declined drastically even after the first slashing and burning. Nevertheless, the detailed analysis of the secondary forest plots uncovered a high number of tree species still present in the shrub/herb layer, i.e. as saplings or young plants. A multivariate analysis of the secondary forest plots, also carried out separately for the two strata, showed two distinct floristic groups, representing tree and shrub/herb layer, and each of them forming a continuum of floristic composition. At long date it can therefore be expected that the secondary forest will develop progressively towards a mature forest similar to the primary forest, an undisturbed development provided. It is obvious that the growth-form type "Treelet" plays a key role in the succession of the forests in the experimental area. This type is defined here as a short-lived, woody plant with few ramifications and few, but large leaves, and which regenerates mainly from seeds. In the secondary forests of the experimental region, treelets are represented by numerous species of different families. In the experimental sites, the abundance of many species of *Miconia* (Melastomataceae), which largely belong to that growth-form type, is striking. In the autecological approach, the studies were therefore initiated with 6 species of Melastomataceae (sample species), belonging to the growth-form types "Treelets", "Low trees" and "Medium sized trees".

The comparative studies in autecology of *Miconia tomentosa*, *M. phanerostila*, *Bellucia dichotoma*, *B. grossularioides* and *Miconia pyrifolia* revealed that the 6 species form a sequence with an increasing plant height and biomass, with specific morphological traits (of growth-forms, leaf size and structure, pattern of nutritional elements in the plant organs, inter alia) and with regard to the behaviour in succession (Preisinger et al. 1999). The comparative study on *Bellucia dichotoma* and *B. grossularioides*, being taxonomically and ecologically very similar, indicate which of the morphological differences leads to the slight differences in their ecological behaviour (Richter 1999). The most important differentiating traits were identified as leaf size, mechanical structure and chemical substances (phenolic substances) of the leaves. The sequence of the sample species was extended to 13, the additional species belonging to other plant families than Melastomataceae (see chapter 4). Anatomical characteristics of the leaves and the wood were studied and the results, being mainly results in fundamental research, were laid down in detailed reports (Morais 1998, Aguiar 2000). The functional plant types derived from the autecological studies relate to the successional stages found in the experimental sites. The results imply that a classification of frequently occurring plant species of the Amazonian flora would be possible. However, the number of species and morphological traits which could be surveyed within the present project was too limited to derive a functional classification of general validity. The autecological studies on the 13 sample species did therefore not lead to a fundamental amplification or change of the growth-form system, but to more precise definitions of the types. In this context, an attempt was made to define the growth-form types with reference to Grime's strategy types (see Table 9.2).

The spatial and temporal patterns of flora and structural traits of the spontaneous vegetation in the SHIFT experimental plantation had been surveyed for 8 years, using the growth-form system. The following questions had to be answered:

1. How did the spontaneous vegetation develop in the plots of the different plantation systems, and under the regime of the plantation management?
2. Is it possible to indicate changes of site conditions from changes in structural traits of the spontaneous vegetation?
3. Which prognoses can be made, from the development of the spontaneous vegetation, for a sustainable agricultural use of the sites?

Re 1:

In the beginning of the experiment in 1993, the vegetation survey showed a *spatial gradient* with regard to flora and growth-form composition in the experimental site of elongated shape, ranging from block A to E (Preisinger et al. 1994, Preisinger et al. 1997: chapter 3.5.2). The proportions of the growth-form types "Rhizomatous herbs", "Shrubs" and "Tussock grasses" increase from block A to block E, while the proportions of the regenerating "Trees" decrease. The cause of the gradient has to be interpreted as differences in the duration of pre-use between the experimental blocks. The spatial gradient could still be detected 5 years later in 1998, but the differences had in part been equalized under the regime of plantation management. A marked *temporal gradient* from 1993 to 1995, consisting of a shift in growth-form composition, showed increasing proportions of lianas and shrubs and decreasing proportions of regenerating trees, rhizomatous and tussock grasses. The total number of species decreased during the same period. In contrast, from 1995 to 2000 the proportions of rhizomatous and tussock grasses increased again, just as (dicotyledonous) herbs and shrubs. Moreover, the total vegetation cover decreased. The vegetation developped differently in the different plantation systems: In the monoculture plots, the number of species was higher than in the polyculture plots. Intensity and frequency of disturbance for the wild plants were higher in the polyculture than in the monoculture plots, propably because the cultivation measures in the polyculture systems were more intensive than in the monoculture systems. An effect of the fertilization measures on the spontaneous vegetation could not be detected. The multivariate analysis of flora, carried out in all the plots where Cupuaçu (*Theobroma grandiflorum*) was planted (plantation systems 1, 2, 3 and 7), showed that the yield of Cupuaçu (= weight of fruits) is lower in blocks D and E than in the others. From the results of the analysis, presented graphically in an ordination model, plant species and growth-form types can be identified which indicate unproductive sites (e.g. bracken, *Pteridium aquilinum* and growth-forms "Tussock" and "Rhizomatous grasses") and productive sites (e.g. lianas as Kudzu, *Pueraria phaseoloides*).

Re 2 (page 72):
The results presented above show that it is possible to indicate site conditions and their changes in space and time from structural characteristics of vegetation. In agricultural sites, the complex environmental factors "duration and intensity of pre-use" and "actual plantation management" determine the floristic composition and structural traits of the spontaneous vegetation. These factors mean disturbance and/or stress to the plants (terms used in accordance with Grime 1979), they cannot be measured directly and are therefore only available from indirect deduction, i.e. the indicator value of vegetation. It can be assumed that agricultural use of tropical rain forest sites will lead to drier site conditions at long date. In particular the top soil can dry out and change its physical attributes during the rain-lacking season, because of the sparse vegetation cover which is regularily cut and hoed (cf. Teixeira, in prepar.). Rhizomatous and tussock grasses, being indicators for sites used for long periods of time, can grow on temporarily dry sites with the help of deep root systems or rhizomes.

Re 3 (page 72):
The yields obtained from the polyculture plots and the development of the spontaneous vegetation during the 8 years of observation show that there is no uncertainty on the potentiality for an agricultural use of the sites within that period of time. However, the spatial and temporal tendencies in vegetation development indicate that even the use by polyculture systems leads to drier sites at long date. For that reason there will be a temporal limit for the agricultural use on these sites. Oberservations show patches in some of the plots of the experiment which are bare of vegetation (e.g. plot a9; see chapter 9.3, Photo 10.6). They will be starting-points for a degradation of the sites and/or for soil erosion. The problem of the treatment of the spontaneous vegetation in Amazonian plantations is still unsolved: The farmer considers the spontaneous vegetation as a competitor for the useful plants (= weeds) and tries to control it mechanically.

This leads at first to a sparse vegetation cover and later to degradation and at least to the abandonment of the sites. Sowing of a cover crop like *Pueraria* offers advantages (see above: positive correlation between the productivity of Cupuaçu and the cover of lianas, which is mainly *Pueraria*). However, the smallholders mostly reject the introduction of *Pueraria*, because they cannot afford the additional labour necessary to keep the useful plants free of the tendrils of *Pueraria* (pers. commun. with farmers). More than that, the introduction of *Pueraria* leads to a drastic decrease of the species diversity of the spontaneous vegetation. This would prevent or delay a forest regeneration in case of the abandonment of the site. However, if the useful plants are not kept free from wild vegetation, they would be overgrown and eliminated by the wild plants.

The study of mechanisms responsible for the regeneration of the Amazonian forest vegetation, being a dissertation work (Skatulla, in prepar.; excerpt see chapter 5), followed a similar concept than the one presented above (comparative analysis of flora and structural traits of example sites). This approach is directed to those morphological elements of the vegetation stand showing a relation to the generative and vegetative spreading of the plants (e.g. density of saplings, spatial-temporal patterns of flowering and fruiting, dispersal types). The results of this work will be a contribution to a more precise knowledge on the mechanisms responsible for successional processes taking place in abandoned agricultural sites, inter alia.

Many of the results, experiences and observations accumulated during the project work were fed into the classification of more than 1.000 vascular plant species with regard to growth-form and dispersal type (see chapter 9.2).

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8 Publications and presentations of members of the working group

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Chapter 9

Appendix

9.1 Growth-form system

In the approach presented here we proceed from the well-known fact that growth-forms of vascular plants (in accordance with Raunkiaer 1934) represent a complex of characteristics closely linked to the ecological behaviour of the species and their site conditions (cf. also Hallé et al. 1978). Growth-form types must therefore be the starting point as well for the synecological as for detailed autecological studies. For that reason, a growth-form system had been developped especially for the vegetation under study. It was therefore focussed on the *growth-forms present in the Amazonian vegetation altered by man*, but it includes also growth-form types present in the primary forest. The system comprises ideas of Barkman (1979, 1988), but was kept as simple as possible to enable an easy use in practice.

The system includes 15 growth-form types and, for practical reasons, an additional life-form (Epiphytes, see table 9.1). The approach assumes that these types represent "functional types" (cf. Grime 1985) in a general form. Their names refer to morphological and *not* to taxonomic categories, because the system is strictly based on traits which are believed to be morpho-physiological traits. However, in Table 9.1 examples for plant families are added which typically comprise plant species with that growth-form type. The definitions given in table 9.1 for the categories make use of *leaf size and form*, because as well the observation in the field as the autecological studies had shown that these traits play an important role for the ecological behaviour of the species.

Only few dicotyledonous plants can be found in the study area which are really herbaceous (type "UH"). The majority of that category is in part woody, mostly at base of the stem. The transition from "herbaceous" to "woody" is continuous. "Real shrubs" with a *basitonic growth* in accordance with Raunkiaer (1934) were not found in the study area, and it can be doubted if there are any. Many of the plants classified as "shrubs", e.g. in herbarium samples, are "treelets" within our growth-form system. The "shrubs" in our system are of a shrubby growth-form, but with a *mesotonic ramification* (e.g. *Borreria verticillata*, Rubiaceae). The "HR" type is represented by only few species of Polypodiaceae, and bracken (*Pteridium aquilinum*) is the only one which occurs frequently and in mass development in some places.

The classification of branched out trees with regard to plant size ("low" - "medium" - "high") is a preliminary one. A more sophisticated division would be clearly desirable, but this cannot be achieved at the moment. For the majority of the primary forest trees, the information available on that subject from literature is poor or not existent. The "Flora da Reserva Ducke" (Ribeiro et al. 1999), being the first field guide for the identification of vascular plant species for the Central Amazon, concentrates mainly on taxonomic traits. The ecological information given in this book is related mainly to higher taxonomic groups, but not to the species. Information on growth-form is given frequently in herbarium samples, but this does not help much for the classification, because it is often not clear whether the sample had been collected from a mature plant or not. It is for that reason that the vast majority of the trees had to be classified due to the knowledge and experience of the authors.

Species belonging to the growth-form types which are set off in table 9.1 play key roles in the succession of secondary forests and therefore species from these groups were selected for closer autecological studies ("sample species").

Because the growth-form types pretend to be "functional types" in a general form, a description of the range of ecological behaviour for each of the types would be desirable. For that reason an attempt was made to describe the ecological behaviour of the growth-form types with the help of Grime's CSR strategy concept (Grime 1979, Grime, Hodgson & Hunt 1988). However, the characteristics "annual" and "biennial" used by Grime for the definitions of the strategy types are not relevant in the Amazonian vegetation. That is why the terms "annual" and "biennial" have to be replaced by "short lived" and the term "perennial" by "long-lived". For example: in the Amazonian vegetation, the strategy type "Competitive Ruderal" is a short-lived, mostly woody plant, whereas in the temperate regions it can be annual, biennial or perennial and is mostly herbaceous. Table 9.2 gives a description of the responses of the growth-form types to disturbance and/or stress as defined by Grime (1979) and the supposed range of strategy types due to the CSR system. The growth-form system used is a simplified version of Table 9.1, mainly because of the difficulties with regard to the classification of trees (see above).

Table 9.1:
Growth-form system for the most commonly occurring growth-form types of Central Amazonian Terra Firme (secondary-) forests, developped for practical use (Preisinger et al. 1998, 1999).

- in brackets: plant families which typically represent species with that growth-form type;
- set off: growth-form types which are represented by the "sample species" (see chapter 4);
- see text for more explanations.

	non self-supporting		**self-supporting**	
herbaceous	**WH**	Winding Herbs = vines*	**GS**	Graminoid herbs, spreading by Stolons (e.g. *Poaceae*)
	SC	Spread Climbers*	**GR**	Graminoid herbs, spreading by Rhizomes (e.g. *Poaceae*)
			GT	Graminoid herbs, forming Tussocks (e.g. *Poaceae, Cyperaceae*)
			BF	Broad-leaved Forbs (*Musaceae* inter alia)
			UH	Upright or prostrate growing Herbs with medium or small leaves
			HR	Herbs, spreading by Rhizomes (*Polypodiaceae*)
woody	**WT**	Winding or Twining plants = ***woody lianas*** (e.g. *Bignoniaceae, Dilleniaceae*)	**SH**	SHrubs
			ST	Sparsely ramified, short-lived Treelets which regenerate mainly from seeds, forming broad or medium, simple, lobed or compound leaves (e.g. *Melastomataceae, Cecropiaceae*)
	SC	Spread Climbers	**RT**	Rosette-Trees, forming a single terminal crown of broad, compound leaves (*Arecaceae*)
				Branched out trees, medium or small leaves:
			LT	Low Trees, height <12m, often regenerating from subterranean roots and shoots
			MT	Medium Trees, height 12-20m
			TT	Tall Trees (height >20m)
additional life form: **EPI** = Epiphytes				

Table 9.2:
Generalisations of morphological characteristics and ecological behaviour of the growth-form types, with reference to strategies (in accordance with Grime 1979).

