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CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

IBAMA Instituto Brasileiro de Meio Ambiente e Recursos Renovaveis

BMFT Bundesministerium für Forschung und Technologie

GERMANY BRAZIL · COOPERATION IN ENVIRONMENTAL RESEARCH AND TECHNOLOGY ·

Recultivation of abandoned monoculture areas in Amazonia.

(ENV-23)

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Summary

The project concerns an experiment in recultivating a fallow rubber plantation of 19 ha by establishing mixed plantations of selected crops, mainly trees. In order to achieve sustainability, different crop combinations and different strategies for management of the spontaneous vegetation will be tested, and the crop systems will be stabilized by inoculating the plants with spores of mycorrhizal fungi. The experimental area was divided into five blocks with eighteen plots each to test four mixed cultivation systems, compared to four conventional monoculture systems. Fallow plots will be analyzed for reference. The scientific research is focused on the ecological role of mycorrhizal fungi in the field trial, analysis of the structural and functional traits of the spontaneous vegetation due to management, and identification and control of plant diseases. In addition, economic and acceptance studies will be conducted to find out whether farmers are willing to apply the tested cultivation systems.

1. Introduction

The main objective of the project is to develop an ecologically, socially and economically viable system of agriculture that is better suited to the humid, tropical conditions of Amazonia than are existing production methods. It concerns an experiment in recultivating a fallow rubber plantation by establishing mixed plantations of selected, mainly perennial, crops. The function of trees as reservoirs for nutrients and their role in the recycling of biomass in complex systems has often been demonstrated (e.g., Shubarth 1977, Sioli 1980, Burger 1986). Any scheme to recultivate fallow lands in the Amazon must take into account the pedological and soil-microbiological factors. The areas in question were originally cultivated by slashing-and-burning the primary forest, the soil structure has been altered. First soil-biological analyses in rubber plantations show a dramatic change in the populations of soil microbes (Feldmann & Lieberei 1992) and the plants show an increased susceptibility to stress. In most cases, the lands were also cleared mechanically after burning and subjected to high inputs of pesticides during the cultivation phase (Faßbender 1990).

Mycorrhizal fungi can promote the growth and health of crop plants in the humid tropics. There is evidence that young rubber trees (*Hevea sp.*) inoculated with spores of mycorrhizal fungi grow faster and are more resistant to South American leaf blight (*Microcyclus ulei*) compared with reference plants (Feldmann, 1990). But there are also other measures which can be taken to improve plant growth and health in a plantation setting.

In the 19 ha plantation, we intend to test the three following ways of stabilizing crops using different test variants and to analyze the crop systems on a scale that is close to practical conditions.

1. Inoculation of the plants with spores of mycorrhizal fungi,
2. Testing of different mixed cultivation systems,
3. Experiments on management of the spontaneous vegetation in the crop systems to improve the competitive conditions for the planted crops.

The project has its scientific basis in the field of phytopathology and mycology. However, the operational basis for implementation of the project is much broader. The existing working group is composed of scientists from EMBRAPA, Manaus, the Institute of Applied Botany of Hamburg University, the Federal Research Institute for Timber and Forestry in Hamburg and INPA, Manaus. It covers the areas of the disciplines that are illustrated in **Fig. 1.**

