Embrapa Amazônia Ocidental
BIBLIOTECA

Manaus, May 2002

Relatório para avaliação do projeto ENV.23/2

Recultivation of abandoned monoculture areas through mixed cropping systems in central amazon.

Recuperação de áreas degradadas através de sistemas de policultivo na Amazônia Central.

Rekultivierung brachliegender Monokulturflächen mittels ausgewogener Mischkulturen unter besonderer Berücksichtigung bodenbiologischer Faktoren.

Contents

IDENTIFICATION

German-Brazilian Environmental Research Cooperation

PROGRAM SHIFT: Studies of Human Impact on forests and Floodplains in the Tropics

Project title:

Recultivation of fallow lying monoculture areas under special consideration of soil biological factors

Project Number: **CNPq Process No. 68 00 35 / 96-9**
DLR 01 LT 0009 - ENV 23/2 - FKZ: 0339457 B (BEO, until 1999)

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Feldmann, Falko, Dr. German coordinator in Hamburg 1992 - 1996
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Project Context: **The project to be reported about is CNPq Process No. 68 00 35 / 96-9 and DLR 01 LT 0009**
synonymous with - ENV 23/2 - FKZ: 0339457 B (BEO, until 1999)
Duration in Germany from 1996 to 2000, in Brazil to 1998/99

It is the follow up of project ENV 23
synonymous with BEO FKZ 0339457 A
in which the infrastrucutral basis, i.e. the experimental field and planting concept for most of the following activities was installed.

Key – words: **polyculture systems, nutrient recycling, soil biology, soil microbiology, root systems, secondary vegetation, functional biodiversity, phytopathology, economics, acceptance, gap management.**

1. SUMMARY

Organization and Objectives

The project "Recultivation of fallow lying monoculture areas with polycultures under special consideration of soil biological factors" is the first prolongation and thus, the second phase of the project, which was initiated in 1992 (see Figure 1). In the first phase (1992 to 1995) an experimental area of more than 17 ha was installed after slash and burn treatment of a fallow area of the EmbrapaAmazônia Ocidental, Manaus. The installation phase and the transition phase of the polyculture experimental system was qualitatively and quantitatively analysed and documented until the end of 1995.

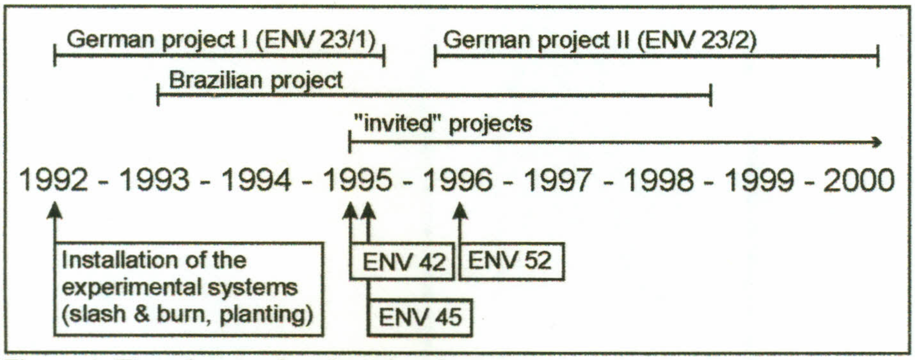

Figure 1: Time frame of project development

In 1996, when most of the polyculture plant components had entered the production phase, the follow up project (ENV 23/2) was started. The project was composed of five subprojects (Figure 2): the management and economy of the polycultures in comparison to the monocultures (S1), plant development and root system studies (S2), soil microbiology with special emphasis on plant-microbe interaction (S3), plant variability and economic suitability of cupuaçu as a key crop (S4), and vegetation analysis (S5).

The Brazilian counterpart activity consisted of the direct partnership in the polyculture system manangement (B1), of plant nutrition analysis and fertilizer use (B2), of phytopathological assessments (B3) on economic evaluation (B4).

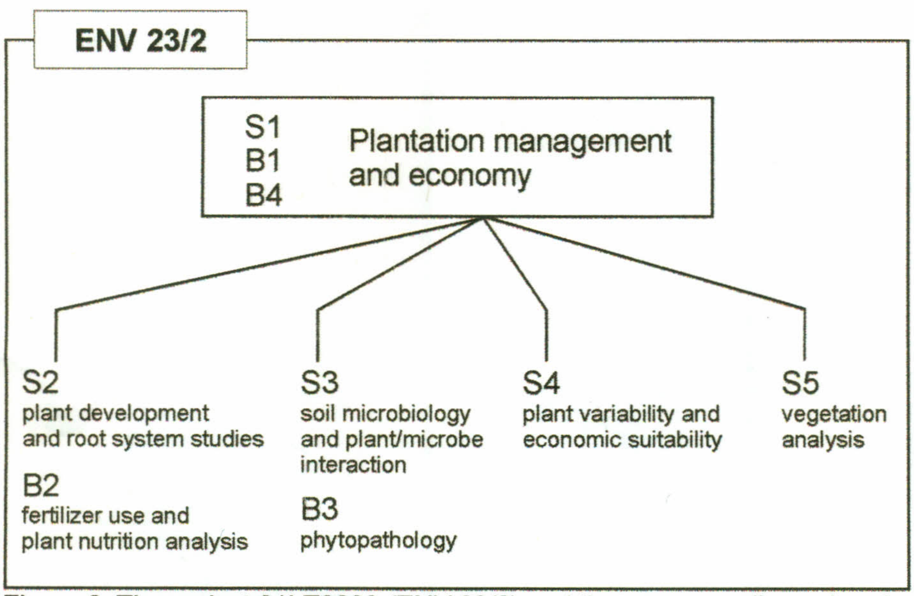

Figure 2: The project 01LT0009 (ENV 23/2) and the corresponding subprojects
(S: German leadership; B: Brazilian leadership)

Structure of the complete approach

In addition to the German Brazilian approach it had been discussed to enlarge the research input into the experimental installation and thus, other projects have been invited to join us in order to cover most intensively the studies on the characteristics of the agroecological experimental area. In this context the projects

ENV 42 "Investigations on tree species suitable for the recultivation of degraded land areas in Central Amazonia"
ENV 45 "Water and nutrient fluxes as indicators for sustainability"
ENV 52 "Soil fauna and litter decomposition in primary and secondary forests and in polyculture forestry plantations in Amazonia"

started their activities on the experimental SHIFT-site. The results of this concerted action of four connected SHIFT-projects forms the complex and detailed outcome of this research approach and allows to identify, quantify and evaluate the resources and their distribution and recycling in the agroecological systems. From these data many management measures can be taken for transfer to practice.

