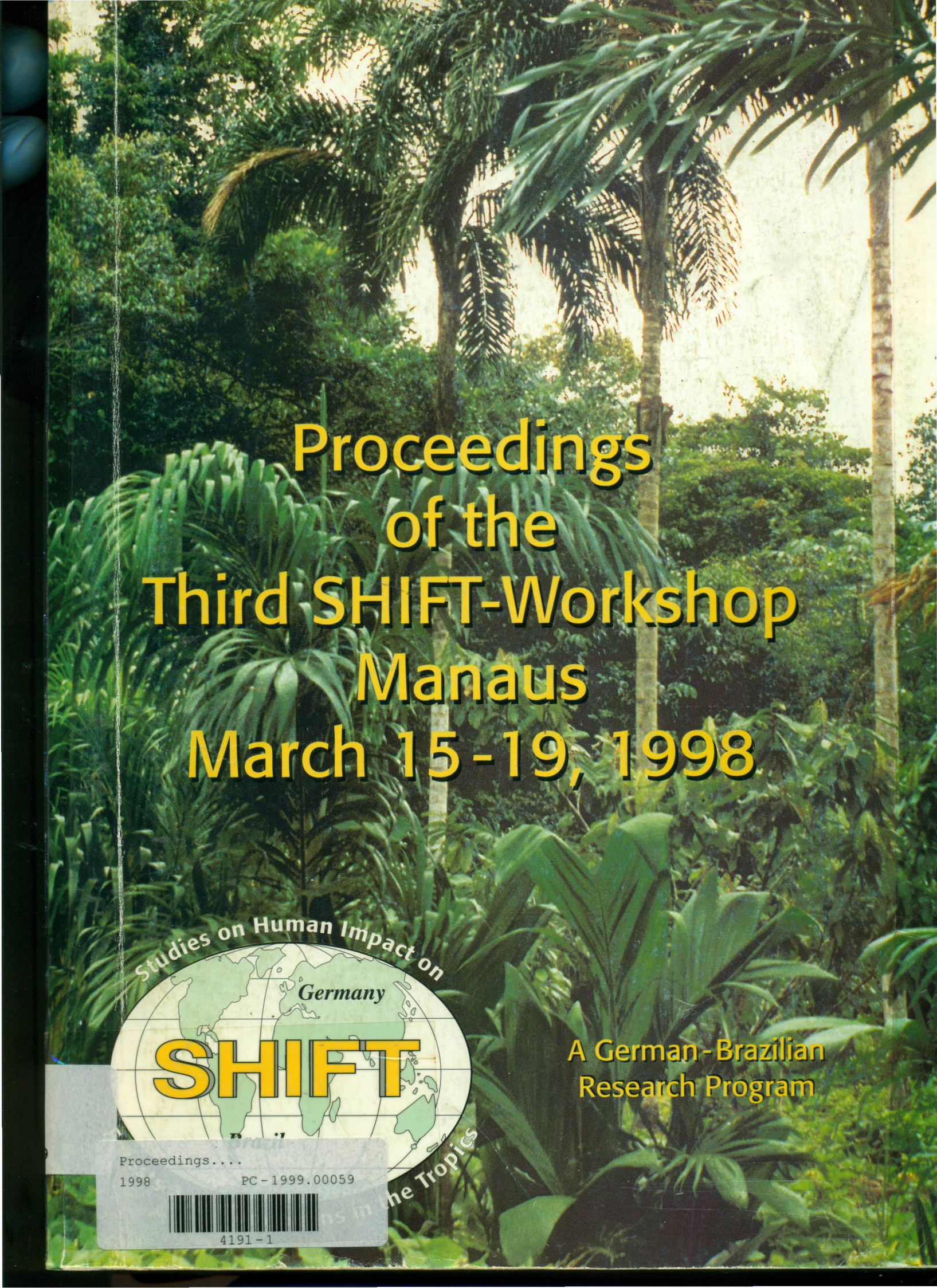

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Indicator value of anthropogenic vegetation in the Amazon

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ABSTRACT

The paper presents the conceptual basis for the vegetation science approach to the ENV 23/2 project. This project attempts to provide a comparative, functional description of different types of anthropogenic vegetation in terra firme sites of the Central Amazon and of the plant types occurring in these sites. The main objective is to devise a system whereby individual species of vascular plants and structural traits of vegetation can serve as indicators of site conditions. The classification of frequently occurring plant species on the basis of growth form types and characteristics of generative and vegetative propagation was a first step towards this goal. The approach requires floristic, syn- and autecological studies at a broad range of sites. The data sets and the results of their analysis to date are presented and discussed.