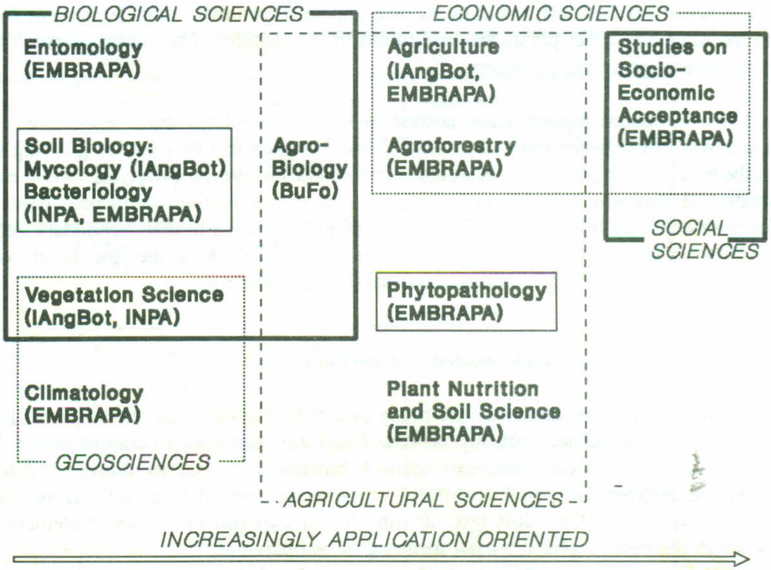

Fig. 1. Basic knowledge has been or is being accumulated in the field of mycology, bacteriology and vegetation science; application-orientedness increases in the direction of the arrow. For this reason, the acceptance studies designed to find out whether farmers in the region are in fact willing to apply the tested cultivation systems are positioned on the far right.

Scientific disciplines and institutions involved in the project "Recultivation of abandoned areas ...". IAngBot = Institut für Angewandte Botanik, Hamburg; BuFo = Bundesforschungsanstalt für Holz- und Forstwirtschaft, Hamburg; EMBRAPA = Empresa Brasileira de Pesquisa Agropecuária da Amazônia, Manaus; INPA = Instituto Nacional de Pesquisa da Amazônia, Manaus

2. Field trial

The experimental area concerns terra firme lands on the EMBRAPA site north of Manaus. The area was first cleared of primary forest about ten years ago to make way for a rubber plantation. The plantation was abandoned soon after. In August/September 1992, the approximately eight-year-old secondary forest, which had evolved, was cleared and burnt in the traditional manner. The plantation is now in the process of being established.

2.1 Planted crops and plantation systems

Fourteen species of useful plants will be planted in the experimental field (Table 1). Four different mixed cultivation systems (Systems 1-4, see Table 2) and four conventional monocultures (Systems

6-9) will 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 early years while establishing 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, cover plants (puerária) will be sown after the annual crops have been harvested.

2.2 Plantation systems and implemented test variants

The nine plantation systems described are being established in different test variants (Table 3). In systems 1-3, plants inoculated with mycorrhizal fungi are compared to control plants. The fungi were applied to all plants cultivated in system 4, but not to the monocultures. The fertilization variants include zero fertilizer, 30 % and 100 % of the recommended dose for the respective species. That gives a total of n=54 possible test variants. In our experiment we are implementing the 18 variants which promise to give the most meaningful comparisons.

Table 1: List of species planted

Common name	Scientific name	Plant family	Use
Seringueira	Hevea spp.	Euphorbiaceae	Rubber production, oil production from seeds
Cupuaçu	Theobroma grandiflorum	Sterculiaceae	Pulp (juice, ice, dessert), pods (chocolate)
Pupunha	Bactris gasipaes	Arecaceae	Fruit, palmito, fodder (leaves), food colourings (fruit flesh), weaving material
Castanha do Brasil	Bertholecia excelsia	Lecythidaceae	Brazil nuts, timber
Urucum	Bixa orellana	Bixaceae	Dyestuffs sunscreens
Côcos	Cocos nucifera	Arecaceae	Oil, copra, coconut milk, feeding stuffs (oil cake), weaving material, fibres, construction timber, particle board
Citrus	Citrus sinensis	Rutaceae	Fruit, oil, pectin
Paricá	Schizolobium amazonicum	Caesalpiniaceae	Timber, charcoal
Mogno	Swietenia macrophylla	Meliaceae	Timber
Andiroba	Carapa guianensis	Meliaceae	Timber, oil
Mamão	Carica papaya	Caricaceae	Fruit, papain, carpain, feeding stuffs
Mandioca	Manihot esculenta	Euphorbiaceae	Starch, vegetables from the leaves
Feijão	Vigna sinensis	Fabaceae	Green fodder, starch
Milho	Zea mays	Poaceae	Starch, edible oil, feeding stuffs
Puerária	Pueraria phaseoloides	Fabaceae	Cover crops