Activities and goals

The aims of the project were

1) to identify methods and management factors which can be used to minimize or to counteract the rapid decline of fertility of neotropical rain-forest soils (which results from inadequate land use) by using selected useful plants and suitable "helper plants" from secondary vegetation.

2) to understand the plant-plant interaction in the course of the system development (installation phase –transition phase – production phase) and its changes in time and space

3) to focus on the root/soil interface in order to identify biotic and abiotic stabilizing factors for the polyculture production systems

4) to follow nutrient transfer of mineral elements from biomass to soil and its respective recycling to the living biomass with special focus on the plant root activty and the microbial biomass

5) to evaluate production and plant health in polyculture systems versus monocultural plots

6) to study the variability of cupuaçu (*Theobroma grandiflorum*) with respect to its suitability as multifold crop by processing of the seeds to a value added product.

7) to understand the comparative developmental factors of the secondary vegetation in order to develop vegetation based indicator systems with respect to anthropogenic disturbances.

The overall aim of this second phase of the project is to understand and quantify most of the stabilizing factors of the multicomponent agroforestry systems (polycultures) with the aim to use these informations for the design of sustainable, economically healthy smallholder production systems which can, finally, be installed and tested on site with farmer cooperatives in the third project phase.

Materials and Methods

The materials for the project are:
a polyculture system that had been installed in the first phase (1992-1995 ENV 23)
a mobile climatological station
the research infrastructure of the Embrapa institution
institutional infrastructure of the respctive institutes of the German counterpart
special equipments purchased in the course of the SHIFT-program

The methods applied for the five subprojects of the project are

► For subproject S1 and B1 ("Plantation management and economy"):

Evaluation of all inputs into the area, quantification of all costs of production factors, labor costs, consumables, e.g. fertilizer

Quantification of all outputs, i.e. especially the products from agriculturally mature, producing plots of the useful plants.

These methods give the frame about the complete size and amount of the 17 ha project. Methods in detail are given in the respective publications and reports, which will be provided by the author if necessary.

► For subproject S2 and B2, plant-plant interaction ("plant development and root system studies"; "fertilizer use and plant nutrition analysis"):

Nutrient uptake and interspecies competition about nutrient
Nutrient transformation (inorganic to organic) and transport in the system
Nutrient storage and recycling by plants and microbes
Water distribution and water mobility
Regulation of microclimate and its effect on productivity
Root systems formation, growth and interaction
Mineral uptake and its kinetics

The methods applied for studying mineral element recycling are standard methods. They have in part been carried out in cooperation with project ENV 45. Above ground water analysis after sampling rainwater, canopy through flow, stem flow, soil water sampling by lysimeter/tensiometers, in some cases stable isotopes have been used to study the water mobility and mineral uptake pattern.

Microclimatic measurements have been made using Assmann psychrometer, Piche apparatus and the automated climate station. Stomatal aperture was measured by a Delta-T porometer. Sap flow was quantified by Granier elements and stomate activity and distribution was estimated by tape/microscopy use.

Root system development was analyzed after digging and purifying partial root systems in defined sectors by a species related root characterization scheme, by studying soil core samples according to root types and their relative abundance.

Mineral element uptake and mobility was analysed using ICP-OES for K, Mg, Mn, Ca, Fe, Al and photometric quantification for the anions; nitrate and sulfate were estimated in an ionochromatographic device. For special uptake kinetics using stable isotopes in nutrient solutions a LAMMA-500 device (Laser-Microprobe mass analyser) of the German research center in Juelich was used.

► For subproject S3 and B3 ("Soil microbiology and plant-microbe interaction"; "Phytopathology"):

Bacterial biomass was measured using fumigation/extraction techniques
Bacterial physiological groups were studied
Defined isolates with special respect to phosphate solubilization were detected
Exudates of roots were collected and quantified and qualitatively analysed and soil enzymic characteristics were followed.
Disease incidences were estimated throughout the whole year in monthly steps

In total more than 370 isolates of the rhizospheres of *Bactris gasipaes* and of *Theobroma grandiflorum* were cultivated on selective nutrient agars, tested for their substrate utilization patterns using BIOLOG-plates and, in four cases, analysed by DGGE (denaturing gradient gel electrophoresis) for their 16 S r-DNA with broad band primers. Identification took place by DNA-sequencing and using physiological parameters.

Further work with *Gordonia sp.* (*Actinomycetes*) and *Bacillus sp.* with respect to phosphate solubilization studies were carried out in monaxenic cultures using goethit as phosphate source. The enzymes catalase, alkaline and acid phosphatase, peroxidase were tested photometrically using standard tests. Studies on seasonal effects on microorganisms in the rhizospheres of *B. gasipaes* and *T. grandiflorum* were based on fumigation-extraction (Marschner et al. 2002, Biol. Fertil. Soils 35, 68-71), applying correction factors for acid soil types.

Plant root exsudates were collected in the field from prewashed roots after equilibration processes. Exsudates were tested for organic acids by HPLC (High performance liquid chromatography), sugars by gas chromatography and amino acids by HPLC.

► For subproject S4 ("plant variability and economic suitability"):

The variability of the key crop cupuaçu was estimated with respect to the morphology, canopy structure, growth habit, fruit form and size, seed number, seed form and seed size in order to have a first idea about the heterogeneity of the planting material.
Data concerning production structure, seasonality of production, physiological changes from juvenile to adult plants were collected by field assessment by the Brazilian group members, as were the data on pests and diseases.
Seed quality parameters with respect to their biochemical potentials to develop aroma precursors like cocoa seeds during fermentation were taken from biochemical analysis of phenolics, storage protein amounts and types, and activity and characteristics of the endoproteases and the carboxy-exoproteases. These enzymes, when present, form the aroma specific precursors from storage protein components, provided that during fermentation the acidification of the seeds reaches a pH-range of about pH4.5 to 5.5 for sufficient time.

For estimation of protein patterns various extraction systems had to be applied in order to avoid artefactual modifications due to high amount of phenolics. The protein analysis was done using gel chromatography and ammonia sulfate precipitation for the purification step, differential solubilization of storage protein according to the traditional Osborne-classification, and SDS-Gel electrophoresis for analysis of the storage protein forms in comparison to the storage protein fraction of *Theobroma cacao.*

The proteases were analyzed with a set of artificial substrates and with specific inhibitors and were compared directly with the activity patterns and inhibition profiles of the respective enzymes of the cocoa seeds.