RESUMO

O artigo apresenta a base conceptual do trabalho desenvolvido no projeto ENV 23/2, com o enfoque em ciência de vegetação. É uma tentativa para elaborar uma descrição comparativa e funcional de diferentes tipos de vegetação antrópica e identificar os tipos de plantas que ocorrem em sítios de terra firme na Amazônia Central. O principal objetivo é desenvolver uma base para a indicação de condições ecológicas através de espécies isoladas de plantas vasculares e de caraterísticas estruturais da vegetação. O primeiro passo para atingir este objetivo foi a classificação das espécies que ocorrem frequentemente, considerando os tipos de formas de crescimento e as caraterísticas de dispersão vegetativa e propagação generativa. O enfoque requer estudos florísticos, sinecológicos e auto-ecológicos em uma grande variedade de sítios. Os conjuntos de dados e alguns resultados obtidos até o momento são apresentados e discutidos.

ZUSAMMENFASSUNG

Der Aufsatz stellt die konzeptionellen Grundzüge für den vegetationskundlichen Teil des Projekts ENV 23/2 dar. Dabei handelt es sich um den Versuch einer vergleichenden, funktionalen Beschreibung unterschiedlich anthropogen veränderter Vegetation von Terra-Firme-Standorten Zentralamazoniens sowie der dort vorkommenden Pflanzentypen. Das Hauptziel ist die Erarbeitung von Grundlagen für die Indikation von Standortbedingungen mit Hilfe einzelner Gefäßpflanzenarten und von Strukturmerkmalen der Vegetation. Erste Schritte hierbei waren die Klassifikation häufiger Arten nach Wuchsformentypen und nach

Merkmalen der generativen und vegetativen Ausbreitung. Der Ansatz erfordert floristische sowie syn- und autökologische Untersuchungen von einer Vielzahl von Standorttypen. Die bisher erarbeiteten Datensätze und bereits vorliegende Ergebnisse werden dargestellt und diskutiert.

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* (as defined in Grime 1979) is one of the key factors in the variation of vegetation. 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).

It is assumed that the behavior of vascular plants in the humid tropics can be explained in part with the help of CSR theory (Grime 1974, 1979), a life history concept which has already proven its practical validity for anthropogenic vegetation of temperate regions (see e.g. Preisinger 1991). The starting point for the autecological studies is the classification of species in a growth form system (see Preisinger et al., in print) 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 five 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.
- Comparison of structural traits of the vegetation of the experimental site with selected agricultural sites of smallholders of the Manaus region.

The approach requires three main branches of activity: floristic, autecological and synecological (see table 1).

Recording of the flora is the basic precondition for the other approaches. Because very little is known of the ecological behavior of the vast majority of the approximately 1,100 species of vascular plants occurring in the experimental site, it is necessary to accumulate a basic knowledge of the autecology of selected secondary forest "key 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; see table 1 for an overview of the data sets). Some results of the synecological and the autecological approach available so far are then presented in a concise form.

Table 1: Overview of the data sets built up so far in the vegetation subproject

1. Floristic data - Recording of all vascular plants in the habitats mentioned below, preferably on the species level (approx. 1.100 species); - Classification of the most frequently occurring species with regard to growth form types and regenerative behavior (approx. 300 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 (1993) and two and four years after; last survey planned in 1999; 2. in the secondary forest: all plots in 1994, 10 plots in 1996 and 1998 (planned); - 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 four species of *Miconia* and two of *Bellucia* (Melastomataceae), as well as biomass and content of mineral nutrients of the overground parts of plants; - Life history of leaf development of individuals of 11 species of different plant families, including the six species of Melastomataceae mentioned; - Phenology of frequently occurring species of flowering plants; characteristics of fruits and seeds.

SYNECOLOGICAL STUDIES

The vegetation types which were studied in the EMBRAPA/SHIFT experimental site represent a combination of a spatial and a temporal sequence (cf. table 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 analyzed. Table 2 summarizes the floristic, taxonomic and structural traits of the vegetation types under study.