<table>
<tr><th colspan="2">Growth-form types*</th><th>Morphological characteristics</th><th>Response to disturbance and/or stress</th><th>Range of strategy types</th><th></th></tr>
<tr><td rowspan="2">1</td><td>Trees (LT, MT, TT)</td><td>Branched out trees with an acrotonic ramification, medium or small leaves</td><td>Sensitive against frequently occurring disturbances, but rare disturbance events can be survived, e.g. by sprouting from roots and stumps</td><td>(CR -) C - SC</td><td rowspan="4">Plants mostly native to rainforests</td></tr>
<tr><td>Treelets (ST)</td><td>Short-lived treelets with mesotonic, sparse ramifications, which regenerate mainly from seeds, forming a canopy consisting of few, but broad or medium, simple, lobed or compound leaves</td><td>Flexible response to disturbance events by growing new plants from seeds in suitable places (= forest gaps, disturbed areas); rapid growth rates</td><td>CR (- SR)</td></tr>
<tr><td colspan="2">2 Shrubs (SH)</td><td>Woody, at least at base, mostly fast growing, short to longer-lived plants with basitonic to mesotonic ramifications and medium to small leaves</td><td>Flexible response to frequently occurring disturbances, by rapid sprouting from the base of the stem, sometimes from roots</td><td>(CR -) SC</td></tr>
<tr><td colspan="2">3 Lianas and spread-climbers (WT, WH, SC)</td><td>Winding or twining plants, herbaceous or woody</td><td>Ecologically heterogenous plant group which mostly responds very flexible to disturbance (= mechanical damage) and stress (= shading, inter alia)</td><td>all strategy types except R</td></tr>
<tr><td colspan="2">4 Rhizom. and tussock grasses (GT, GR)</td><td>Graminoid herbs, forming tussocks or spreading by rhizomes</td><td rowspan="2">Tolerant against occasionally occurring destruction of overground biomass and periods of drought, but sensitive to shading; regenerating by tillering from the axils of leaves or from rhizomes and roots</td><td>SC - CSR</td><td rowspan="4">mostly invasive plants of cultivated areas</td></tr>
<tr><td colspan="2">5 Rhizom. herbs (HR)</td><td>Long-lived, herbaceous plants with rhizomes (in the experimental site: bracken - Pteridium aquilinum)</td><td>SC</td></tr>
<tr><td colspan="2">6 Stolon grasses (GS)</td><td>Graminoid herbs, spreading by stolons</td><td>Flexible response to frequently occurring disturbances by sprouting and rooting from fragmented shoots</td><td>R - CSR</td></tr>
<tr><td colspan="2">7 Herbs (UH)</td><td>Short-lived, herbaceous, upright or prostrate growing herbs with medium or small leaves</td><td>Tolerant against frequently occcurring disturbances by producing seeds in an early ontogenetic stage</td><td>R</td></tr>
</table>

* simplified version as used for the survey of growth-form types in the experimental plantation

9.2 Species list with autecological traits[1]

Legend:

Species Species and author's names; nomenclature after Bogan et al (1992); spp. = species not identified, samples collected may include several species; sp. + number = species not identified;

Gf Growth-form types (for abbreviations see growth-form system chapter 9.1);

Dispersal Dispersal types (ANE = anemochory; AUT = autochory; EPI = epizoochory; HYD = hydrochory; MYR = myrmecochory; SYN = synchory; END = endozoochory; the endozoochorous dispersal can be devided due to their dispersal agent in CHI = chiropterochory; ORN = ornithochory and PRIM = primatochory); more detailed information will be available in Skatulla (in prep.);

Fam Number of plant families in accordance with Cronquist (1981).

Species	Gf	Dispersal	Fam
Abarema cochleatum (Willd.) Barn.	TT		180
Abarema jupunba (Willd.)Britton&Killip.	TT		180
Abarema laeta (Poepp.&Endl.)Barn.&Gr.		ORN / PRI	181
Abuta grandifolia (Mart.) Sandw.	WT	PRI	35
Abuta grisebachii Triana & Planch.	WT		35
Abuta panurensis Eichl.	WT	END / SYN	35
Abuta sp. 1	WT	END / SYN	35
Abuta sp. 2	WT	END / SYN	35
Abuta spp.	WT	END / SYN	35
Abuta velutina Gleason	WT	END / SYN	35
Acacia adhaerens Benth.	LT		180
Acacia altiscandens Ducke	WT		180
Acacia multipinnata Ducke	WT		180
Acacia sp. 1	WT		180
Acacia tenuifolia (L.) Willd.	WT		180
Acalypha arvensis Poepp.	UH		232
Acanthospermum hispidum DC.	UH		318
Achyranthes spp.	UH		71
Aciotis anomala Brade	UH	ANE	198
Aciotis circaeifolia (Bonpl.) Triana	UH	ANE	198
Acrocomia aculeata (Jaq.) Lodd. ex Mart.	RT		335
Acrocomia sclerocarpa Mart.	RT		335
Adenocalymna subincanum Huber	WT	ANE	301
Adiantum sp. 1	UH		0
Aechmea mertensii (Mey.) Schult. f.	Epi	END	356
Aechmea sp. 1	Epi	END	356
Aegiphila amazonica Mold.	LT		286
Aegiphila integrifolia (Jacq.) B.D. Jacks.	SH		286
Aegiphila racemosa Vell.	WT		286
Aegiphila scandens Mold.	SH		286
Aegiphila spp.	SH		286
Aeschynomene spp.	UH		182
Ageratum fastigiatum (Gardn.) K. & R.	UH		318
Agonandra brasiliensis Miers.	TT		208
Alchornea schomburgkii Klotzsch	LT	AUT	232
Alchornea spp.	LT		232
Alchorneopsis floribunda (Benth.) Muell. Arg.	TT	AUT	232
Alibertia myrciifolia K. Schum.	LT		311
Allophyllus amazonicus	LT		252
Allophyllus edulis (St. Hil.) Radlk.	MT		252
Allophyllus sp. 1	LT		252
Allophyllus sp. 2			252
Allophyllus sp. 3			252
Allophyllus sp. 4			252
Allophyllus sp. 5			252
Allophyllus spp.			252
Alternanthera ficoidea (L.) R.Brown ex R. & S.	WH		71
Alternanthera tenella Colla	UH		71
Amaioua corymbosa Kunth	LT	END	311
Amaioua guianensis Aubl.	LT	END	311
Amaioua spp.	LT	END	311
Amaranthus spp.	UH		71
Amasonia campestris (Aubl.) Moldenke	UH		286
Ambelania acida Aubl.	MT	END	274
Ambelania tenuiflora Muell. Arg.	LT		274
Ampelocera edentula Kuhlm.	TT		51
Amphirrhox longifolia (St. Hil.) Speng.	LT		115
Amphirrhox spp.	LT		115
Amphirrhox surinamensis Eichl.	LT	CHI / PRI	115
Anacampta riedelii (Muell. Arg.) Markgr.	ST		274
Anacampta rigida (Miers.) Markgr.	ST	ORN	274
Anacardium parvifolium Ducke	TT	END	256
Andira micrantha Ducke	TT	ROD / CHI	182
Andira parviflora Ducke		ROD / CHI	182
Andropogon bicornis L.	GT	ANE / END	352
Andropogon condensatus Kunth	GT	ANE / END	352
Andropogon leucostachyus Kunth	GT	ANE / END	352
Anemopaegma floridum Mart. ex DC.	WT		301
Anemopaegma oligoneuron (Sprague&Sandw.)A.Gentry	WT		301
Anemopaegma paraense Bureau & K. Schum.	WT		301
Anemopaegma parkeri Sprague	WT		301
Anemopaegma spp.	WT		301
Aniba canelilla (Kunth) Mez	TT	ORN / PRI	17
Aniba ferrea Kubitzki	TT	ORN / PRI	17
Aniba hostmanniana (Nees) Mez		ORN / PRI	17
Aniba panurensis (Meissn.) Mez	TT	ORN / PRI	17
Aniba terminalis Ducke	LT	ORN / PRI	17
Anisacanthus scandens Leonard	UH		299
Anisophyllea manausensis Pires & W. Rodr.	TT		169
Annona foetida Mart.		END	8
Annona montana Macfadyen	MT	END	8
Annona paludosa Aubl.	TT	END	8
Annona spp.	MT	END	8
Annona tenuipes R.E. Fries	MT	END	8
Anomospermum reticulatum (Mart.) Eichl.	WT		35
Anthurium atropurpureum R.E. Schultes & Maguire	Epi	END	338
Anthurium bonplandii Bunting	Epi	END	338
Anthurium gracile (Rudge) Lindl.	Epi	ORN	338
Anthurium spp.		END	338
Aparisthmium cordatum (Adr. Juss.) Baill.	MT	AUT	232
Apeiba echinata Gaertn.	LT		99
Apeiba petoumo Aubl.	LT		99
Apeiba spp.	MT		99
Araecoccus micranthus Brongn.	Epi		356
Aristolochia cordigera Willd.	WH	AUT	22
Aristolochia spp.	WT	AUT	22
Arrabidaea candicans (L.C. Rich.) DC.		ANE	301
Arrabidaea chica (Humb. & Bonpl.) Verl.	WT	ANE	301
Arrabidaea cinnamomea (DC.) Sandw.	WT	ANE	301
Arrabidaea conjugata (Vell.) Mart.		ANE	301
Arrabidaea inaequalis (DC.ex Splitg.)K.Schum.		ANE	301
Arrabidaea nigrescens Sandw.	WT	ANE	301
Arrabidaea sp. 1		ANE	301
Arrabidaea sp. 2	WT	ANE	301
Arrabidaea sp. 3		ANE	301
Arrabidaea sp. 4	WT	ANE	301
Arrabidaea sp. 5		ANE	301
Arrabidaea spp.	WT	ANE	301
Arrabidaea trailii Sprague	WT	ANE	301
Artocarpus integrifolia L.	MT		53
Aspidosperma album (Vahl)Benoist ex Pichon	TT	ANE	274
Aspidosperma carapanauba Pichon		ANE	274
Aspidosperma desmanthum Benth.	TT	ANE	274
Aspidosperma discolor A. DC.	TT	ANE	274
Aspidosperma eteanum M.G.F.	TT	ANE	274
Aspidosperma sp. 1		ANE	274
Aspidosperma sp. 2	TT	ANE	274

[1] List includes mainly Central Amazonian species found near Manaus-AM, but also few species of the Eastern Amazon (Zona Bragantina), which were needed for comparisions.

Aspidosperma sp. 3	TT ANE	274
Aspidosperma spp.	TT ANE	274
Asplenium angustum Sw.	UH SYN	0
Astrocaryum acaule Mart.	RT SYN	335
Astrocaryum aculeatum G. Mey.	RT SYN	335
Astrocaryum gynacanthum Mart.	RT SYN	335
Astrocaryum munbaca Mart.	RT SYN	335
Astrocaryum murumuru Mart.	RT SYN	335
Astrocaryum sciophilum (Miq.) Pulle	RT SYN	335
Astrocaryum sp. 1	RT SYN	335
Astrocaryum spp.	RT SYN	335
Astrocaryum tucuma Mart.	RT SYN	335
Astronium sp. 1	TT	256
Attalea attaleoides (Barb.Rodr.) Wessels Boer	RT SYN	335
Bactris constanciae Barb. Rodr.	RT ORN	335
Bactris elegans B.Rodr.&Trail exB.Rodr.	RT ORN	335
Bactris humilis (Wallace) Burret	RT ORN	335
Bactris simplicifrons Mart.	RT ORN	335
Bactris spp.	RT ORN	335
Banara guianensis Aubl.	TT END	107
Banisteriopsis spp.	WT ANE	241
Batesia floribunda Benth.	TT	181
Batocarpus amazonicus (Ducke) Fosb.	TT	53
Bauhinia coronata Benth.	WT AUT	181
Bauhinia guianensis Aubl.	WT AUT	181
Bauhinia sp. 1	WT AUT	181
Bauhinia sp. 2	WT AUT	181
Bauhinia splendens H.B.K.	WT AUT	181
Bauhinia spp.	WT AUT	181
Bauhinia viridiflorens Ducke	LT AUT	181
Bellucia dichotoma Cogn.	LT ORN / PRI	198
Bellucia grossularioides (L.) Triana	LT ORN / PRI	198
Bernardinia fluminensis (Gardner) Planch.	WT	157
Bertholletia excelsa Humb. & Bonpl.	TT	103
Bidens cynapiifolia Kunth	UH	318
Bisboecklera spp.	HYD / ANE	351
Blepharodon nitidus (Vell.) Macbr.	WT	275
Blepharodon spp.	WT	275
Bocageopsis multiflora (Mart.) R.E. Fries	MT ORN	8
Bocoa viridiflora (Ducke) Cowan	TT AUT	181
Bombacopsis macrocalyx (Ducke) A. Robyns	TT ANE	101
Bombax globosum Aubl.	TT	101
Bonamia maripoides H. Hallier	WT	279
Borrerea latifolia (Aubl.)K.Schum	UH HYD	311
Borreria alata (Aubl.) DC.	UH HYD	311
Borreria laevis (Lambert) Griseb.	UH HYD	311
Borreria latifolia (Aubl.) K. Schum.	UH HYD	311
Borreria spp.	UH HYD	311
Borreria verticillata (L.) G. Mey.	SH AUT	311
Bowdichia nitida Spruce ex Benth.	TT	182
Brachiaria brizantha (Hochat) Stapf.	GT ANE / END	352
Brachiaria mollis (Swartz) Parodi	GT ANE / END	352
Brachiaria purpurascens	GT ANE / END	352
Bromelia karatas L.	EP	356
Bromelia plumieri (E. Morren) L.B. Smith	EP	356
Brosimum guianense (Aubl.) Huber	TT ORN / PRI	53
Brosimum lactescens (S. Moore) C.C. Berg	TT ORN / PRI	53
Brosimum parinarioides Ducke	ORN / PRI	53
Brosimum rubescens Taub.	TT ORN / PRI	53
Brosimum sp. 1	TT ORN / PRI	53
Brosimum sp. 2	TT ORN / PRI	53
Brosimum spp.	ORN / PRI	53
Brunfelsia brasiliensis (Spreng.) Smith & Down	SH END	278
Brunfelsia martiana Plowman	ST END	278
Brunfelsia spp.	END	278
Buchenavia congesta Ducke	TT ORN / PRI	199
Buchenavia grandis Ducke	ORN / PRI	199
Buchenavia parvifolia Ducke	TT ORN / PRI	199
Buchenavia sp.1	TT ORN / PRI	199
Buchenavia spp.	TT ORN / PRI	199
Bulbostylis spp.	GT	351
Byrsonima aerugo Sagot	TT ORN	241
Byrsonima chrysophylla Kunth	MT ORN	241
Byrsonima crassifolia (L.) Kunth	LT ORN	241
Byrsonima crispa Adr. Juss.	MT ORN	241
Byrsonima duckeana W.R. Anderson	MT ORN	241
Byrsonima sp. 1	MT ORN	241
Byrsonima sp. 2	LT ORN	241
Byrsonima spicata (Cav.) DC.	LT ORN	241
Byrsonima spp.	MT ORN	241
Byrsonima stipulacea Adr. Juss.	MT ORN	164
Calathea altissima (Poepp. & Endl.) Krn.	BF ORN / MYR	364
Calathea fragilis Gleason	BF ORN / MYR	364
Calathea sellovii Koern.	BF ORN / MYR	364
Calatropis spp.	WT	275
Calliandra purpurea Benth.	LT	180
Calliandra spp.		0
Calophyllum angulare A.C. Smith	TT	97
Calotropis spp.	WT	275
Calycobulus ferrugineus	WT	279
Calycolpus glaber (Benth.) O. Berg	LT	194
Calycolpus goetheanus (Mart. ex DC.) O. Berg	LT	194
Calyptranthes sp. 1	ORN / PRI	194
Calyptrocarya poeppigiana Kunth	GT AUT	351
Cariniana decandra Ducke	TT ANE	103