► For subproject S5 ("vegetation analysis"):

The analysis of primary forest, secondary forest, fallow plots of the ENV 23 project and analysis of the secondary vegetation in the production plots was carried out over an extended period for more than five years. A herbarium for references was established using a temperature controlled laboratory. The study comprised the analysis of growth form types of the regenerating flora, the amount of biomass produced per vegetation type, the typical indicators for the respective vegetation. Functional plant groups like strong accumulators in the early growth phase and plants with "long storage strategy" in the next succession step could be defined. Seed and fruit dispersal and the possible management of regeneration of opened patches in order to avoid too much of edge effects are deduced from these findings.

> The seeds, fruits and the litter production were taken from traps localized in defined distances from the borders and from each other. The individual plant development was done with morphometric measures and the production of biomass was calculated using allometric approaches whereever possible. Calculations and statistical analysis was done using the Canoco-program and the Program STATISTICA. Principal component analysis and redundancy analysis were applied for deeper analysis of interactions.

► Subproject B4: Economic analysis of the system: see Brazilian report to CNPq and Rodrigues et al. 2000.

Interest for the research in national and international scope

National scope: The main goal of the project, resp. the combination of projects that are active on the experimental area, is to develop an agroecological systems design, which leads to long term stable agroecosystems with continuous production in an economically acceptable input/output ratio and with an environmentally needed function in climate regulation and conservation of biodiversity functions.

The first step in reaching this goal is to understand the deficiencies of the former systems, of the monocultures which led to fast degradation. This step is reached. The deficiencies are in direct combination with the disruption of the sensitive resource recycling systems of the primary vegetation. In contrast to geographical areas with young soils,in which the soil acts as a storage compartment for minerals, the highly weathered acid soils do not store the minerals needed in the biological system. In this situation the vegetation cover of the neotropics used the inherent high flexibility and variability to develop efficient recycling systems adapted to the soil deficiency. The recycling systems are not working on the basis of only one plant component, but in contrast, depends on various interacting biotic components.

Thus, the second step in development of adapted production systems has to be based on the inherent knowledge of the special features with which a single plant species is contributing to the recycling process. When these plants with their remarkable special properties are combined with the respective other plant components which functionally "fit into the puzzle" to close the still existing gap, then a certain level of stability can be reached, if not any controversy exists on other levels of plant-plant interaction. Therefore the "plant passport" or "descriptor" to evaluate the positive and negative features for combination in polycultures is an inevitable need for rationale plantation design.

The national interest can be satisfied by producing a selection of potentially useful plants which are able to close the resource cycles and are also tolerant to grow together with useful tropical crop plant. On this basis economically and ecologically acceptable systems can be designed. The next step is to analyse the best site adapted systems in on farm research and to enlarge the number of plant selections.

International scope: Stable production systems guarantee long term stability and allow to estimate the contribution of such sites for carbon sequestration and for other climatically relevant functions. In this context this type of production system is a stable ground truth basis for evaluation of environmental services as it is done e.g. by LBA.

New theoretical approaches in environmental issues since the mid 90ies (eg Jordan, CF 1995: Conservation: Replacing Quantity with Quality as a Goal for Global Management. John Wiley and Sons, Chichester) clearly point out, that plant inherent functions can and must be used for rational environmental design. Recently, Hobbs and Morton (1999) (Hobbs, RJ and Morton, SR. 1999: Moving from descriptive to predictive ecology. Agroforestry Systems 45, 43-55) pointed out "Ecology is now beginning openly to extend its interest from supposedly natural systems, in order to include human-dominated systems. Anthropogenic disturbances can now be incorporated into ecology in the same way as any natural disturbance, rather than being regarded as distractive noise." and he goes on saying ". .. one can predict that the ecology of agricultural systems will also undergo fresh growth in the coming years ...". This aspect of applied ecology underlines that functional traits of agroecosystems become important components of environmental management.

This short outline may stress the position, that our research leads directly to modern agroecological management of the environment in one of the most sensitive and most threatened areas of our world.

3. RESULTS OF THE RESEARCH

Reached Goals

The definitive goals of the five subprojects have widely been reached.

► The goal of subproject 1: The management and economy approach for the polycultures is derived from the results of the combination of the projects ENV 23, ENV 42, ENV 45 and ENV 52. The combination of results clearly shows (report on project Embrapa 08.0.94.010 and Rodrigues et al. 1998), that the economic input/output structure allows for an acceptable income in farmer households, which are based on these plant combinations.

The management aspect with the aim to design a site adapted plantation requires a wide knowledge about almost all input factors of a plant, which goes far behind the traditional knowledge of an agriculture or plantation management. Input factors are derived from

- the plants, resp. the varieties,
- the plant combinations,
- the planting patterns,
- the combination of plants with respect to their root systems,
- the combination of plants with respect to their canopy structures,
- the demand of the plants for mineral elements,
- the water demand of the plants and their impact of water,

- the relative drought tolerance in the dry season,
- the plants input into soil with respect to solubilization of phosphate,
- the plants input with respect to the nitrogen pool and the relative amounts of ammonia and nitrate,
- the plant – microbe interaction e.g. obligate mycotrophic plants, high exsudate producers etc.,
- the plant long term influence on the site as carried out by the litter and pruning materials,
- the recycling value of a plant with regard to the root system, esp. the shallow rooting, undergrowth roots or deep roots for pumping services in order to reduce inwash losses.

In 1988 Lieberei and Gasparotto described the first type of a plant descriptor in order to visualize the demand for this complex knowledge. At the end of 2000, on the occasion of the German-Brazilian Workshop on Neotropical Ecosystems (Hamburg 2000), many contributions have been presented on this topic, especially by the groups working on the experimental field in Manaus. On the basis of these data a rationale design of polyculture planting systems can be transferred to on site conditions of farmers, and has been done to a restricted amount. It would be very efficient, to optimize the systems with respect to inclusion of some more plant species which provide good and necessary products, especially for daily life of families based on subsistence economy. This activity would be the third phase of the project ENV 23.