The number of species found in the 1.600 m^2 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 behavior. 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 2 are restricted to stratification, growth form types and types of reproduction and/or regeneration. In table 2, 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 firmeprimary 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). 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 and Prance (1985), because of the concise description given there. Klinge (1973) and Prance, Rodriguez and 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. It was dominated by low trees, e.g. *Vismia guianensis* agg., 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 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 2).

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 favorable 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 2: Characteristics 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!

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

[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;

[3] locally dominance is reached by other species, e.g. *Clidemia hirta* (L.) D.Don

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 (see example in chapter 3) 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).

AUTECOLOGICAL STUDIES

The studies on autecology of secondary forest species started with six species of Melastomataceae (*Bellucia dichotoma* Cogn., *B. grossularioides* (L.) Triana, *Miconia alata* (Aubl.) DC., *M. phanerostila* Pilger, *M. pyrifolia* Naud. and *M. tomentosa* (Rich.) D. Don. ex DC.). The studies are being 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.

Table 3: Links between some morpho-physiological traits and site characteristics of 6 species of Melastomataceae (genera *Bellucia* and *Miconia*) occurring frequently at the experimental site

No.	Species of *Bellucia* and *Miconia*	Growth form type	max. tree height [m]	avaraged leaf area [cm²]	Site characteristics or successional stages
1	*M. alata*	treelet	2	(109)[1]	open landscape and abandoned agricultural sites = degraded areas
2	*M. tomentosa*	treelet	6	776	Preferably Capoeiras and young secondary forests, forest gaps, roadsides
3	*M. phanerostila*	treelet	10	416	
4	*B. dichotoma*	low tree	12	330	
5	*B. grossularioides*	low tree	15(-25)	140	Preferably older secondary forests
6	*M. pyrifolia*	medium tree	25(?)	51	

[1] large variability of leaf size observed

The selected species of Melastomataceae represent a wide range of physiognomic and morphological traits and of ecological behavior, but within one taxonomic group, and among plants growing on the same site. This permits an ecologically meaningful comparison of the results. The studies on autecology are being complemented by the comparison of nutrient patterns in different organs of secondary forest species and of useful plant species grown in the experimental site.

Observations in the field and the studies mentioned indicate that it is possible to identify "plant functional types" not only at the global scale (cf. Box 1981, Box 1996, Díaz and Cabido 1997), but also at the regional scale. The selected species form a sequence of morphological types, whereas the morphological traits are linked to a distinct ecological behavior (table 2). Note that five of the species occur in different successional stages of regenerating secondary forests (= progressive, secondary succession) and one species (*Miconia alata*) primarily invades the open landscape of degraded areas, sometimes as a dominating species, indicating regressive successional processes. The species produces a large quantity of small seeds, dispersed by birds. Vegetative spreading was never observed. *M. alata* shows a marked variability of leaf size, depending on the site conditions.

CONCLUSIONS

The forest vegetation of terra firmesites of the Amazon responds to different intensities and frequencies of disturbance events by changes in species composition and structural traits, resulting in a continuum of vegetation characteristics linked to a distinct type of disturbance (see table 2). The comparative studies of stands in primary and secondary forest vegetation of different use history (= synecological approach) permits a functional classification of frequently occurring species with regard to their ecological behavior after disturbance events, provided that the history of the sites is known. This is true for the majority of the study areas mentioned in table 1.

Growth form types and some single morphological traits of species of vascular plants show close interrelations with the ecological behavior of the species in a disturbance gradient. In principle, those traits can be used for the indication of past disturbance events, or pre-use and possible reversible or irreversible changes of site conditions, respectively. The comparative analysis of the morphology and sites of individual plant species of secondary forest vegetation (= autecological approach) contributes to a better understanding of the ecological behavior of Amazonian plant species and to the identification of functionally important morphological traits ("morpho-physiological traits"), e.g. leaf characteristics (see table 3).

Classification of frequently occurring species of secondary forest vegetation on the basis of growth form types and single morpho-physiological traits, including characteristics of regenerative behavior (approx. 300 species classified until now), makes it possible to present the composition of traits in a stand and draw conclusions about site conditions (= combination of synecological and autecological approach).

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