Carpotroche crispidentata Ducke	MT	107
Caryocar glabrum (Aubl.) Pers.	TT END	84
Caryocar spp.	TT	84
Caryophylla spp.	UH	75
Casearia aculeata Jacq.	LT END	107
Casearia arborea (L.C. Rich.) Urb.	TT END	107
Casearia grandiflora Camb.	TT ORN	107
Casearia javitensis Kunth	MT ORN / MYR	107
Casearia negrensis Eichl.	LT END	107
Casearia pitumba Sleumer	MT END	107
Casearia sp. 1	LT END	107
Casearia sp. 2	LT END	107
Casearia spp.	LT END	107
Casearia sylvestris Swartz	LT ORN / MYR	107
Casearia ulmifolia Vahl ex Ventenat	LT END	107
Casimirella rupestris (Ducke) Howard	CHI / ORN / PRI	224
Cassia apoucouita Aubl.	TT	181
Cassia chrysocarpa Desv.	WT	181
Cassia fruticosa Mill.	SH	181
Cassia hoffmannaegiana Marth.	SH	181
Cassia latifolia G.F.W.Mey	LT	181
Cassia macrophylla Kunth	SH	181
Cassia multijuga L.C.Rich.	MT	181
Cassia quinquangulata Rich.	SH	181
Cassia riparia Kunth	SH	181
Cassia sp. 1		181
Cassia spp.	MT END	181
Cassipourea guianensis Aubl.	SH	200
Catasetum gnomus L. & Rchb. f.	Epi ANE	383
Cecropia concolor Willd.	ST CHI / ORN	53
Cecropia palmata Willd.	ST CHI / ORN	53
Cecropia purpurascens C.C. Berg	ST CHI / ORN	53
Cecropia sciadophylla Mart.	ST CHI / PRI	53
Cecropia spp.	ST CHI / ORN / PRI	53
Cecropia ulei Snethlage	ST CHI / ORN	53
Cenchrus echinatus L.	GS ANE / END	352
Centratherum punctatum Cass.	UH	318
Cephaelis colorata Willd.	UH	311
Ceratophytum sp. 1	WT	301
Cestrum latifolium Lam.	SH	278
Chamaecrista apoucouita (Aubl.) Irwin & Barneby	TT	181
Chamaesyce hirta (L.) Millsp.	UH	232
Chamaesyce thymifolia (L.) Millsp.	UH	232
Cheiloclinium cognatum (Miers) A.C. Smith	WT PRI	220
Cheiloclinium sp. 1	WT PRI	220
Cheiloclinium sp. 2	WT PRI	220
Cheiloclinium sp. 3	WT PRI	220
Cheiloclinium sp. 4	WT PRI	220
Cheiloclinium sp. 5	WT PRI	220
Cheiloclinium sp. 6	WT PRI	220
Cheiloclinium sp. 7	WT PRI	220
Chimarrhis barbata (Ducke) Bum.	LT ANE	311
Chimarrhis spp.	LT ANE	311
Chimarrhis turbinata DC.	TT ANE	311
Chromolaena odorata (L.) R.King & H.Robins.	UH	318
Chrysophyllum argenteum Jacq.	TT END	148
Chrysophyllum auratum Miq.	TT END	148
Chrysophyllum oppositum (Ducke) Ducke	END	148
Chrysophyllum prieurii A. DC.	TT END	148
Chrysophyllum sp. 1	TT END	148
Chrysophyllum sp. 2	TT END	148
Chrysophyllum sp. 3	TT END	148
Chrysophyllum sp. 4	TT END	148
Chrysophyllum sp. 5	TT END	148
Chrysophyllum sp. 6	END	148
Chrysophyllum sp. 7	TT END	148
Chrysophyllum spp.	TT END	148
Cissampelos andromorpha DC.	WT END	35
Cissampelos spp.	WT END	35
Cissus erosa L.C. Rich.	WH	235
Clarisia ilicifolia (Spreng.) Lanj.& Rossb.	SH PRI / ORN	53
Clarisia racemosa Ruiz & Pav.	TT ORN / PRI	53
Clarisia spp.		53
Cleome aculeata L.	UH	133
Cleome spinosa Jacq.	SH	133
Cleome spp.	SH	133
Clidemia allardii Wurd.	SH ORN	198
Clidemia hirta (L.) D. Don	SH ORN	198
Clidemia japurensis DC.	SH ORN	198
Clidemia novemnervia (DC.) Triana	SH ORN	198
Clidemia rubra (Aubl.) Mart.	SH ORN	198
Clidemia spp.	SH ORN	198
Clidemia strigillosa (Swartz) DC.	SH ORN	198
Clusia grandiflora Splitg.	EP ORN / PRI	97
Clusia nemorosa G. Mey.	ORN / PRI	97
Clusia sp. 1	Epi ORN / PRI	97
Coccocypselum hirsutum Bartling ex DC.	UH	311
Coccoloba excelsa Benth.	WT ORN / PRI / HYD	76
Coccoloba racemulosa Meissn.	WT ORN / PRI / HYD	76
Coccoloba spp.	ORN / PRI / HYD	76
Cochlospermum orinoccense Steud.	MT	109
Codonanthe crassifolia (Focke) C. Morton	Epi ORN	298
Codonanthopsis huebneri Mansf.	Epi	298
Combretum rotundifolium L.C. Rich.	WT	199
Commelina benghalensis L.	UH	343

Commelina longicaulis Jacq.	UH	343
Commelina nudiflora L.	UH	343
Commelina spp.	UH	343
Compsoneura ulei Warb.	LT PRI	9
Conceveiba guianensis Aubl.	LT AUT / MYR	232
Concoveiba martiana Baill.	AUT	232
Condylocarpon amazonicum (Markgr.) Ducke	WT HYD	274
Connarus angustifolius (Radlk.) Schel.	MT ORN	157
Connarus erianthus Benth. ex Baker	ORN	157
Connarus perottetii (DC.) Planch.	MT ORN	157
Connarus ruber (Poepp.& Endl.) Planch.	WT ORN	157
Connarus sp. 1	x ORN	157
Connarus sp. 2	ORN	157
Connarus sp. 3	WT ORN	157
Connarus spp.	ORN	157
Conythophora spp.	MT	103
Conyza bonariensis (L.) Cronquist	UH	318
Conyza floribunda Kunth	UH	318
Copaifera martii Hayne	MT	181
Copaifera multijuga Hayne	TT END	181
Cordia exaltata Lam.	TT ORN / PRI	285
Cordia multispicata Cham.	SH ORN	285
Cordia nodosa Lam.	MT ORN / PRI	285
Cordia scabrida Mart.	MT ORN / PRI	285
Cordia scabrifolia A. DC.	ORN / PRI	285
Cordia sellowiana Chamb.	ORN / PRI	285
Cordia spp.	MT ORN / PRI	285
Cordia sprucei Mez	LT ORN / PRI	285
Corythophora rimosa W. Rodrigues	TT SYN	103
Corythophora spp.	MT SYN	103
Corytophora alta R. Knuth	TT SYN / AUT	103
Corytophora sp. 1	TT SYN	103
Costus arabicus L.	BF	361
Couepia bracteosa Benth.	TT ROD / CHI / PRI	177
Couepia canomensis (Mart.)Bth.ex J.D.Hook.	MT ROD / CHI / PRI	177
Couepia excelsa Ducke	MT ROD / CHI / PRI	177
Couepia guianensis Aubl.	TT ROD / CHI / PRI	177
Couepia habrantha Standley	MT ROD / CHI / PRI	177
Couepia longipendula Pilger	TT ROD / CHI / PRI	177
Couepia magnoliifolia Benth. ex Hook. F.	ROD / CHI / PRI	177
Couepia obovata Ducke	TT ROD / CHI / PRI	177
Couepia racemosa Benth. ex Hook. f.	TT ROD / CHI / PRI	177
Couepia sp. 1	ROD / CHI / PRI	177
Couepia spp.	MT ROD / CHI / PRI	177
Couepia ulei Pilger	ROD / CHI / PRI	177
Couma macrocarpa Barb. Rodr.		274
Couratari guianensis Aubl.	TT	103
Couratari oblongifolia Ducke & Knuth	TT	103
Couratari spp.	MT	103
Coussapoa magnifolia Trec.	TT	53
Coussapoa spp.	EP	53
Coussarea ampla	LT END	311
Coutoubea spicata Aubl.	UH	272
Crepidospermum glaziovii Swart	LT END	255
Crepidospermum goudotianum (Tul.) Triana & Planch.	TT END	255
Crepidospermum rhoifolium (Benth.)Triana &Planch.	TT END	255
Crepidospermum sp. 1	TT END	255
Crepidospermum spp.	MT END	255
Croton glandulosus L.	UH AUT	232
Croton lanjouwensis Jablonski	MT AUT	232
Croton lobatus L.	UH AUT	232
Croton matourensis Aubl.	TT AUT	232
Croton miguelensis Ferg.	UH AUT	232
Croton spp.	LT AUT	232
Croton trinitatis Millsp.	UH AUT	232
Ctenitis protensa (Afz.) Ching	UH ANE	0
Cupania diphylla Vahl	SH ORN / PRI	252
Cupania hirsuta Radlk.	SH ORN / PRI	252
Cupania hispida Radlk.	LT ORN / PRI	252
Cupania scrobiculata L.C. Rich.	SH ORN / PRI	252
Cupania spp.	LT ORN / PRI	252
Cuspidaria spp.	WT	301
Cuspidaria subincana A. Gentry	WT	301
Cyanthea spp.	UH	0
Cyanthillium cinereum (L.) H. Robinson	UH	318
Cyathea spp.	UH	0
Cybianthus detergens Martins	UH ORN	154
Cybianthus sp. 2	LT ORN	154
Cyclopeltis semicordata	UH	0
Cydista aequinoctialis (L.) Miers.	WT	301
Cymbopetalum spp.	END	8
Cynanchum spp.	WT	275
Cyperus aggregatus (Willd.) Endl.	GT	351
Cyperus diffusus	GT	351
Cyperus flavus (Vahl.)Nees	GT	351
Cyperus laxus Lam. s.l.	GT	351
Cyperus ligularis L.	GT	351
Cyperus obtusatus (Presl.)Mattf.	GT	351
Cyperus sphacelatus Rottb.	GT	351
Cyperus spp.	GT	351
Dacryodes spp.	END	255
Dalbergia spp.	WT	182
Dalbergia subcymosa Ducke	WT	182
Dalechampia hastata	WT	232
Dalechampia heteromorpha Pax & K. Hoffm.		232
Davilla kunthii A. St. Hil.	WT ORN	78
Davilla latifolia Casar	WT ORN	78
Davilla nitida (Vahl) Kubitzki	WT ORN	78
Davilla rugosa Poir.	WT ORN	78
Davilla spp.	WT ORN	78
Dendropanax arboreus (L.) Decne. & Planch.		268
Derris floribunda (Benth.) Ducke	WT ANE	182
Derris sp. 1	WT ANE	182
Derris spp.	WT ANE	182
Derris spruceanus Benth.	WT ANE	182
Desmodium adscendens (Swartz) DC.	UH	182
Desmodium asperum (Poir.) Desv.	UH	182
Desmodium axillare (Swartz) DC.	WH	182
Desmodium barbatum (L.) Benth. & Oerst.	UH	182
Desmodium canum (Gruel)Schinz&Mill.	UH	182
Desmodium incanum (Swartz) DC.	UH	182
Desmoncus polyacanthos Mart.	SC ORN	335
Desmoncus spp.	SC ORN	335
Dialium guianense (Aubl.) Sandw.	TT PRI	181
Dicella conwayi Rusby	WT ANE	241
Dicella spp.	LT ANE	241
Dichapetalum pedunculatum (DC.) Baill.	WT SYN	228
Dichapetalum rugosum (Vahl) Prance	WT SYN	228
Dichapetalum sp. 1	SYN	228
Dichapetalum spp.	WT SYN	228
Dichromena ciliata Vahl	GT	351
Dicorynia sp. 1	TT END	181
Dicranostyles densa Spr.ex Meissn. in Mart.	WH END	279
Dicranostyles holostyla Ducke	END	279
Dicranostyles laxa Ducke	END	279
Dicypellium manauense W. Rodr.	LT ORN /PRI	17
Didymocistrus chrysasadenius Kuhlm.	LT AUT	232
Digitaria fuscescens (J. Presl) Henr.	GT ANE / END	352
Digitaria horizontalis Willd.	GT ANE / END	352
Dilkea sp. 1	SH END	122
Dilkea sp. 2	SH END	122
Dilkea sp. 3	END	122
Dimorphandra parviflora Spruce ex Benth.	TT AUT	181
Dimorphandra spp.	AUT	181
Dinizia excelsa Ducke	TT	181
Dioclea melanocarpa Ducke	WT	182
Dioclea sclerocarpa Ducke	WT	182
Dioclea virgata (Rich.) Amsh.	WT	182
Diodia multiflora Dl.	MT	311
Diodia ocimifolia (Willd.ex R.&S.)Bremek.	UH	311
Dioscorea dodecaneura Vell.	WT	379
Diospyros praetermissa Sandw.	MT PRI	149
Diospyros sp. 1	MT PRI	149
Diospyros sp. 2	MT PRI	149
Diospyros spp.	PRI	149
Diplasia karataefolia L.C. Rich.	GT HYD	351
Diplotropis purpurea (Rich.) Amsh.	TT AUT	182
Diplotropis sp. 1	TT AUT	182
Diplotropis spp.	TT AUT	182
Dipteryx odorata (Aubl.) Willd.	TT END	182
Dipteryx punctata (Blake) Amsh.	TT END	182
Distictis granulosa Bureau & K. Schum.	WT	301
Distictis spp.	WT	301
Doliocarpus brevipedicellatus Garcke	WT ORN	78
Doliocarpus dentatus (Aubl.) Standl.	WT ORN	78
Doliocarpus major J.F. Gmelin	WT ORN	78
Doliocarpus sp. 1	ORN	78
Doliocarpus sp. 2	ORN	78
Doliocarpus spp.	WT ORN	78
Dracontium asperum K. Koch	BF	338
Drymonia sp. 1	WT	298
Drypetes sp. 1	TT END	232
Duckedendron cestroides Kuhlm.	TT SYN	276
Duckesia verrucosa (Benth.) Cuatrec.	TT CHI	237
Duguetia argentea (R.E. Fr.) R.E. Fr.	TT END	8
Duguetia flagellaria Huber	LT END	8
Duguetia guianensis R.E. Fries	PRI	8
Duguetia lepidota (Miq.) Pulle	MT END	8
Duguetia sp. 1	LT END	8
Duguetia spp.	MT END	8
Duguetia uniflora (Dum.) Mart.	END	8
Duroia macrophylla Huber	LT ORN	311
Duroia saccifera	PRI / ORN	311
Duroia sp. 1	LT PRI / ORN	311
Duroia sp. 2	LT PRI / ORN	311
Duroia sp. 3	LT PRI / ORN	311
Duroia sp. 4	LT PRI / ORN	311
Duroia spp.	LT PRI / ORN	311
Dyrmonia spp.		298
Ecclinusa abbreviata Ducke	TT PRI / ORN	148
Ecclinusa guianensis Eyma	LT PRI	148
Ecclinusa sp. 1	TT PRI	148
Echinochloa spp.	GT ANE / END	352
Elephantopus scaber L.	UH	318
Eleusine sp. 1	GT ANE / END	352
Elizabetha sp. 1	TT AUT	181
Elizabetha spp.	AUT	0
Emilia sonchifolia (L.) DC. ex Wight	UH	318
Emmotum acuminatum (Benth.) Miers	MT END	224
Emmotum fagifolium Desv. ex Hamilton	LT END	224