Table 1: Resource management and options for influencing polyculture development

Resource	Management Option	Reference
Water	Water distribution varies with plants Soil hydraulic conductivity is changed by plants Root distribution, deep root pumping, undergrowth of compatible root systems, avoidance of root incompatible combinations	Schroth et al. 1999 b Dissertation W. Teixeira, Bayreuth 2001 Emmerich et al. 2000 a Emmerich 2002
Light	Shade trees, Canopy structure, planting pattern and density Active life span of leaves	Reisdorff 2002, Ph.D. thesis
Mineral elements	Uptake, root competition Avoiding losses by root gap management Internal and external recycling Adjust fertilization time scale to needs Define the place for fertilizer localization with respect to competitivity of root systems	Schmidt et al. 1999 Schroth et al. 2001 b, c Lehmann et al. 2000, 2001
N-management	Balance between N inorganic and N organic, use of legume plants and management of soil microbes Tree-specific N-forms and distribution patterns in ths oil	Schroth et al. 1999, 2001 d Lehmann et al. 2000
P-management	Mycorrhiza nurse plants Transfer P inorg to P org by continuous litter of Pueraria phaseoloides, lateral nutrition transport through P. phaseoloides, soil microbes for P solubilization	Feldmann et al. 1995 Feldmann 1998 Marino et al. 2000a,b Marschner et al. 2002
Litter management	Combination of leaf qualities with low and with high degradation patterns Analysis of mineral storage in leaves	Schroth et al. 2002 Boehm, thesis in prep. Uguen et al. 2000a, 2000b Duenisch et al Schmidt et al. 1999
Soil biology management	Select plants with suitable litter quality, combine root systems of tolerant species	Emmerich et al. 2000 a,b Beck et al. 1998

Microbe management	P-solubilizers and litter degrading microbes as Biofertilizers Introduction of obligate mycotrophic plants	Marino, thesis 2000
Microclimate management	Fast growing trees, no border effects, stay near to primary forest margin, modify planting patterns	Reisdorff et al 2000
Biological disease control	Hyperparasites, plant health management by mycorrhiza, manual pruning control	Gasparotto et al 1996, 1998
Economy of production	Selection of high quality plants Value added product in cottage industry	Rodrigues et al. 1998 Reisdorff et al. 1996
Regeneration processes	Suitable plants for seed dispersal fauna Pollinator attractants Maintain soil seedbanks	Preisinger et al 1994 Skatulla et al. 2000 Skatulla 2002 Thesis

► The goals of the subproject 2 ("plant development and root system studies"): The outcome of this subproject clearly shows, that the plant species specific functional aspect of the root systems is significantly different. The four plants under study follow completely different strategies in formation of root biomass, in the root distribution relative to the above ground mass, the root architecture, especially the relative amounts of fine roots to gross roots. Furtheron some root systems are formed extremely near the soil surface, whereas others form a second layer in the deep soil. Also the nutrient uptake kinetics vary strongly. These data have just recently been completed and will be published within a short duration. (Emmerich, S. 2002: Die Feinwurzelsysteme von vier tropischen Nutzbäumen, ihre Nährstoffaufnahme und ihre Interaktionen in einer agroforstlichen Mischkultur in Zentralamazonien. (The fine root systems of four tropical useful tree species, their nutrient uptake and their interactions in an agroforestry polyculture in Centra Amazon). May 2002, Düsseldorf).

The data on the roots' functional diversity allows to define the uptake gaps for fertilizer around the plants. This knowledge provides a basis for a structural combination of plants with respect to canopy dependent water fluxes and root dependent water and nutrient uptake.

Further plants with high economic potential in Central Amazon wait for the comparable studies in order to minimize uneconomic losses of fertilizers.

► The goals of the subproject 3 ("soil microbiology with special emphasis on plant-microbe interaction"): The goal of this subproject was to analyse if there is a natural potential of phosphate solubilizing microbes in the rhizosphere of useful tropical plants and to isolate and cultivate them. More than 70 % of more than 370 isolates sampled were positive with respect to P-solubilization (Marino, W. 2000). Four isolates were identified by molecular methods and have been studied in detail with respect to the P-solubilization process in liquid culture. The potential use in controlled plant cultivation systems has been studied in greenhouse experiments (Hoberg 2002). A transfer of these experiments to the tropical environment would be the next step on the way to work with biofertilizer systems. In addition, the strong seasonal influence on microbe population density and, possibly, on microbe population structure (Marschner et al. 2002) needs to be understood with special emphasis on functional changes.

The management of arbuscular mycorrhizal fungi has already been transferred to the EMBRAPA center by Dr. Feldmann, who propagated fungal inoculum on a maize based nurse plant system. This system is not costly and easy to handle.

► The goals of the subproject 4 ("plant variability and economic suitability of cupuaçu as a key crop"): Reisdorff, C. et al. (2000) analysed the above mentioned seed quality parameters with respect to their biochemical potentials to develop aroma precursors like those occurring in cocoa seeds after fermentation. The aspartic proteases and the seryl-carboxypeptidases in seeds of *T. grandiflorum* reveal the same substrate specificity and the same pH-range in their activity profile as in *T. cacao*. The storage protein, a vicilin like compound, is also directly comparable to that of *T. cacao*. The biochemical potential of cupuaçu seeds for the formation of cocoa-aroma is given. It seems to be highly interesting now to work on the fermentation procedure in order to develop a suitable manufactorial approch for the small farmer to develop a high quality product, which can be produced under reproducible quality parameters. Further research seems to be highly interesting to reach additional value added products.

► The goals of the subproject 5 ("vegetation analysis"): In her thesis of May 2002 (Skatulla, M. 2002) Dr. Skatulla describes the development from the slash and burn field to a twelve years old fallow. She analyses the differential mechanisms for the vegetation development and underlines the importance for special functions in the regeneration process. *Vismia guianensis* and other species of the *Vismia* complex fulfil a function after slash and burn which can be called high potential accumulation. Indeed the leaf mass of *Vismia sp.* contains a high amount of accumulated minerals (Schmidt et al. 1996) and seems to be low in antinutritive compounds and in addition, Silva et al. (2000) used leaves of *Vismia* as a standard litter, because it is degraded at high rates, offers a good reproducibility. After six to nine years of *Vismia* dominated fallow, the next dominating plant groups belong to the Melastomataceae, a group which contains high amounts of tannins and scleromorphic leaves. These leaves do not degrade in short times. They cover the soil and lead to a completely different microclimate. So far there are no detailed studies about positive or negative impacts of these leaves on soil microfauna or on microorganisms.

Litter management, which, in consequence, is far more a microfauna and mesofauna mangement and a potential means to shift the microbe populations in new functional gaps. These potentials still have not been studied.

From the studies on the vegetation, first important management strategies for recuperation of fallow lying areas without using useful plants can be deduced, on the other hand they clearly help to understand, how to manage a secondary vegetation in order to keep edge effects in the polycultures as low as possible.

Products and processes reached

The products of the study on diverse polycultures was thought to be a list of plant properties and a sum of reasonable arguments how to use a certain plant or plant combination in order to reach as soon as possible a stable and producing polyculture system. This aim has been reached for at least a small number of selected plants, but these plants are of high importance for production. It is possible to give very clear data to practice. So far this analysis has been carried out only under the edaphoclimatic conditions of the experimental area of the EMBRAPA institution. In order to give good manuals to the extension officers it would be very reasonable to have a series of experiments on the properties of selected farmers. But this is still missing.

Under these assumptions that a unique methodology can be delivered to the practice, the observations are too premature, especially when we regard the fact, that a small holder runs the whole risk of investment when he starts to work on the basis of this system. A series of experiments to understand the influence of site specific factors would be necessary.

In general, this aspect is a question of the maturity of the system. In fact, the SHIFT experimental frame was designed to operate in a three phase system (Lieberei and Salati 2000), in which the third phase was designed to form transfer packages to practice.
In a general approach, it can be stated, that the applicability is given, but the variability due to the on farm site conditions has to be worked out.

Forms of accompaniment of the research (implemented/improved)

The design of the agroforestry systems studied on the SHIFT experimental site has been adopted by 85 farmers in two communities near Manaus, namely the Município de Itacoatiara and in the Município de Manicoré. On these private properties respective test modules of 2 ha have been installed according to the technical advice of well experienced participants of the project ENV 23. The implementation and maintainance of the agroforestry systems is supported by PRODEX (Programa de Desenvolvimento de Reservas Extrativistas).

Difficulties that justify the non-accomplishment of the foreseen goals

Most of the goals have been reached in the given time, but due to incertainties of the export conditions for the scientific samples many of the detailed analytics could not be carried out, because the samples which were prepared for further analysis in the institutions of the German counterparts were not allowed to be exported and had to stay in Brazil.

Thus we cannot speak about non-accomplishments but about incomplete data sets with respect to varied or incomplete sample sets.

Justification of occurrence of activities non foreseen in the project
See above

Analysis of the results obtained according to the initial proposal

The results obtained allow the conclusion, that the collaboration – at least from the point of view of the experimental crew – was highly efficient and allowed to reach the essential point of functional description of most of the factors of resource recycling in the systems.

Integration of potential users

In the report of EMBRAPA dealing with the impact of the project and dealing with the importance of the large size polyculture experiment, it becomes clear that this experimental installation served as an example for many groups of farmers, but also for politicians, how to direct the agroforestry management to a new future. In addition, new appraoches in models with interested farmers have been installed around Manaus. Without the impact of the SHIFT experiment this – most probably – would not have been done at that time and in this instensity.

4. CO-OPERATION

History, evolution and difficulties of the co-operation

The intrainstitutional collaboration was highly efficient and was characterized by a high amount of personal positive engagement. In most cases the transfer of knowledge was done freely and with the willingness to cooperate. Some individual persons had difficulties to integrate fast into the working group. Especially for these persons the regular group meetings were essential

The interinstitutional collaboration was also very good, but in some aspects difficulties arose due to changes of personal. It is of high importance to have a solid and efficient base of information by means like a short monthly news report about new co-workers, small scientific events and so on.

Among the German and the Brazilian staff, the collaboration was good. In many cases the project coordinators had a high working load, because they did not only work with the reseach collaboration, but had also their daily business. Joint events for evaluation and reorientation of the cooperation is a necessary, though time consuming event, but it is extremely helpful to promote the aim-oriented activities. Numberless joint events took place on informal as well as on formal level since the project ideas have been born until now.

5. STAFF

Qualification of the involved staffs and human resources formation in consequence of the project

ANDERSSON, M., 2002: Die Samenschale von Theobroma cacao L.: Ihre Bedeutung für Fermentationsprozesse. Diploma – thesis: 05/02, supervisor: Reinhard Lieberei, Universität Hamburg

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Participation on technical – scientific events and similar

The staff members of the project as well as the associated and interested members of the involved institutions and students participated in numerous national and international scientific events focussing on diverse topics of tropical ecology. For instance, presentations (lectures and posters) on the ongoing research and on preleminary results of the project have been made at the congresses of the German Society of Tropical Ecology (GTÖ) in 1998, 1999, 2000 and 2001, at the Conference on Fruit Production in the Tropics and Subtropics in Berlin and at the International Symposium on Multi-Strata Agroforestry Systems with Perennial Crops, Turrialba, Costa Rica. The ongoing integrative analyses of the particular outcomes and observations will bring forward the understanding of the functionality of agroecosystems in the humid tropics. This growing understanding will be the basis for presentations and discussions at scientific meetings, workshops and congresses in the course of the next years.

6. ADDITIONAL INFORMATION

Evaluation of the relations with sponsoring agency

Good. No problems.

Co-relations with other projects

As stated earlier in this report there was a close relationship to the other SHIFT-projects active on the experimental site (ENV 42, ENV 45, ENV 52). Beside the thematical and technical intersections with these projects the daily work was dominated by the spirit of helpfulness which was reflected in technical as well as in personal assistance.

There was a lot exchange of experiences between the SHIFT-projects and other projects located at the EMBRAPA, e.g. with projects concerning phytopthological subjects or breeding projects.

The SHIFT-experimental site has been visited by many scientists and representatives of different institutions and research projects. Research projects of local institutions (e.g. of the University of Manaus or the INPA) have been initiated in close cooperation with the SHIFT-projects located at the EMBRAPA.

Relevance of the provided financial assistance to the research

The relevance of the financial assistance to the research is to be called very high. Beside the travel costs and per diem allowances the financial assistance made it possible to tackle the elucidation of complicated processes by recent technologies (cf. section "materials and methods").

Other financial assistance funds/institutions of the project

Infrastructure of the Universities of Hamburg and Düsseldorf
Staff and infrastructure of the Institute of Applied Botany
Staff and infrastructure of the EMBRAPA Amazônia Ocidental

Other means of publication of the project information and results

See list of references

7. CONCLUSIONS

Project impact to the institution

The Institute of Applied Botany of the University of Hamburg was traditionally focussed on tropical and subtropical ecosystems and tropical crops, e.g. there was an intensive research focus on semi-arid areas in the Sudan with the University of Khartoum and on rubber tree cultivation with the Rubber Research Institute of Malaysia and with several institutions in Brazil. The SHIFT-project enforced the activities with Brazil and gave rise to many new projects. Also the academic orientation in research and in teaching was directed to these fields of environmental problems.

Relevant contribution to the scientific and technological development of the area

The methodological approaches and findings of the projects of SHIFT were and are highly relevant to the scientific and technological development. They are also relevant to the introduction of new laboratory facilities and to the introduction to more analytical skills and to new scientific ways to approach the tasks of developing and assessing agroforestry systems with regard to their sustainability.