Emmotum spp.	LT END	224
Endlicheria arunciflora Mez	MT ORN / PRI	17
Endlicheria longicaudata (Ducke) Kosterm.	LT ORN / PRI	17
Endlicheria sp. 1	LT ORN / PRI	17
Endlicheria spp.	ORN / PRI	17
Endopleura spp.	TT END	237
Endopleura uchi (Huber) Cuatr.	TT END	237
Enterolobium schomburgkii (Benth.) Benth.	TT PRI / ORN	180
Eperua bijuga Mart. ex Benth.	TT AUT / SYN	181
Eperua duckeana Cowan.	AUT	181
Ephedranthus amazonicus R.E. Fries	LT ORN	8
Eragrostis ciliaris (L.) R. Brown	GT ANE / END	352
Erechtites hieracifolia (L.) Raf. ex DC.	UH	318
Erigeron bonariensis L.	UH	318
Eriotheca globosa (Aubl.) A. Robyns	TT	101
Erisma spp.	ANE	242
Eryngium foetidum L.	UH	269
Erythroxylum leptoneurum O.E. Schulz	SH ORN	236
Erythroxylum macrophyllum Cav.	LT ORN	236
Erythroxylum mucronatum Benth.	LT ORN	236
Erythroxylum spp.	LT ORN	236
Erythroxylum tucuriense Plowman	SH ORN	236
Eschweilera bracteosa (Poepp. ex Berg) Miers	TT SYN	103
Eschweilera decolorans Sandw.	TT SYN	103
Eschweilera micrantha (Berg) Miers	TT SYN	103
Eschweilera odora (Poepp.) Miers	TT SYN	103
Eschweilera ovata (Cambess.) Miers.	TT SYN	103
Eschweilera pisonis Cambress.	x SYN	103
Eschweilera rodriguesiana Mori	MT SYN	103
Eschweilera spp.	TT SYN	103
Eugenia albicans (O. Berg) Urb.	MT PRI / ORN	194
Eugenia biflora (L.) DC.	LT PRI / ORN	194
Eugenia egensis DC.	MT ORN / PRI	194
Eugenia ferreireana O. Berg	MT PRI / ORN	194
Eugenia flavescens DC.	LT PRI / ORN	194
Eugenia lambertiana DC.	LT PRI / ORN	194
Eugenia patrisii Vahl	MT PRI / CHI / ORN	194
Eugenia protracta O. Berg	PRI / ORN	194
Eugenia sp. 1	MT PRI / ORN	194
Eugenia sp. 2	MT PRI / ORN	194
Eugenia spp.	LT PRI / ORN	194
Eugenia subterminalis DC.	PRI / ORN	194
Eugenia tapacumensis O. Berg	LT PRI / ORN	194
Eugenia uniflora L.	MT ORN	194
Eulophia alta (L.) Fawc. & Rendle	UH	383
Eupatorium conyzoides Mill.	UH	318
Eupatorium odoratum L.	UH	318
Euphorbia hirta L.	UH	232
Euphorbia pilulifera L.	UH	232
Euphorbia thymifolia (G.Don.)Exell.	UH	232
Euterpe oleracea Mart.	RT ORN	335
Euterpe precatoria Mart.	RT PRI / ORN	335
Exellodendron coriaceum (Benth.) Prance	LT	177
Faramea capillipes Muell. Arg.	LT END	311
Faramea multiflora A. Rich.	LT END	311
Faramea sessiliflora Aubl.	END	311
Faramea sp. 1	END	311
Faramea spp.	LT END	311
Fatylosanthes guianensis Sw.		0
Fernandusa goudotiana K. Schum.	MT	311
Ficus americana Aubl.	EP END	53
Ficus americanus ssp. guianensis (Harms)Berg	EP END	53
Ficus krukovii Standl.	LT END	53
Ficus mathewsii (Miq.) Miq.	MT END	53
Ficus maxima Mill.	TT END	53
Ficus nymphaeifolia Mill.	Epi END	53
Ficus paraensis (Miq.) Miq.	Epi END	53
Ficus sp.1	END	53
Ficus spp.	MT END	53
Ficus trigona L.	PRI	53
Fimbristylis annua (Allioni) Roem.&Schult.	GT	351
Fischeria martiana Decne.	WH	275
Fusaea longifolia (Aubl.) Safford	PRI	0
Geissospermum argenteum Woodson	TT	274
Geissospermum laevis (Vell.) Miers	MT PRI / ORN	274
Geissospermum sericeum (Sagot) Benth.&J.D.Hook	TT PRI	274
Genipa americana L.	MT	311
Geonoma aspidiifolia Spruce	RT END	335
Geonoma baculifera (Poit.) Kunth	RT END	335
Geonoma deversa (Poit.) Kunth	RT END	335
Geonoma sp. 1	END	335
Geonoma spp.	RT END	335
Glycydendron amazonicum Ducke	TT PRI / CHI / ORN	232
Gnetum nodiflorum Brongn.		0
Gnetum schwackeanum Taub.	WT	0
Gnetum sp. 1	WT	0
Gnetum sp.2		0
Gomoma spp.	RT	335
Gomphrena spp.	UH	71
Gossypium hirsutum L.	SH	102
Gouania cornifolia Reiss	WT	233
Goupia glabra Aubl.	TT ORN / PRI	219
Guapira spp.	ORN / PRI	66
Guarea duckei C. DC.	MT END	260
Guarea humaitensis Penn.	MT END	260
Guarea kunthiana Adr. Juss.	MT PRI	260
Guarea macrophylla Vahl	MT PRI / ORN	260
Guarea pubescens (L.C. Rich.) Adr. Juss.	LT END	260
Guarea silvatica C. DC.	LT END	260
Guarea sp. 1	MT END	260
Guarea spp.	END	148
Guarea subsessifolia C. DC.	TT END	260
Guatteria dielsiana R.E. Fries	LT ORN	8
Guatteria discolor R.E. Fries	TT ORN	8
Guatteria guianensis (Aubl.) R.E. Fries	MT ORN	8
Guatteria olivacea R.E. Fries	MT ORN	8
Guatteria paraensis L.E. Fries	TT ORN	8
Guatteria poeppigiana Mart.	TT ORN	8
Guatteria procera R.E. Fries	TT ORN	8
Guatteria schomburgkiana Mart.	TT ORN	8
Guatteria scytophylla Diels	MT ORN	8
Guatteria sp. 1	MT ORN	8
Guatteria sp. 2	MT ORN	8
Guatteria spp.	LT ORN	8
Gurania bignoniacea (Poepp.&Endl.)C.Jeffrey	END	127
Gurania cissoides (Benth.)Cogn.	END	127
Gurania huberi Cogn.	WT END	127
Gurania huebneri Harms	WT END	127
Gurania robusta Suessang.	END	127
Gurania spp.	END	127
Gurania tricuspidata Cogn.	WT END	127
Gustavia augusta L.	MT	103
Gustavia elliptica Mori	TT SYN / END	103
Gustavia sp.1		103
Guterpia spp.		335
Guzmania lingulata (L.) Mez	Epi AUT	356
Gypsophylla spp.	UH	75
Haplolophium rodriguesii A. Gentry	WT	301
Haplolophium spp.	WT	301
Hebepetalum humiriifolium (Planch.) Benth.	MT	240
Heisteria densifrons Engl.	SH ORN / PRI	207
Heisteria insculpta Sleumer	MT ORN / PRI	207
Heisteria sessilis Ducke	UH ORN / PRI	207
Heisteria sp. 1	ORN / PRI	207
Helianthostylis sprucei Baill.		53
Heliconia acuminata L.C. Rich.	BF ORN	358
Heliconia psittacorum L.f.	BF END	358
Heliconia sp. 1	END	358
Helicostylis podogyne Ducke	TT PRI	53
Helicostylis scabra (MacBr.) C.C. Berg	TT PRI	53
Helicostylis sp. 1	PRI	53
Helicostylis spp.	TT PRI	53
Helicostylis tomentosa (Poepp. & Endl.) Rusby	TT PRI	53
Henriettella caudata Gleason	SH ORN	198
Henriettella ovata Cogn.	SH ORN	198
Heteropsis integrifolia Schott	WHORN / PRI	338
Heteropsis longispathaceae Engl.	WHORN / PRI	338
Heteropsis spruceana Schott	WHORN / PRI	338
Heteropterys sp. 1	WT ORN / PRI	241
Heteropterys spp.	TT ORN / PRI	241
Hevea brasiliensis (Adr.Juss.) Muell. Arg.	TT AUT / SYN	232
Hevea guianensis Aubl.	TT AUT / SYN	232
Himatanthus spp.	TT ANE	274
Himatanthus sucuuba (Spr.ex M.Arg.)Woodson	MT ANE	274
Hippocratea sp. 1	WT ANE	220
Hippocratea sp. 2	WT ANE	220
Hirtella bicornis Mart. & Zucc.	END	177
Hirtella burchellii Britton	LT END	177
Hirtella duckei Huber	LT END	177
Hirtella gracilipes (Hook F.) Prance	SH END	177
Hirtella hispidula Miq.	END	177
Hirtella myrmecophila Pilger	LT END	177
Hirtella paraensis Prance	SH END	177
Hirtella racemosa Lam.	LT ORN	177
Hirtella spp.	LT END	177
Holopyxidium jarana (Hub.) Ducke	TT	103
Homolepis aturensis (Kunth) Chase	GS ANE / END	352
Humiranthera spp.		224
Humiria balsamifera (Aubl.) St. Hil.	TT	237
Humirianthera rupestris Ducke	WT	224
Humirianthera spp.	MT	224
Humiriastrum cuspidatum (Benth.) Cuatrec.	TT END	237
Hybanthus calceolaria (L.) G.K. Schulze	UH	115
Hybanthus ipecacuanha Baill.	UH	115
Hymenachne spp.	GT ANE / END	352
Hymenaea parviflora Hub.	TT	181
Hymenolobium sp.	ANE	181
Hymenophyllum sp. 1		0
Hypolytrum laxum Kunth	GT AUT	351
Hyptis atrorubens Poit.	UH	287
Hyptis spicata Pohl.	UH	287
Hyptis spp.	UH	287
Ichthyothere terminalis (Spreng.) Blake	UH	318
Imperata brasiliensis Trin.	GR ANE / END	352
Inga alba (Swartz) Willd.	TT PRI / ORN	180
Inga bourgoni (Aubl.) DC.	MT PRI	180
Inga bracteosa Benth.	MT PRI / ORN	180
Inga brevialata Ducke	TT PRI / ORN	180
Inga cayennensis Sagot ex Benth.	MT PRI	180
Inga disticha Benth.	PRI / ORN	180

Inga edulis (Vell.) Mart.	TT PRI / ORN	180
Inga falcistipula Ducke	MT PRI / ORN	180
Inga flagelliformis (Vell.) Mart.	MT PRI / ORN	180
Inga gracilifolia Ducke	TT PRI / ORN	180
Inga heterophylla Willd.	TT PRI / ORN	180
Inga leiocalycina Benth.	TT PRI / ORN	180
Inga longiflora Spruce ex Benth.	MT PRI / ORN	180
Inga macrophylla Kunth	MT PRI / ORN	180
Inga nitida Willd.	MT PRI / ORN	180
Inga pilulosa (L.C. Rich.) MacBride	MT PRI / ORN	180
Inga rubiginosa (L.C. Rich.) DC.	TT PRI / ORN	180
Inga sp. 1	MT PRI / ORN	180
Inga sp. 2	MT PRI / ORN	180
Inga sp. 3	MT PRI / ORN	180
Inga spp.	MT PRI / ORN	180
Inga stipularis DC.	MT PRI / ORN	180
Inga thibaudiana DC.	TT PRI / ORN	180
Inga vera Willd.	PRI / ORN	180
Ipomoea asarifolia (Desr.) Roem. & Schult.	WH	279
Ipomoea bahiensis Willd. ex Roen.	WH	279
Ipomoea batatas (L.) Poir.	WH	279
Ipomoea goyazensis Gardn.	WH	279
Ipomoea spp.	WH	279
Ipomoea squamosa Choisy	WH	279
Iriartella setigera (Mart.) H. Wendl.	RT END	335
Irlbachia alata (Aubl.) Maas	UH ANE	272
Iryanthera coriacea Ducke	LT END	9
Iryanthera elliptica Ducke	TT ORN / PRI	9
Iryanthera juruensis Warb.	TT ORN / PRI	9
Iryanthera laevis Markgr.	MT END	9
Iryanthera sp. 1	MT END	9
Iryanthera ulei Warb.	MT PRI	9
Ischnosiphon arouma (Aubl.) Krn.	BF ORN / MYR	364
Ischnosiphon gracilis (Rudge) Krn.	BF ORN / MYR	364
Ischnosiphon martianum Eichl. ex Petersen	BF ORN / MYR	364
Ischnosiphon ovatus Krn.	BF ORN / MYR	364
Ischnosiphon puberulus Loes.	BF ORN / MYR	364
Ischnosiphon spp.	BF ORN / MYR	364
Isertia hypoleuca Benth.	LT	311
Ixora francavillana Muell. Arg.	SH ORN / CHI	311
Ixora ulei Krause	SH	311
Jacaranda copaia (Aubl.) D. Don	TT ANE	301
Jessenia bataua (Mart.) Burret	RT END	335
Kyllinga pungens Link	GT	351
Lacistema aggregatum (Bergius) Rusby	MT	112
Lacistema grandifolium Schnizlein	ORN	112
Lacistema pubescens Mart.	MT ORN	112
Lacistema sp. 1		112
Lacistema sp. 2		112
Lacistema spp.	LT	112
Lacmellea gracilis (Muell. Arg.) Monach.		274
Lacmellea spp.		0
Lacunaria jenmani (Oliver) Ducke	LT PRI	93
Lacunaria sp. 1		93
Lacunaria spp.	LT	93
Laetia procera (Poepp.) Eichl.	MT	107
Laetia spp.	LT	107
Laetia suaveolens (Poepp.) Benth.	TT	107
Lagenocarpus verticillatus (Spreng.)T.Koy.&Maguire	GT HYD	351
Lantana camara L.	SH ORN	286
Lasiacis ligulata Hitchc. & Chase	GT ANE / END	352
Leandra micropetala (Naud.) Cogn.	SH END	198
Leandra secunda (Don) Cogn.	SH END	198
Leandra spp.	SH END	198
Lecythis lurida (Miers.) Mori	TT SYN	103
Lecythis paraensis	TT SYN	103
Lecythis pisonis Cambess.	TT SYN	103
Lecythis retusa Spruce & Berg	TT SYN	103
Lecythis sp. 1	SYN	103
Lecythis spp.	TT SYN	103
Leonia cymosa Mart.	SH	115
Leonia glycycarpa Ruiz & Pav.	PRI	115
Lepidaploa remotiflora (L.C. Rich.) H.Robinson	UH	318
Leptochloa virgata (L.) P. Beauv.	GT ANE / END	352
Leucocalanthe aromatica Barb.Rodr.	WT ANE	301
Licania bracteata Prance	SYN	177
Licania canescens Benoist	SYN	177
Licania discolor Pilger	SYN	177
Licania elliptica Standl.	TT SYN	177
Licania gracilipes Taub.	TT SYN	177
Licania hypoleuca Benth.	SYN	177
Licania kunthiana J.D. Hook.	TT SYN	177
Licania laevigata Prance	TT SYN	177
Licania lata MacBr.	TT SYN	177
Licania laxiflora Fritsch	TT SYN	177
Licania macrophylla Benth.	SYN	177
Licania majuscula Sagot	TT SYN	177
Licania micrantha Miq.	TT SYN	177
Licania octandra (Hoff.exRoem.&Schul)Ktz	SYN	177
Licania sp. 1	TT SYN	177
Licania sp. 2	TT SYN	177
Licania sp. 3	TT SYN	177
Licania sp. 5	TT SYN	177
Licania sp. 6	TT SYN	177
Licania sp. 7	TT SYN	177