8. FIGURES

Figure 3a to e: The systems design and its development in time and in space

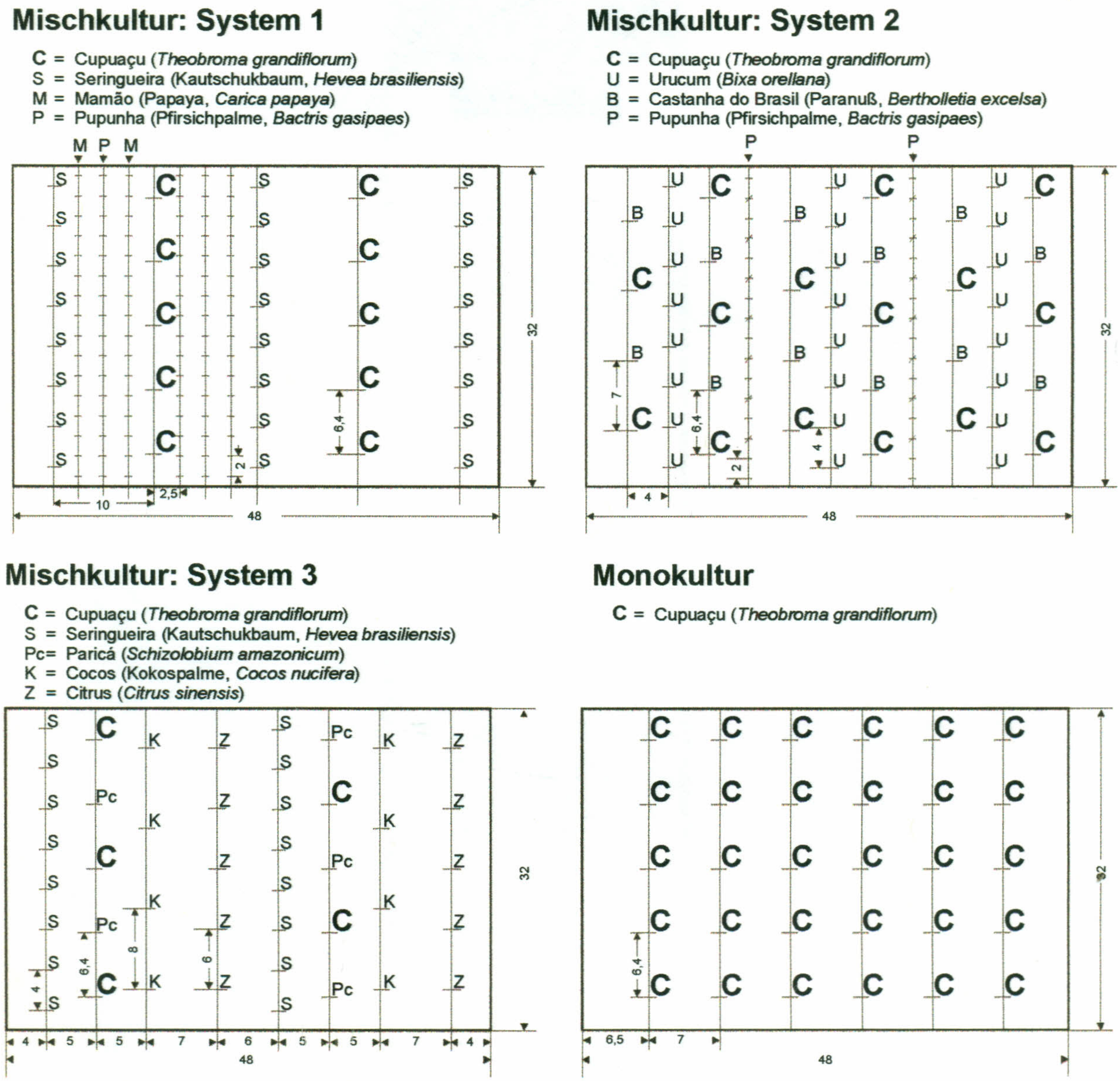

Figure 3a: plantation scheme of the three agroforestry systems and a monoculture

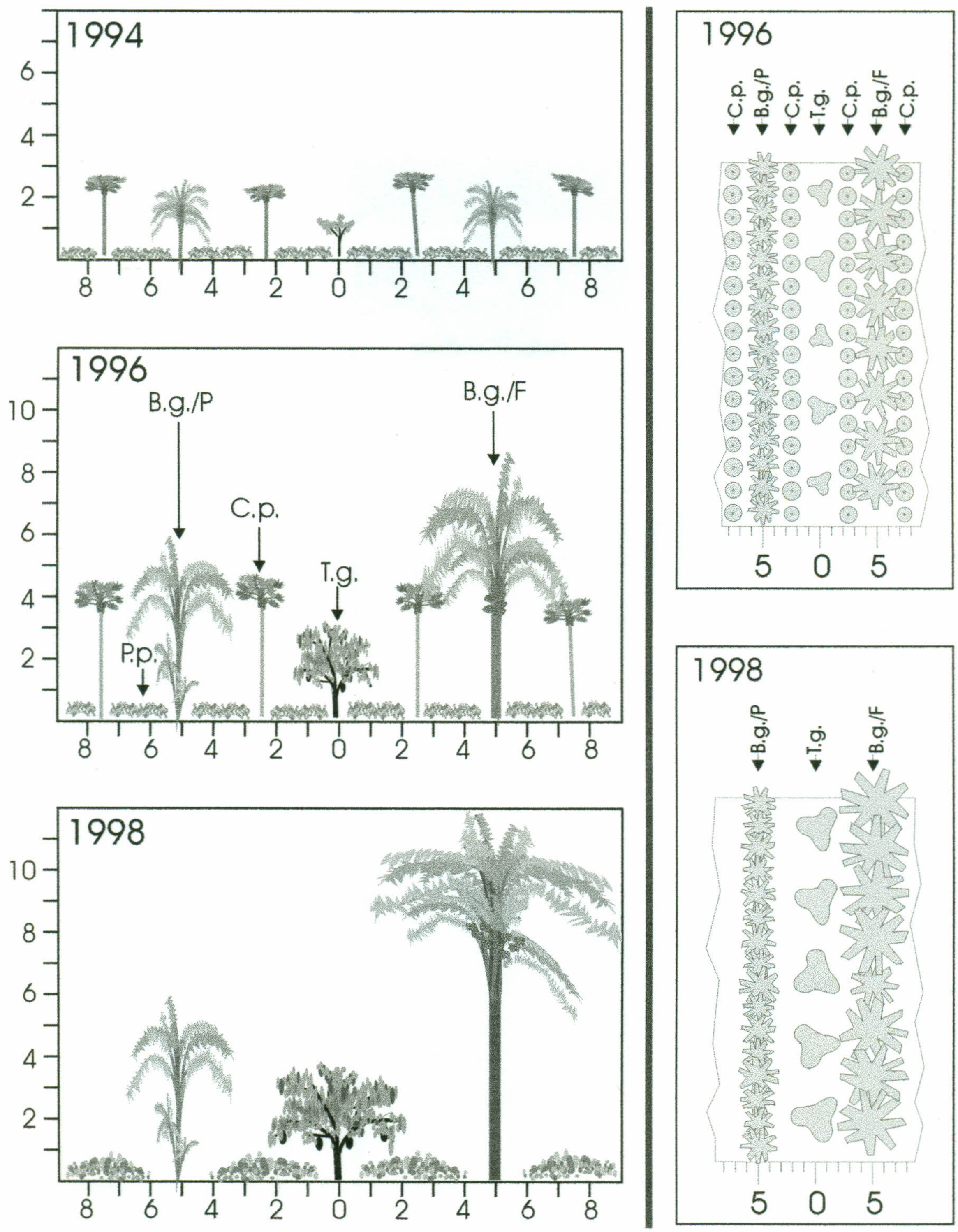

Figure 3b: chronosequence of agroforestry system No 1
T.g. – Theobroma grandiflorum; C.p. – Carica papaya; B.g./P - Bactris gasipaes for production of palmito; B.g./F – B. gasipaes for fruit production; P.p. – Pueraria phaseoloides.