Licania sp. 8	TT SYN	177
Licania spp.	TT SYN	177
Licania sprucei (J.D. Hook.) Fritsch	SYN	177
Licania unguiculata Prance	TT SYN	177
Licaria aritu Ducke	TT ORN	17
Licaria cannella (Meissn.) Kosterm.	TT ORN / PRI	17
Licaria chrysophylla (Meissn.) Kosterm.	TT ORN / PRI	17
Licaria guianensis Aubl.	TT ORN / PRI	17
Licaria rodriguesii Kurz	MT ORN / PRI	17
Licaria sp. 1	ORN / PRI	17
Licaria sp. 2	ORN / PRI	17
Licaria spp.	ORN / PRI	17
Lindernia diffusa Wettst.	UH	294
Lindernia spp.	UH	0
Lomariopsis japurensis (Mart.) J. Sm.	WH	0
Loreya spruceana Benth. ex Triana	SH END	198
Ludwigia hyrsopiflia (G. Don.) Exell.	UH	196
Luehea rosea (Ducke) Burret	x	99
Lygodium venustum Swartz	WH	0
Mabea angustifolium Benth.	LT AUT	232
Mabea speciosa Muell. Arg.	MT AUT	232
Mabea spp.	AUT	232
Machaerium amplum Benth.	WT ANE / HYD	182
Machaerium brasiliense Vog.	WT ANE / HYD	182
Machaerium castaneiflorum Ducke	WT ANE / HYD	182
Machaerium ferox (Mart. ex Benth.) Ducke	WT ANE / HYD	182
Machaerium floribundum Benth.	ANE / HYD	182
Machaerium froesii Rudd.	WT ANE / HYD	182
Machaerium hoehnearum Ducke	WT ANE / HYD	182
Machaerium madeirense Pittier	WT ANE / HYD	182
Machaerium microphyllum (E. Mey.) Standl.	WT ANE / HYD	182
Machaerium multifoliolatum Ducke	WT ANE / HYD	182
Machaerium quinata (Aubl.) Sandw.	WT ANE / HYD	182
Machaerium salzmannii Benth.	WT ANE / HYD	182
Machaerium sp. 1	WT ANE / HYD	182
Machaerium sp. 2	WT ANE / HYD	182
Machaerium sp. 3	WT ANE / HYD	182
Machaerium sp. 4	WT ANE / HYD	182
Machaerium sp. 5	WT ANE / HYD	182
Machaerium sp. 6	WT ANE / HYD	182
Machaerium sp. 7	WT ANE / HYD	182
Machaerium spp.	WT ANE / HYD	182
Macrolobium bimbatum	ANE	181
Maieta guianensis Aubl.	ORN	198
Maieta spp.	ORN	198
Malmea manausensis Maas & Miralha	LT	8
Malouetia duckei Markgr.	LT	274
Mandevilla hirsuta (A. Rich.) K. Schum.	WH	274
Manilkara amazonica (Hub.) Chev.	TT PRI	148
Manilkara bidentata (A. DC.) Chevalier	PRI	148
Manilkara sp.	PRI	148
Mansoa alliacea (Lam.) A. Gentry	WT	301
Mansoa difficilis (Cham.)Bur.&K./D.C.	WT	301
Mapania sylvatica Aubl.	HYD	351
Maprounea guianensis Aubl.	TT PRI / ORN	232
Maquira calophylla (Poepp.& Endl.)C.C.Berg	MT PRI / ORN	53
Maquira guianensis Aubl.	TT PRI / ORN	53
Maquira sclerophylla (Ducke) C.C. Berg	PRI / ORN	53
Maquira scleroxylon ()Berg	PRI / ORN	53
Maquira spp.	LT PRI / ORN	53
Margaritaria nobilis L.f.	UH	232
Maripa reticulata Ducke	WT PRI	279
Maripa sp. 1	WHPRI	279
Maripa sp. 2	PRI	279
Maripa sp. 3	PRI	279
Maripa spp.	PRI	279
Markea coccinea L.C. Rich.	Epi ORN / CHI	278
Marlierea sp. 1	MT	194
Marsypianthes chamaedrys (Vahl) Kuntze	UH	287
Mascagnia sepium (Adr. Juss.) Griseb.	WT	241
Mascagnia sp. 2	WT	241
Mascagnia sp. 3	WT	241
Mascagnia spp.	WT	241
Matayba opaca Radlk.	SH END	252
Matayba sp. 1	END	252
Matayba spp.	LT END	252
Maxillaria brunnea Linden & Rchb. f.	Epi	383
Maximiliana maripa (Corrêa) Drude	RT	335
Melampodium camphoratum Benth.&Hook	UH	318
Melothria pendula L.	WHORN	127
Memora adenophora Sandw.	WT ANE	301
Memora allamandiflora Bur. & K. Schum.	WT ANE	301
Memora cladotricha Sandw.	WT ANE	301
Memora consanguinea Bur. & K. Schum.	WT ANE	301
Memora croatii A. Gentry	WT ANE	301
Memora flavida (DC.) Bureau & K.Schum.	WT ANE	301
Memora flaviflora (Miq.) Pulle	WT ANE	301
Memora jasminifolia	WT ANE	301
Memora longilinea A. Samp	WT ANE	301
Memora magnifica (Mart. ex DC.) Bur.	WT ANE	301
Memora moringifolia (DC.) Sandw.	WT ANE	301
Memora pedunculata (Vell.)Miers.	WT ANE	301
Memora racemosa A. Gentry	WT ANE	301
Memora schomburgkii (DC.) Miers	WT ANE	301
Memora sp. 1	WT ANE	301

Memora sp. 2	WT ANE	301
Memora spp.	WT ANE	301
Mendoncia hoffmannseggiana Nees	WT ORN / PRI	302
Mendoncia spp.	WT ORN / PRI	302
Mendoncia sprucei Lindau	WT ORN / PRI	302
Meniscium sp. 1	UH	0
Merremia macrocalyx (Ruiz & Pav.) O'Donell	WH	279
Metrodorea flavida Krause	MT	261
Mezilaurus itauba (Meissn.) Taub. ex Mez	ORN	17
Miconia alata (Aubl.) DC.	ST ORN	198
Miconia argyrophylla DC.	ST ORN	198
Miconia astrophocama Donn. Smith	ST ORN	198
Miconia biglandulosa Gleason	ST ORN	198
Miconia ciliata (Rich.) DC.	ST ORN	198
Miconia crassinervia Cogn.	ST ORN	198
Miconia dispar Benth.	ST ORN	198
Miconia egensis Cogn.	ST ORN	198
Miconia elaegnoides Cogn.	ST ORN	198
Miconia eriodonta DC.	ST ORN	198
Miconia fallax DC.	ST ORN	198
Miconia gratissima Benth. ex Triana	ST ORN	198
Miconia hypoleuca (Benth.) Triana	MT ORN	198
Miconia lepidota DC.	LT ORN	198
Miconia longispicata Triana	ST ORN	198
Miconia minutiflora (Bonpl.) DC.	TT ORN	198
Miconia phanerostila Pilger	ST ORN	198
Miconia punctata (Desc.) D. Don	ST ORN	198
Miconia pyrifolia Naud.	LT ORN	198
Miconia regelii Cogn.	MT ORN	198
Miconia sp. 1	LT ORN	198
Miconia sp. 2	ORN	198
Miconia sp. 3	ORN	198
Miconia splendens (Swartz) Griseb.	ST ORN	198
Miconia spp.	ST ORN	198
Miconia tomentosa (Rich.) D. Don ex DC.	ST ORN	198
Micropholis egensis (A. DC.) Pierre	TT PRI / ORN	148
Micropholis guyanensis (A. DC.) Pierre	TT PRI / ORN	148
Micropholis spp.	PRI / ORN	148
Micropholis trunciflora Ducke	MT PRI / ORN	148
Micropholis williamii Aubr. et Pell.	MT PRI / ORN	148
Mikania congesta DC.	UH ANE	318
Mikania cordifolia (L.f.) Willd.	WHANE	318
Mikania micrantha Kunth	WHANE	318
Mikania psilostachya DC.	WHANE	318
Mikania spp.	WT ANE	318
Mimosa debilis Humb.& Bonpl. ex Willd.	SH ANE	180
Mimosa duckei Huber	SC ANE	180
Mimosa leptocarpa DC.	SH ANE	180
Mimosa pigra L.	WT ANE	180
Mimosa pudica L.	SH ANE	180
Mimosa quadrivalvis var. leptocarpa (DC.) Barneby	SH ANE	180
Mimosa sensitiva L.	SH ANE	180
Mimosa spp.	SH ANE	180
Mimosa spruceana Benth.	SH ANE	180
Mimosa velloziana Benth.	SH ANE	180
Minquartia guianensis Aubl.	TT PRI / ORN	207
Mollinedia sp. 1	LT ORN / CHI / PRI	13
Monnieria trifolia Loefling	UH	261
Monotagma plurispicatum (Krn.) K. Schum.	WH	364
Mouriri duckeana Morley	TT ORN / PRI	198
Mouriri huberi Cogn.	TT ORN / PRI	198
Mouriri lunanthera Morley	TT ORN / PRI	198
Mouriri sp. 1	TT ORN / PRI	198
Mouriri spp.	ORN / PRI	198
Mouriri trunciflora Ducke	ORN / PRI	198
Moutabea guianensis Aubl.	WT PRI	245
Mucuna spp.	WT	182
Mussatia prieurei (DC.)Bureau ex K.Schum.	WT ANE	301
Mussatia sp. 1	WT ANE	301
Myrcia amazonica DC.	LT ORN	194
Myrcia atramontifera Barb.Rodr.	LT ORN	194
Myrcia bracteata (L.C. Rich.) DC.	LT ORN / PRI	194
Myrcia citrifolia (Aubl.) Urb.	LT ORN	194
Myrcia cuprea (O. Berg) Kiaerskou	LT ORN	194
Myrcia deflexa (Poir.) DC.	LT ORN	194
Myrcia fallax (L.C. Rich.) DC.	LT ORN	194
Myrcia fenestrata DC.	LT ORN	194
Myrcia magna Legrand.	LT ORN	194
Myrcia multiflora (Lam.) DC.	LT ORN	194
Myrcia pyrifolia (Desv.ex Hamilt.) Nied.	LT ORN	194
Myrcia sp. 1	LT ORN	194
Myrcia spp.	LT ORN	194
Myrcia sylvatica (G. Mey.) DC.	LT ORN	194
Myrciaria floribunda (West ex Willd.) O.Berg	LT	194
Myrciaria tenella (DC.) O. Berg	MT	194
Myriaspora egensis DC.	ST	198
Myrsine guianensis (Aubl.) Kuntze	LT	154
Myrtiluma eugeniifolia (Pierre) Baill.	TT	148
Naucleopsis caloneura (Hub.) Ducke	LT PRI / ORN	53
Naucleopsis sp. 1	LT	53
Naucleopsis sp. 2	LT	53
Nectandra cuspidata Nees & Mart.	TT	17
Nectandra pichurim (Kunth) Mez	TT	17
Nectandra spp.	TT	17
Neea glameruliflora Heimerl	SH ORN / PRI	66
Neea oppositifolia Ruiz&Pav.	SH ORN / PRI	66
Neea ovalifolia Spruce	ORN / PRI	66
Neea sp. 1	LT ORN / PRI	66
Neea sp. 2	LT ORN / PRI	66
Neea spp.	MT ORN / PRI	66
Neojobertia cuprea (Huber)J.M.Pieres&W.Rod	ANE	311
Neoptychocarpus apodanthus (Kuhlmann) Buchheim	LT	107
Nephrolepis spp.	UH	0
Nepsera aquatica (Aubl.) Naud.	UH	198
Ocotea adenotra	ORN / PRI	17
Ocotea adenotrachelium (Nees) Mez	LT ORN / PRI	17
Ocotea amazonica (Meissn.) Mez	TT ORN / PRI	17
Ocotea cujumari Mart.	ORN / PRI	17
Ocotea fasciculata (Nees) Mez	TT ORN / PRI	17
Ocotea glomerata (Nees) Mez	TT ORN / PRI	17
Ocotea guianensis Aubl.	TT ORN / PRI	17
Ocotea longifolia Kunth	TT ORN / PRI	17
Ocotea neesiana (Miq.) Kosterm.	MT ORN / PRI	17
Ocotea opifera Mart.	TT ORN / PRI	17
Ocotea sp. 1	ORN / PRI	17
Ocotea sp. 2	ORN / PRI	17
Ocotea sp. 3	ORN / PRI	17
Ocotea spp.	TT ORN / PRI	17
Ocotea tabacifolia (Meissn.) Rohwer	MT ORN / PRI	17
Odontadenia cognata (Stadelm.) Woodson	WT ANE / HYD	274
Odontadenia funigera Woodson	WT ANE / HYD	274
Odontadenia paraensis (Eichl.)Diel.	ANE / HYD	0
Odontadenia perrottetii (A. DC.) Woodson	WT ANE / HYD	274
Odontadenia puncticulosa (A. Rich.) Pulle	WT ANE / HYD	274
Odontadenia sp. 2	WT ANE / HYD	274
Odontadenia spp.	WT ANE / HYD	274
Odontocarya spp.	WT	35
Oedomatopus obovatus Spr. ex Pl. & Tr.	Epi	97
Oenocarpus bacaba Mart.	RT ORN / PRI	335
Oenocarpus minor Mart.	RT ORN	335
Oenocarpus spp.	RT ORN	335
Ormosia coutinhoi Ducke	TT ORN	182
Ormosia paraensis Ducke	ORN	182
Ormosia sp. 1	TT ORN	182
Ormosia sp. 2	TT ORN	182
Ormosia spp.	TT ORN	182
Orthopappus angustifolium (Swartz) Gleason	UH	318
Oryza latifolia Desv.	GT ANE / END	352
Osteophloeum platyspermum (Spruce ex A.DC.) Warb.	TT	9
Ouratea discophora Ducke	ST ORN	80
Ouratea ferruginea Engl.	LT ORN	80
Ouratea paraensis Huber	SH ORN	80
Ouratea polygyna Engl.	SH ORN	80
Ouratea racemiformis Ulei	SH ORN	80
Ouratea schomburgkii (Planch.) Engl.	SH ORN	80
Ouratea sp. 1	LT ORN	80
Pachira spp.	SYN	101
Pachyptera alliacea (Lam.)A.Gentry	WT HYD / ANE	301
Pachyptera kerere (Aubl.) A. Gentry	WT HYD	301
Palicourea anisolosa Muell. Arg.	MT ORN / CHI	311
Palicourea calophylla DC.	LT ORN	311
Palicourea comitis (Muell. Arg.) Brem.	ST ORN / CHI	311
Palicourea condensata Standl.	ORN / CHI	311
Palicourea corymbifera (Muell. Arg.) Standl.	LT ORN	311
Palicourea grandifolia (Willd. ex R.&S.)Standl	MT ORN	311
Palicourea guianensis Aubl.	LT ORN	311
Palicourea markgrafia	ORN / CHI	311
Palicourea sp. 1	ORN / CHI	311
Palicourea spp.	LT ORN / CHI	311
Panicum cayennense Lam.	GT ANE / END	352
Panicum laxum Swartz	GS ANE / END	352
Panicum ligulata Hitchc.&Chase	GS ANE / END	352
Panicum pilosum Swartz	GT ANE / END	352
Panicum rudgei Roem. & Schult.	GT ANE / END	352
Panicum spp.	GT ANE / END	352
Paragonia pyramidata (L.C. Rich.) Bureau	ANE	301
Paragonia spp.	WT ANE	301
Pariana campestris Aubl.	GT ANE / END	352
Pariana sp. 1	GT ANE / END	352
Pariana spp.	GT ANE / END	352
Parkia cachimbaensis H.C.Hopkins		180
Parkia decussata Ducke	TT	180
Parkia multifuga		180
Paspalum conjugatum Berg.	GS ANE / END	352
Paspalum decumbens Swartz	GT ANE / END	352
Paspalum malocophyllum Treim.	GT ANE / END	352
Paspalum maritimum Trin.	GR ANE / END	352
Paspalum melanospermum Desv. ex Poir.	GT ANE / END	352
Paspalum paniculatum L.	GT ANE / END	352
Paspalum platyaxi Mes.	GT ANE / END	352
Paspalum spp.	GT ANE / END	352
Paspalum virgatum L.	GT ANE / END	352
Passiflora acuminata DC.	WT ORN / PRI	122
Passiflora alata Sims.	WT ORN / PRI	122
Passiflora araujoi Sacco	WT ORN / PRI	122
Passiflora auriculata Kunth	WT ORN / PRI	122
Passiflora coccinea Aubl.	WT PRI / CHI / ORN	122
Passiflora foetida L.	WHORN / PRI	122
Passiflora longiracemosa Ducke	WT ORN / PRI	122
Passiflora misera Kunth	WHORN / PRI	122

Passiflora nitida Kunth	WT PRI	122
Passiflora picturata Ker-Gawler	WHORN / PRI	122
Passiflora spp.	WT ORN / PRI	122
Paullinia pinnata L.	WT ORN / PRI	252
Paullinia rugosa Benth. ex Radlk.	WT ORN / PRI	252
Paullinia sp. 1	WT ORN / PRI	252
Paullinia sp. 2	WT ORN / PRI	252
Paullinia sp. 3	ORN / PRI	252
Paullinia sp. 4	WT ORN / PRI	252
Paullinia sp. 5	WT ORN / PRI	252
Paullinia spp.	WT ORN / PRI	252
Pausandra macropetala Ducke	AUT	232
Pavonia cancellata Cav.	WH	102
Pavonia malacophylla Britton	SH	102
Paypayrola grandiflora Tul.	MT ORN	115
Peltogyne paniculata Benth.	TT	181
Peltogyne spp.	TT	181
Peperomia macrostachya (Vahl) A. Dietr.	UH	21
Peperomia pellucida (L.) Kunth	UH	21
Pera spp.	ORN	232
Pereba mollis (P.&E.)Huber		53
Perebea mennegae		53
Perebea mollis (Poepp. & Endl.) Huber	TT	53
Perebea sp. 1	MT	53
Periarrabidaea truncata A.Samp.	WT	301
Petrea brevicalyx Ducke	WT	286
Petrea insignis Schau.	WT ORN	286
Petrea volubilis L.	WH	286
Phenakospermum guyannense (L.C.Rich.)Endl.ex Miq.	BF ORN / PRI	357
Philodendron distantilobium Krause	Epi ORN / PRI	338
Philodendron fragrantissimum (Hook.) Kunth	Epi ORN / PRI	338
Philodendron hylaeae Bunting	Epi ORN / PRI	338
Philodendron inba Scholl.	ORN / PRI	338
Philodendron linneai Kunth	Epi ORN / PRI	338
Philodendron megalophyllum Schott	Epi ORN / PRI	338
Philodendron melinonii Brongn. ex Regel	Epi ORN / PRI	338
Philodendron sp. 1	Epi ORN / PRI	338
Philodendron sp. 2	Epi ORN / PRI	338
Philodendron sp. 3	Epi ORN / PRI	338
Philodendron sp. 4	Epi ORN / PRI	338
Philodendron sp. 5	Epi ORN / PRI	338
Philodendron spp.	Epi ORN / PRI	338
Philoxerus spp.	UH	71
Phoradendron crassifolium (Pohl.)Eichl.	EP	211
Phoradendron spp.	LT	211
Phthirusa paniculata (H.B.K.)McBrad.	EP	211
Phthirusa pyrifolia (Kunth) Eichl.	EP	211
Phyllanthus niruri L.	UH	232
Phyllanthus nobilis (L.F.)M.Arg.	UH	232
Phyllanthus orbiculatus L.C. Rich.	UH	232
Phyllanthus spp.	UH	232
Phyllanthus urinaria L.	UH	232
Physalis angulata L.	UH	278
Phytolacca decandra L.	UH	64
Picramnia elliptica Kuhlm.ex Pitani & Thom.	LT	258
Picramnia sellowii Planch.		258
Picramnia sp. 1		258
Piper aduncum L.	SH CHI / ORN	21
Piper bartlingianum (Miq.) C. DC.	SH CHI / ORN	21
Piper carniconnectivum C. DC.	SH CHI / ORN	21
Piper dactylostigmum Yunck.	SH CHI / ORN	21
Piper dilatatum L.C. Rich.	SH CHI / ORN	21
Piper hispidum Swartz	SH CHI / ORN	21
Piper manausense Yuncker	SH CHI / ORN	21
Piper marginatum Jacq.	SH CHI / ORN	21
Piper nigrum L.	WT CHI / ORN	21
Piper plyreanum C. DC.	SH CHI / ORN	21
Piper sp. 1	CHI / ORN	21
Piper sp. 2	CHI / ORN	21
Piper sp. 3	CHI / ORN	21
Piper sp. 4	CHI / ORN	21
Piper spp.	SH CHI / ORN	21
Piptadenia globulifera	ANE	180
Piptadenia graveolens Miq.	ANE	180
Piptadenia minutiflora Ducke	ANE	180
Piptadenia spp.	ANE	180
Piptadenia suaveolens Miq.	TT ANE	180
Piptadenia uaupensis Spruce ex Benth.	WT ANE	180
Piriqueta spp.	UH	120
Pithecellobium claviflorum Benth.	TT HYD / END	180
Pithecellobium racemosum Ducke	TT HYD / END	180
Pithecellobium sp. 1	TT HYD / END	180
Pithecellobium spp.	MT HYD / END	180
Pityrogramma catomelanos (L.)Link	UH ANE	0
Pityrogramma sp. 1	UH ANE	0
Platonia insignis Mart.	TT	97
Platymiscium duckei Huber	TT	182
Platymiscium filipes Benth.	TT	182
Pleonotoma jasminifolia (Kunth) Miers.	WT	301
Pleonotoma spp.	WT	301
Pleurostachys pauciflora Steud.	GT HYD / ANE	351
Plybotrya sp. 1	UH	0
Poecilanthe amazonica Ducke	ANE	182
Poecilanthe effusa (Huber) Ducke	MT ANE	182
Poecilanthe spp.	ANE	182

Pogonophora schomburgkiana Miers. ex Benth.	TT AUT	232
Polybotrya sp. 1	WH	0
Polygala mollis L.	UH	245
Polygala monticola Kunth	UH	245
Polygala violacea Aubl.	UH	76
Polypodium spp.	UH	0
Poraqueiba guianensis Aubl.	TT	224
Porophyllum ellipticum (L.)Cass.	UH	318
Porophyllum ruderale (Jacq.) Cass.	UH	318
Posoqueria spp.	MT	311
Pothomorphe peltata (L.) Miq.	SH	21
Pourouma melinonii Benoist	MT END	53
Pourouma minor Benoist	MT END	53
Pourouma myrmecophylla Ducke	MT END	53
Pourouma sp. 1	END	53
Pourouma sp. 2	END	53
Pourouma sp. 3	MT END	53
Pourouma spp.	MT END	53
Pourouma tomentosa Miq.	MT END	53
Pouteria anomala (Pires) Penn.	TT PRI	148
Pouteria caimito (Ruiz & Pav.) Radlk.	TT PRI / ORN	148
Pouteria campanulata Baehni	MT PRI	148
Pouteria cladantha Sandw.	TT PRI / ORN	148
Pouteria francletella Penn.	PRI	148
Pouteria glomerata (Miq.) Radlk.	TT PRI	148
Pouteria guianensis Aubl.	TT PRI	148
Pouteria jariensis Pires & Penn.	TT PRI	148
Pouteria macrophylla (Lam.) Eyma	TT PRI	148
Pouteria opposita (Ducke) Penn.	TT PRI	148
Pouteria platyphylla (A.C. Smith) Bachni	PRI	148
Pouteria rebineris Penn.	PRI	148
Pouteria sp. 1	TT PRI	148
Pouteria sp. 2	TT PRI	148
Pouteria sp. 3	TT PRI	148
Pouteria spp.	TT PRI	148
Pouteria verniciosa Penn.	MT PRI	148
Prionostemma aspera (Lam.) Miers	WT	220
Prophyllum ellipticum (L.)Cass.	UH	318
Protium altsonii Sandw.	TT ORN / PRI	255
Protium apiculatum Swart	TT ORN / PRI	255
Protium aracouchini (Aubl.) March.	TT ORN / PRI	255
Protium divaricatum Engl.	TT END	255
Protium ferrugineum (Engl.) Engl.	TT END	255
Protium fimbriatum Swart	TT END	255
Protium giganteum Engl.	TT END	255
Protium glabrescens Swart	TT END	255
Protium grandifolium Engl.	TT ORN	255
Protium guianense (Aubl.) March.	TT ORN / PRI	255
Protium hebetatum Daly	TT ORN	255
Protium heptaphyllum (Aubl.) March.	SH ORN	255
Protium krukoffii Swart	TT END	255
Protium nitidifolium (Cuatr.) Daly	TT END	255
Protium opacum Swart	TT END	255
Protium paniculatum Engl.	TT END	255
Protium pilossimum Engl.	TT ORN	255
Protium pilosum (Cuatr.) Daly	END	255
Protium polybotryum (Turcz.) Engl.	TT PRI / ORN	255
Protium robustum (Swart) Porter	END	255
Protium sagotianum March.	TT ORN / PRI	255
Protium sp. 1	END	255
Protium sp. 2	END	255
Protium sp. 3	END	255
Protium spp.	TT END	255
Protium spruceanum (Benth.)Engler	TT END	255
Protium tenuifolium (Engl.) Engl.	TT END	255
Protium trifoliolatum Engl.	LT END	255
Protium unifoliatum Engl.	TT END	255
Pseudima frutescens (Aubl.) Radlk.	MT	252
Pseudoconnarus macrophyllus (Poepp. & Endl.) Radlk.	MT	157
Pseudoconnarus spp.	WT	157
Pseudolmedia laevis (Ruiz & Pav.) MacBr.	TT ORN / PRI	53
Pseudolmedia sp. 1	TT	53
Pseudolmedia sp. 2	TT	53
Pseudolmedia spp.	MT	53
Pseudoxandra coriacea R.E. Fries	END	8
Pseudoxandra leiophylla (Diels) R.E. Fries	LT END	8
Psidium guineense Swartz	SH	194
Psittacanthus spp.	EP	211
Psychotria adderleyi Steyerm.	SH END	311
Psychotria barbiflora DC.	SH END	311
Psychotria cupularis (Muell. Arg.) Standley	UH END	311
Psychotria deflexa DC.	SH END	311
Psychotria iodotricha Muell. Arg.	SH END	311
Psychotria mapourioides DC.	UH END	311
Psychotria oliginosa Sw.	END	311
Psychotria prancei Steyerm.	SH END	311
Psychotria prunifolia (H.B.K.)Steyermark	UH END	311
Psychotria sp. 1	SH END	311
Psycotria mapourioides D.C.	SH END	311
Psycotria spp.	SH END	311
Pteridium aquilinum L.	HR	0
Pterocarpus sp.	ANE	181
Pterolepis trichotoma (Rottb.) Cogn.	UH	198
Pueraria phaseoloides (Roxb.) Benth.	WHAUT	182
Qualea acuminata Spruce ex Warm.	TT ANE	242