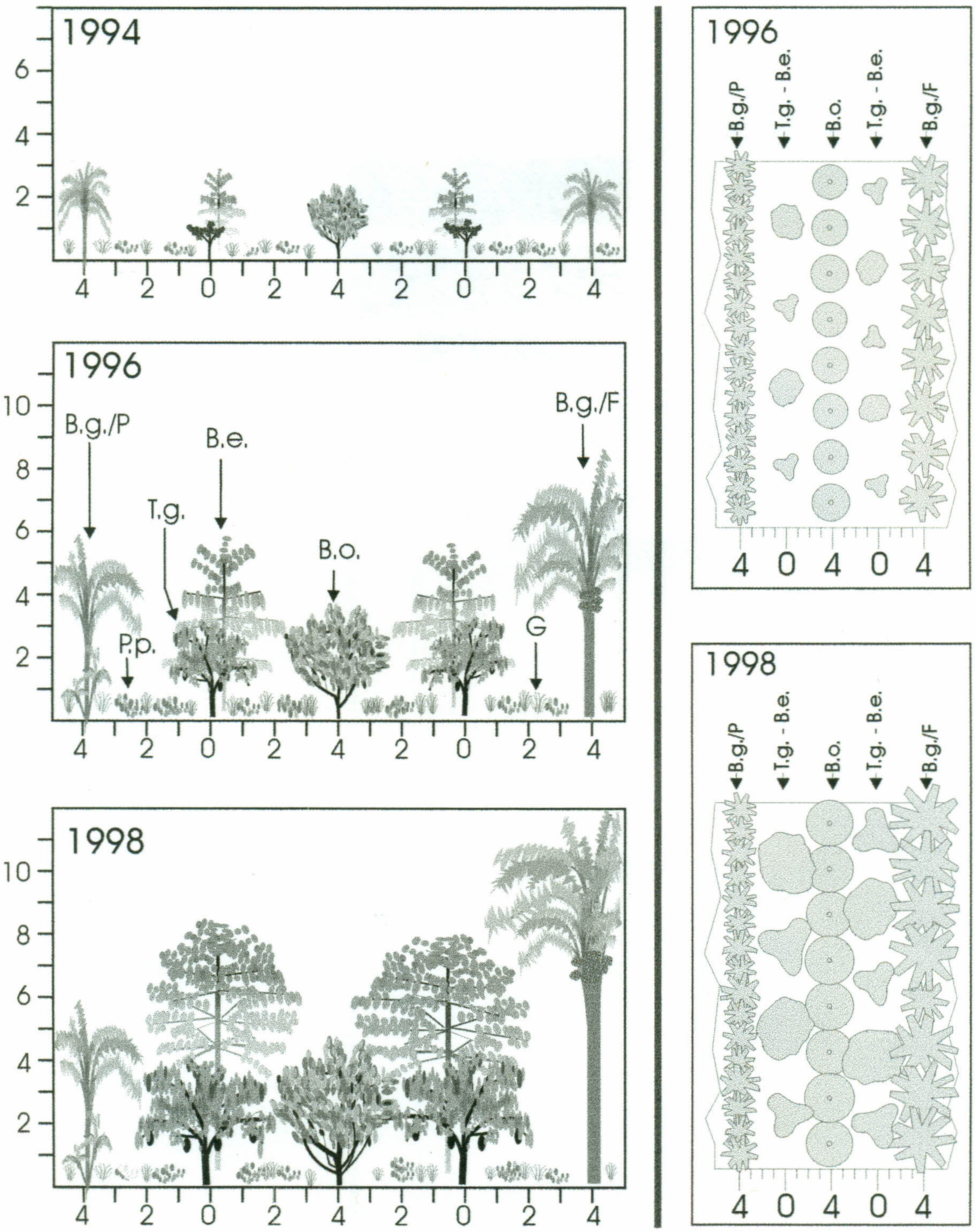

Figure 3c: chronosequence of agroforestry system No 2
T.g. – Theobroma grandiflorum; B.e. – Bertholletia excelsa; B.g./P - Bactris gasipaes for production of palmito; B.g./F – B. gasipaes for fruit production; B.o. – Bixa orellana; P.p. – Pueraria phaseoloides.; G – gramineous (mostly Homolepis aturensis).