Qualea paraensis Ducke	TT ANE	242
Qualea spp.	ANE	242
Quiina amazonica A.C. Smith	LT PRI	93
Quiina pteridophyta (Radlk.) Pires	LT PRI	93
Quiina spp.	LT PRI	93
Radlkoferella macrocarpa (Hub.) Aubr.	TT	148
Radlkoferella spp.	TT	148
Ragala ucuquirana-branca (Aubr.&Pellegr.)W.Rodr.		148
Randia sp. 1	PRI / CHI / ORN	311
Randia spp.	UH PRI / CHI / ORN	311
Rauwolfia paraensis Ducke	LT	274
Rauwolfia pentaphylla Ducke	TT	274
Rauwolfia spp.	TT	274
Ravenala guianensis Petersen	BF	359
Ravenala spp.	BF	359
Remijia glomerata Huber	SH	311
Remijia spp.	LT	311
Renealmia breviscapa Ruiz & Pav.	BF	361
Renealmia floribunda K. Schum.		361
Rhabdodendron amazonicum (Spruce ex Benth.)Huber	LT	179
Rhabdodendron macrophyllum (Spruce ex Benth) Huber	ORN	179
Rheedia acuminata (Ruiz&Pav.) Planch.&Tr.	PRI	97
Rheedia sp. 1		97
Rhigospira quadrangularis (Muell.Arg.)Miers.	LT PRI / ORN	274
Rhynchosia phaseoloides (Swartz) DC.	WT	182
Rhynchospora pallida (Nees)C.B.Clarke	GT	351
Richardella macrophylla (Lam.)Aubr.	TT	148
Richardella manaoensis Aubr.&Pellegr.	TT	148
Richardella spp.	TT	148
Richeria sp. 1	TT	232
Rinorea lindeniana (Tul.) Kuntze	LT AUT	115
Rinorea macrocarpa (Mart.ex Eichl.) Kuntze	LT AUT	115
Rinorea passoura (D.P.)Kuntze	LT AUT	115
Rinorea pubiflora (Benth.) Sprague&Sandw.	LT AUT	115
Rinorea racemosa (Mart. et Zucc.)Kuntze	LT AUT	115
Rinorea sp. 1	LT AUT	115
Rinorea sp. 2	LT AUT	115
Rinorea sp. 3	LT AUT	115
Rinorea spp.	LT	107
Rodriguezia lanceolata Ruiz & Pav.	EP	383
Rolandra argentea Rottb.	UH	318
Rolandra fruticosa (L.) Kuntze	UH EPI	318
Rollinia edulis Tr. & Pl.	MT PRI / ORN	8
Rollinia exsucca (DC. ex Dunal) A. DC.	TT PRI / ORN	8
Rollinia insignis R.E.Fries	LT PRI / ORN	8
Roucheria calophylla Planch.	LT END	240
Roucheria punctata Ducke	MT	240
Rourea doniana Baker	WT ORN	157
Rourea grosourdyana Baill.	WT ORN	157
Rourea ligulata Baker	WT ORN	157
Rourea puberula Backe	ORN	157
Rourea sp. 1	ORN	157
Rourea spp.	WT ORN	157
Rourea surinamensis Miq.	WT ORN	157
Rudolfiella aurantiaca (Lindl.) Hoehne	Epi ANE	383
Ruprechtia spp.	UH	71
Ryania speciosa Vahl	LT END	107
Ryania spp.	LT END	107
Rynchospora nervosa (Vahl) Boeck.	GT	351
Rynchospora pubera (Vahl) Boeck.	GT	351
Sabicea amazonensis Wernh.	WT ORN	311
Sabicea aspera Aubl.	WHORN	311
Saccoloma spp.		0
Sacoglottis amazonica Mart.	CHI / PRI	237
Sacoglottis ceratocarpa Ducke	MT CHI / PRI	237
Sacoglottis guianensis Benth.	TT CHI / PRI	237
Sacoglottis matogrosensis Malme	TT CHI / PRI	237
Sacoglottis sp. 1	TT CHI / PRI	237
Sacoglottis sp. 2	TT CHI / PRI	237
Sacoglottis sp. 3	CHI / PRI	237
Sacoglottis spp.	CHI / PRI	237
Salacea impressifolia (Miers) A.C. Smith	WT PRI	220
Salacea spp.	WT PRI	220
Sapium glandulosum (L.) Morong	MT ORN	232
Sapium spp.	TT ORN	232
Sauvagesia erecta L.	UH	80
Scaphiglottis amazonica Schlechter	Epi	383
Schefflera morototoni (Aubl.) Maguire	MT ORN	268
Schrankia leptocarpa D.C.	SH	180
Sciadotenia amazonica Eichl.	WT PRI / CHI	35
Sciadotenia duckei Mold.	WT PRI / CHI	35
Sciadotenia pachococca Krukoff & Barneby	WT PRI / CHI	35
Sciadotenia paraensis (Eichl.) Diels	WT PRI / CHI	35
Sciadotenia sagotiana (Eichl.) Diels	WT PRI / CHI	35
Sciadotenia sp. 1	WT PRI / CHI	35
Sciadotenia sp. 2	PRI / CHI	35
Sciadotenia sprucei Diels	WT PRI / CHI	35
Scleria bracteata Cav.	SC HYD	351
Scleria foliosa Wright	GT HYD	351
Scleria melaleuca Reichb. ex Schult.	GT HYD	351
Scleria microcarpa Nees	GT HYD	351
Scleria pratensis Lindl.	SC HYD	351
Scleria pterota Presl	SC HYD	351
Scleria secans (L.) Urb.	SC HYD	351
Scleria spp.	SC HYD	351

Sclerolobium paraense Huber	ANE	181
Sclerolobium sp. 1	TT ANE	181
Sclerolobium sp. 2	TT ANE	181
Sclerolobium sp. 3	TT ANE	181
Sclerolobium sp. 4	TT ANE	181
Sclerolobium sp. 5	TT ANE	181
Scleronema micrantha Ducke	TT PRI	101
Scoparia dulcis L.	UH	294
Sebastiana corniculata (Vahl) Muell. Arg.	UH	232
Securidaca bialata Benth.	WT ANE	245
Securidaca coriacea Bonpl.	WT ANE	245
Securidaca paniculata L.C. Rich.	WT ANE	245
Securidaca prancei Wurdack	WT ANE	245
Securidaca retusa Benth.	WT ANE	245
Securidaca sp. 1	WT ANE	245
Securidaca sp. 2	WT ANE	245
Securidaca sp. 3	WT ANE	245
Securidaca spp.	WT ANE	245
Selaginella stellata Spring.	UH ANE	0
Senna chrysocarpa (Desv.) Irwin & Barneby	WT END	181
Senna fruticosa (Mill.) Irwin & Barneby	SH END	181
Senna latifolia (G.Mey.)Irwin & Barneby	SH END	181
Senna multijuga (LC.Rich.)Irwin&Barneby	MT END	181
Senna quinquangulata (LC.Rich.)Irwin&Barneby	SH END	181
Serjania circumvallata Radlk.	WT ANE	252
Serjania exarata Radlk.	WT ANE	252
Serjania paucidentata DC.	WT ANE	252
Serjania sp. 1	WT ANE	252
Sida acuta Burm. f.	SH	102
Sida cordifolia L.	UH	102
Sida glomerata Cav.	UH	102
Sida linifolia Cav.	UH	102
Sida rhombifolia L.	SH	102
Sida spp.	SH	102
Sida urens L.	SH	102
Simaba cedron Planch.	MT END	258
Simaba guianensis Aubl.	LT END	258
Simaba polyphylla (Cav.) Thomas	MT END	258
Simaba spp.	LT END	258
Simarouba amara Aubl.	MT PRI / CHI / ORN	258
Siparuna amazonica (Mart.) A. DC.	LT CHI / ORN	13
Siparuna cuspidata (Tul.) A. DC.	LT CHI / ORN	13
Siparuna decipiens (Tul.) A. DC.	LT CHI / ORN	13
Siparuna guianensis Aubl.	LT CHI / ORN	13
Sloanea eichleri K. Schum.	TT ORN / CHI / PRI	98
Sloanea fendleriana Benth.	ORN / CHI / PRI	98
Sloanea floribunda Spruce ex Benth.	TT ORN / CHI / PRI	98
Sloanea guianensis (Aubl.) Benth.	TT ORN / CHI / PRI	98
Sloanea laxiflora Spruce ex Benth.	TT ORN / CHI / PRI	98
Sloanea rufa Planch. ex Benth.	TT ORN / CHI / PRI	98
Sloanea sinemariensis Aubl.	ORN / CHI / PRI	98
Sloanea spp.	ORN / CHI / PRI	98
Sloanea synandra Spruce ex Benth.	ORN / CHI / PRI	98
Smilax aequatorialis D.C.	WT CHI / ORN	378
Smilax benthaminiana Kunth	WT CHI / ORN	378
Smilax longifolia L.C. Rich.	WT CHI / ORN	378
Smilax pseudosyphilitica Kunth	WT CHI / ORN	378
Smilax santaremensis DC.	WT CHI / ORN	378
Smilax schomburgkiana Kunth	WT CHI / ORN	378
Smilax spp.	WT CHI / ORN	378
Smilax symigoides Griseb.	WT CHI / ORN	378
Smilax syphilitica Willd.	WT CHI / ORN	378
Socratea exorrhiza (Mart.) H. Wendl.	RT	335
Solanum anceps Ruiz & Pav.	SH	278
Solanum caavurana Vell.	SH	278
Solanum crinitum Lam.	ST CHI / ORN	278
Solanum distichophyllum Semaltn.	SH ORN / CHI / PRI	278
Solanum fulvidum Bitter	ST	278
Solanum juripeba Rich.	ST	278
Solanum leucocarpon L.C. Rich. ex Dunal	SH	278
Solanum rugosum Dunal	SH ORN / CHI	278
Solanum schlechtendalianum Walpers	ST	278
Solanum spp.	SH ORN / CHI/ PRI	278
Solanum stramoniifolium Jacq.	ST	278
Solanum subinerme Jacq.	SH	278
Solanum vanhuerckii Muell.	SH	278
Sorocea guilleminiana Gaud.	MT PRI / ORN	53
Sorocea hirtella Mildbr.	PRI / ORN	53
Sorocea muriculata Miq.	LT ORN	53
Sorocea sp. 1	END	53
Sorocea sp. 2	MT END	53
Sorocea sp. 3	END	53
Sorocea spp.	LT END	53
Sparattanthelium tarapotanum Meissn.	WT	18
Spathelia excelsa (Krause)Cowan &Brizicky	MT ANE	261
Sphaeropteris sp. 1	RT ANE	0
Spigelia anthelmia L.	UH	270
Spigelia spp.	UH	270
Sporolobus spp.	GT ANE / END	352
Stachytarpheta angustifolia (Mill.) Vahl	UH	286
Stachytarpheta cayennensis (L.C. Rich.) Vahl	SH	286
Stachytarpheta elatior Schrad.ex Schult.&Roem.	UH	286
Stenosolen heterophyllus (Vahl) Markgr.	SH	274
Sterculia parviflora (Ducke) E. Taylor	MT SYN	100
Sterculia sp. 1	MT SYN	100