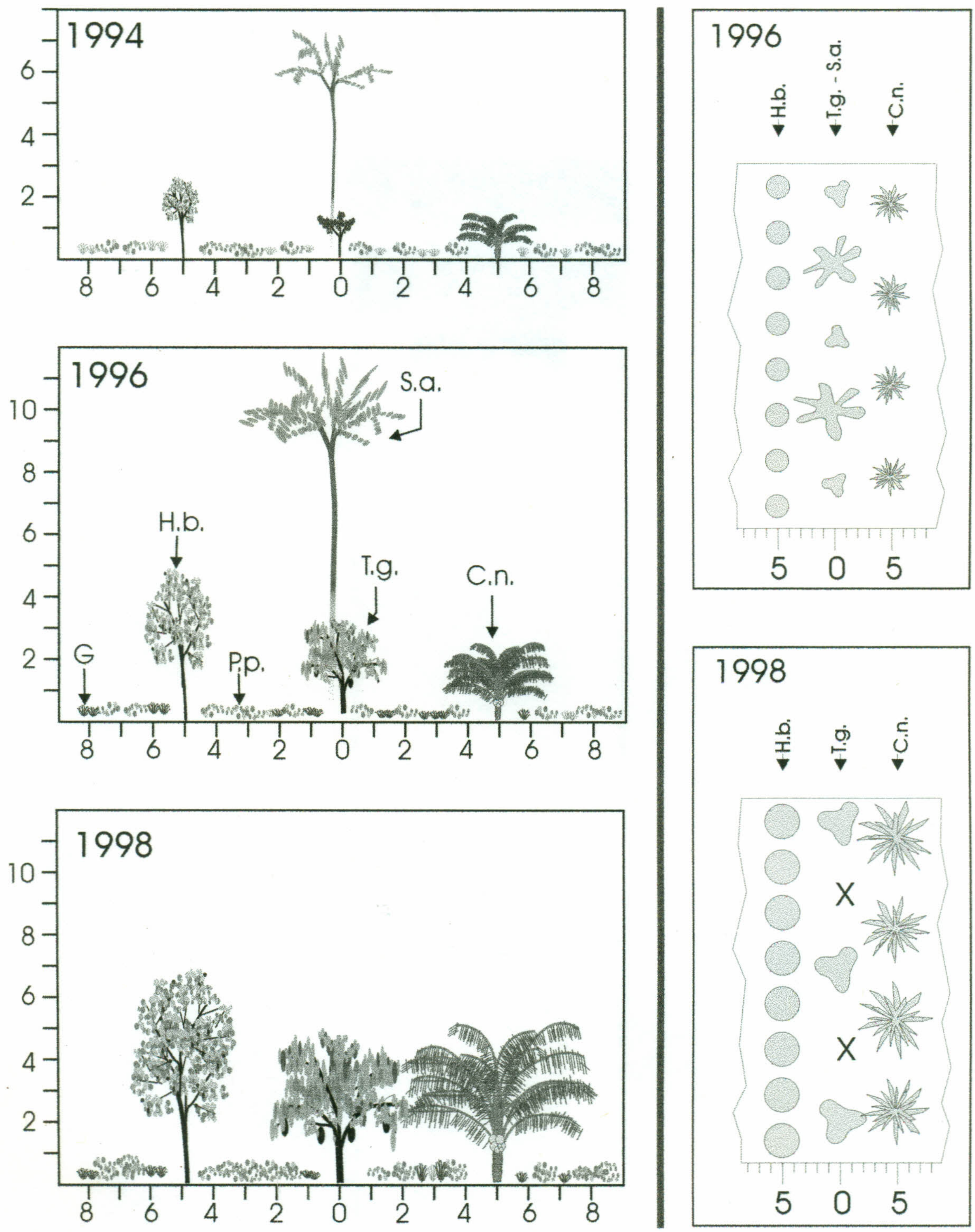

Figure 3d: chronosequence of agroforestry system No 3
T.g. – Theobroma grandiflorum; H.b. – Hevea brasiliensis; C.n. – Cocos nucifera; S.a. – Schizolobium amazonicum; P.p. - Pueraria phaseoloides.; G – gramineous (mostly Homolepis aturensis). S. amazonicum was replaced by Khaya ivorensis, Licaria canela or Calophyllum brasiliense in 1996 („X“).

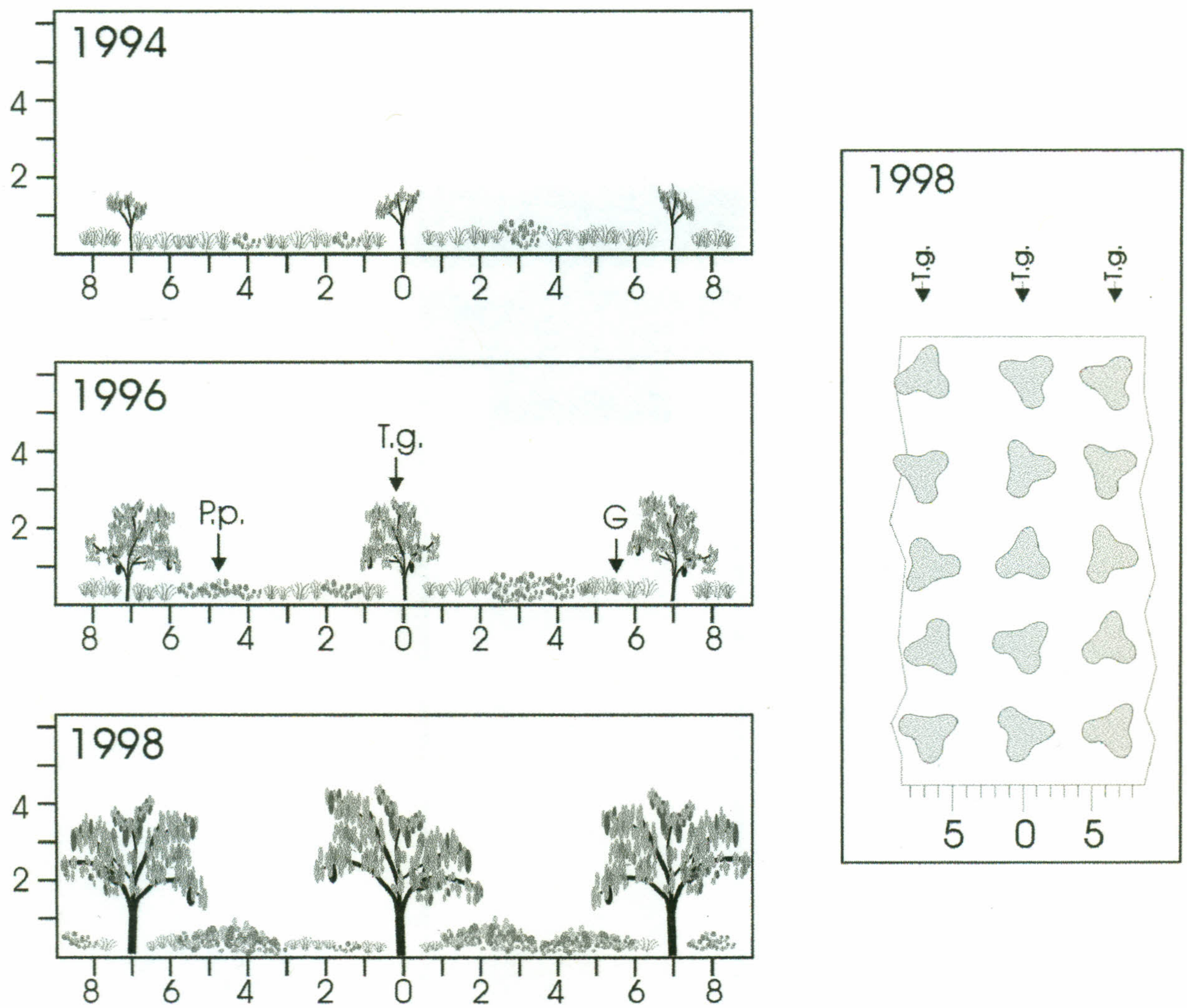

Figure 3e: chronosequence of a monoculture of cupuaçu (*Theobroma grandiflorum*)

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