Sterculia sp. 2	MT SYN	100
Sterculia spp.	SYN	100
Sterigmapetalum obovatum Kuhlm.	MT	200
Stigmaphyllon convolvulifolium Adr. Juss.	WT	241
Stigmaphyllon martianum Juss.	WT	241
Stigmaphyllon sinuatum (DC.) Adr. Juss.	WT	241
Stigmaphyllon spp.	LT	241
Stizophyllum riparium (Kunth) Sandw.	WT ANE	301
Strychnos amazonica Krukoff	WT PRI	270
Strychnos cogens Benth.	WHPRI	270
Strychnos erichsonii Rich. Schomb.	PRI	270
Strychnos glabra Sagot	WT PRI	270
Strychnos guianensis (Aubl.) Mart.	WHPRI	270
Strychnos hirsuta Spruce ex Benth.	WHPRI	270
Strychnos medeola Sagot	WT PRI	270
Strychnos peckii B.L. Robinson	WT PRI	270
Strychnos sp. 1	WHPRI	270
Strychnos sp. 2	PRI	270
Strychnos sp. 3	PRI	270
Strychnos spp.	SH PRI	270
Stryphnodendron guianense (Aubl.) Benth.	END	180
Stryphnodendron pulcherrimum (Willd.) Hochr.	MT END	180
Stryphnodendron racemiferum (Ducke) W. Rodr.	TT END	180
Stryphnodendron sp. 1	END	180
Stryphnodendron spp.	TT END	180
Stylogyne mathewsii Mez	LT	154
Stylogyne micrantha (Kunth) Mez	LT	154
Stylosanthes guianensis (Aubl.) Swartz	UH	182
Styrax guianensis A. DC.	SH	150
Styzophyllum riparium (H.B.K.)Sandw.	WT	301
Swartzia arborescens (Aubl.) Pittier	MT END	181
Swartzia brachyrachis Harms	MT END	181
Swartzia corrugata Benth.	MT END	181
Swartzia cuspidata Spruce ex Benth.	END	181
Swartzia ingifolia Ducke	TT END	181
Swartzia laurifolia Benth.	TT END	181
Swartzia longistipitata Ducke	LT END	181
Swartzia sp. 1	TT END	181
Swartzia sp. 2	x END	181
Swartzia sp. 3	TT END	181
Swartzia spp.	TT END	181
Swartzia ulei Harms	TT END	181
Syagrus inajai (Spruce) Beccari	RT SYN	335
Symphonia globulifera L.f.	TT PRI / CHI	97
Synedrella nodiflora Gaertn.		318
Tabebuia serratifolia (Vahl) Nichols.	TT ANE	301
Tabebuia spp.	TT ANE	301
Tabernaemontana angulata Mart.	SH	274
Tabernaemontana flavicans R.&S.	SH	274
Tabernaemontana heterophylla (Vahl.)Muell.	SH	274
Tachia guianensis Aubl.	SH	272
Tachigalia myrmecophila (Ducke) Ducke	ANE	181
Tachigalia paniculata Aubl.	TT ANE	181
Tachigalia spp.	TT ANE	181
Talisia cupularis Radlk.	LT PRI	252
Talisia guianensis Aubl.	LT ORN / PRI	252
Talisia hemidasya Radlk.	LT PRI	252
Talisia longifolia (Benth.) Radlk.	LT PRI	252
Talisia macrophylla (Mart.) Radlk.	LT PRI	252
Talisia medrii G.G. Neto	LT PRI	252
Talisia retusa Cowan	TT PRI	252
Talisia sp. 1	LT PRI	252
Talisia sp. 2	PRI	252
Talisia sp. 3	LT PRI	252
Talisia sp. 4	LT PRI	252
Talisia sp. 5	LT PRI	252
Talisia spp.	LT PRI	252
Tapirira guianensis Aubl.	TT ORN / PRI / CHI	256
Tapura amazonica Poepp. & Endl.	MT SYN / ORN	228
Tapura guianensis Aubl.	LT SYN / ORN	228
Tapura spp.	MT SYN / ORN	228
Tassadia martiana Decne.	WT	275
Tassadia trailiana (Benth.) Fontella	WH	275
Telitoxicum krukovii Mold.		35
Telitoxicum rodriguesii Krukoff	WT	35
Tetracera willdenowiana Steud.	WT	78
Tetragastris spp.	TT	255
Tetrameranthus duckei R.E. Fries	LT END	8
Tetrapterys discolor (G. Mey) DC.	WT	241
Thelypteris serrata (Cay.) Alston	UH ANE	0
Thelypteris sp. 1	UH ANE	0
Theobroma subincanum Mart.	MT END	100
Theobroma sylvestre Willd.	MT PRI	100
Thyrsodium paraense Huber	TT	256
Thyrsodium spruceanum Benth.	MT	256
Tococa discolor Pilger		198
Tococa guianensis Aubl.	SH ORN	198
Tococa sp. 1	SH ORN	198
Toulicia guianensis Aubl.	MT ANE	252
Toulicia spp.	MT	252
Tournefortia spp.	WT	285
Touroulia guianensis Aubl.	LT PRI	93
Tovomita paraensis Huber	MT END	97
Tovomita sp. 1	MT END	97
Tovomita sp. 2	MT END	97
Trattinnickia glaziovii Swart	TT	255
Trattinnickia rhoifolia Willd.	TT	255
Trattinnickia sp. 1	TT	255
Trattinnickia sp. 2	TT	255
Trattinnickia sp. 3		255
Trattinnickia sp. 4		255
Trema micrantha (L.) Blume	LT ORN	51
Trichilia cipo (Adr. Juss.) C. DC.	LT PRI / ORN	260
Trichilia duckei	PRI / ORN	260
Trichilia lecointei Ducke	MT PRI / ORN	260
Trichilia micrantha Benth.	MT PRI / ORN	260
Trichilia quadrijuga Kunth	MT PRI / ORN	260
Trichilia rubra C. DC.	TT PRI / ORN	260
Trichilia schomburgkii C. DC.	PRI / ORN	260
Trichilia sp. 1	MT PRI / ORN	260
Trichilia sp. 2	PRI / ORN	260
Trichilia spp.	TT PRI / ORN	260
Trichipteris sp. 1	UH ANE	0
Trichipteris spp.	ANE	0
Trichomanes pinnatum Hdw.	UH ANE	0
Trigonia spp.	WT	243
Triumfetta althaeoides Lam.	SH	120
Trymatococcus amazonensis P.&P.	LT ORN	53
Trymatococcus magnifolia Trec.	LT	53
Trymatococcus sp. 1		53
Trymatococcus spp.	MT	53
Turnera brasiliensis Willd.ex Roem.&Schultes	UH	120
Turnera ulmifolia L.	UH	120
Tynanthus elegans Miers.	WT ANE	301
Tynanthus spp.	WT ANE	301
Unonopsis duckei R.E. Fries	LT END	8
Unonopsis rufescens (Baill.) R.E. Fries	LT END	8
Unonopsis sp. 1	LT END	8
Unonopsis stipitata Diels	LT ORN / PRI	8
Unxia camphorata L.f.	UH	318
Urena lobata L.	SH	102
Vantanea macrocarpa Ducke	TT PRI / ORN	237
Vantanea parviflora Lam.	TT PRI / ORN	237
Vantanea sp. 1	TT PRI / ORN	237
Vantanea sp. 2	TT PRI / ORN	237
Vantanea spp.	UH PRI / ORN	237
Vernonia cinerea (L.)Less.	UH	318
Vernonia remotiflora Rich.	UH	318
Vernonia scabra Pers.	UH	318
Vernonia spp.	UH	318
Vigna spp.	UH	182
Virola caducifolia W. Rodr.	TT END	9
Virola calophylla Warb.	TT ORN	9
Virola divergens Ducke	TT PRI	9
Virola multinervia Ducke	TT END	9
Virola sebifera Aubl.	TT END	9
Virola sp. 1	TT END	9
Virola spp.	END	9
Virola theiodora (Benth.) Warb.	TT END	9
Virola venosa (Benth.) Warb.	TT END	9
Vismia cavalcantei v.d. Berg	LT END	97
Vismia cayennensis (Jacq.) Pers.	LT ORN / MYR	97
Vismia duckei Maguire	LT END	97
Vismia guianensis (Aubl.) Choisy	LT CHI / ORN	97
Vismia japurensis Reichardt	LT END	97
Vismia spp.	LT END	97
Vitex sp. 1		286
Vitex spp.	LT	286
Vitex triflora Vahl	MT	286
Vochysia floribunda Mart.	TT ANE	242
Vochysia maxima Ducke	ANE	242
Vochysia spp.	TT ANE	242
Vochysia vismaefolia Spruce ex Warm.	MT ANE / HYD	242
Vouacapoua americana Aubl.	SYN	181
Vouacapoua pallidior Ducke	TT	181
Voyria sp. 1	x	272
Waltheria americana L.	ST	100
Waltheria indica L.	ST	100
Wedelia trilobata (L.) Hitchc.	UH	318
Williamodendron spp.	LT	17
Wulffia baccata (L.f.) Kuntze	UH ORN	318
Xiphidium coeruleum Aubl.	GR	367
Xylopia amazonica R.E. Fries	PRI / ORN	8
Xylopia benthamii R.E. Fries	PRI / ORN	8
Xylopia crinita R.E. Fries	PRI / ORN	8
Xylopia longifolia (Sagot) R.E. Fries	MT PRI / ORN	8
Xylopia nitida Dunal	TT PRI / ORN	8
Xylopia sp. 1	MT PRI / ORN	8
Xylopia spp.	MT PRI / ORN	8
Zanthoxylum djalmabatistae (de Alb.)Waterm.	LT AUT	261
Zanthoxylum rhoifolium Lam.	MT AUT	261
Zanthoxylum spp.	ST AUT	261
Zanthoxylum trifolium	AUT	261
Zornia latifolia J.E. Smith	UH	182
Zygia racemosa (Ducke)Barneby & Grimes		180

Chapter 9.3

Photographic documentation

Photo 1:
The primary forest plot

Photo 2:
The 1 ha secondary forest plot

Photo 3:
Miconia pyrfolia Naud.
(Melastomataceae)
and Sr. Luiz F. Coêlho

Photo 4:
Croton lanjouwensis Jabl. (Euphorbiaceae)

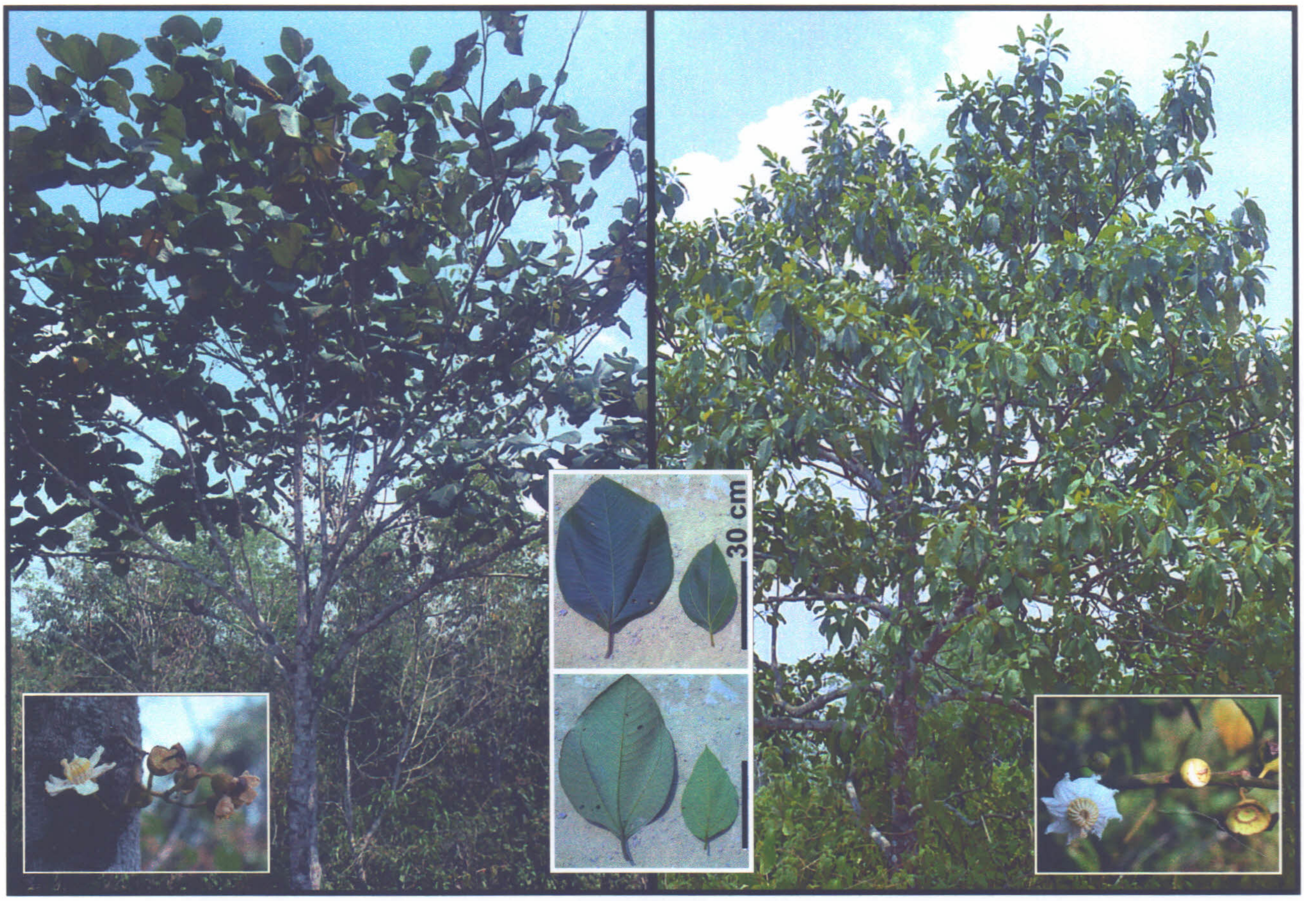
Miconia alata (Aubl.) DC.

Miconia tomentosa (Rich.) D. Don ex DC.

Miconia phanerostila Pilger

Miconia pyrifolia Naud.

Photo 5:
Sample species: The four species of *Miconia* (Melastomataceae)



Flowers
(mainly cauliflor)

Leaves

Flowers
(mainly ramiflor)

Bellucia dichotoma

Bellucia grossularioides

Photo 6:
Comparison between *Bellucia dichotoma* Cogn. and *B. grossularioides* (L.) Triana

Photo 7:
Vismia guianensis (Aubl.) Choisy

Photo 8:
Davilla kunthii A. St. Hil.
(Dilleniaceae)

Photo 9:
Smilax syphilitica Willd.
(Smilacaceae)

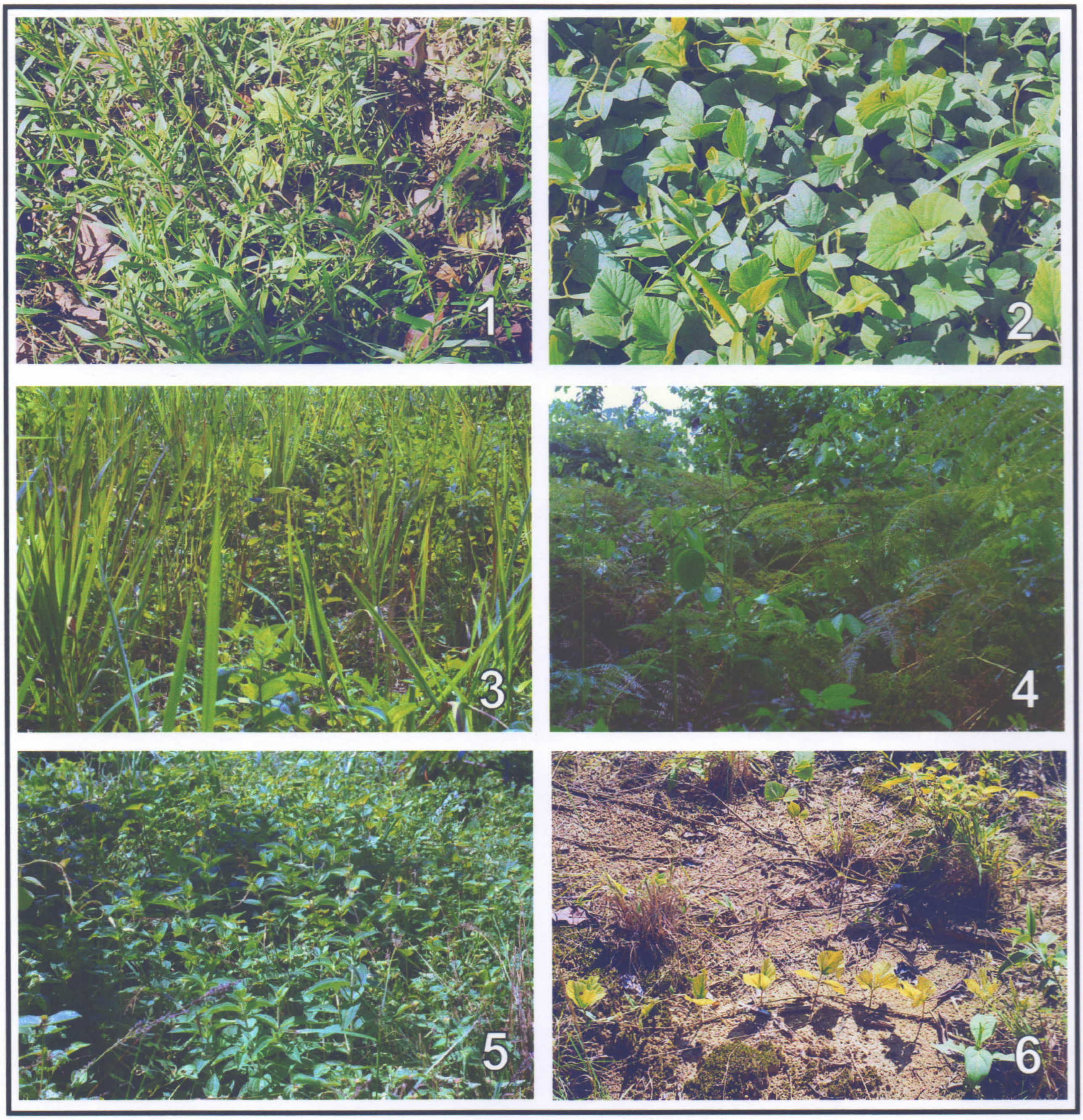


Photo 10:
Types of spontaneous vegetation in the experimental site (May 2000)

1 Stolon grasses (mainly *Homolepis aturensis*)
2 Lianas (Kudzu - *Pueraria phaseoloides*)
3 Rhizomatous grasses
4 Bracken (*Pteridium aquilinum*)
5 Shrubs (mainly *Clidemia* spp.)
6 Patch with bare soil