Table 2: Useful plants and plantation systems

	Plantation systems									
	mixed cultiv.				f	monocultures				
	1	2	3	4	5	6	7	8	9	
Seringueira	*		*	*		*				
Cupuaçu	*	*	*				*			
Pupunha	*	*						*		
Castanha do Brasil		*								perennial
Urucum		*								useful
Côcos			*							plants
Citrus			*						*	
Paricá			*	*						
Mogno				*						
Andiroba				*						
Mamão	*									short
Mandioca		*	*							lived
Feijão			*							useful
Milho			*							plants
Puerária	*	*	*			*	*			cover
spontan. vegetation				*	*			*	*	crops

f = fallow (for comparison)

Table 3: Plantation systems and test variants applied

n = 54	0 fertilizer		30 % fertil.		100 % fertil.		
	- myc.	+ myc.	- myc.	+ myc.	- myc.	+ myc.	
system 1			*	*	*	*	mixed
system 2			*	*	*	*	culti-
system 3			*	*	*	*	vation
system 4				*			
system 5	*						fallow
system 6					*		
system 7					*		mono-
system 8					*		culture
system 9					*		

- myc. = not inoculated with spores of mycorrhizal fungi
+ myc. = inoculated with spores of mycorrhizal fungi

2.3 Experimental area and layout of the field test

In the field test, 18 variants are being laid out in five separate, i.e. repeated blocks. The position of the variants within the blocks is completely randomized. The plots have an area of 48 x 32 m^2 each. The layout of the plots is determined by the elongated, irregular shape of the experimental area. A 100 x 100 m^2 patch of secondary forest was left standing at the edge of the area for comparative studies of the secondary vegetation.

3. Focus of scientific research

3.1 The role of mycorrhizal fungi in the field trial

The symbiosis of plants and vesicular-arbuscular mycorrhizal fungi (VAMF) has several advantages for the plants. As the VAMF improve the availability of nutrients in the soil, in particular phosphorus, their host plants often perform better than non-mycorrhizal plants (Cooper 1984). Furthermore, mycorrhizal plants are more resistant to stress induced by drought (Nelsen & Safir 1982, Müller & Höfner 1991), soil salinity (Hirrel & Gerdemann 1980), high soil temperature (Schenck & Schroder 1974) or pathogens (Dehne 1982, Feldmann 1990).

The number of VAMF propagules in the soils of abandoned monoculture areas is low (Feldmann & Lieberei 1992). An important step in the recultivation of these areas is therefore the reestablishment of effective endomycorrhizal fungi in the soil. In agricultural systems, VAMF can be introduced in the field in two ways. Perennial crops can be inoculated in the nurseries. The mycorrhizal plants will benefit from their fungal partners during the transplanting to the field. The inoculation of maize, for example, will not only be beneficial to the host plants, but will also lead to multiplication of the VA-mycorrhizal fungi in the field (Feldmann 1990). Non-mycorrhizal plants growing close to the mycorrhizal maize can also be infected in this way. In the case of contact between the mycorrhizal root of a maize plant and the roots of a non-mycorrhizal plant, the maize plant can serve as a nurse plant with regard to application of the fungus.

The development of the VAMF population and the mycorrhizal status of the plants will be monitored in the field trial and the growth and health of the mycorrhizal and non-mycorrhizal plants compared. Finally the ecological significance of the introduced VAMF will be assessed.

3.2 Spontaneous vegetation and plantation management

Before the secondary forest on the test area was cleared, a floristic study was carried out, which yielded 178 species, mainly trees. Four months after clearing and after the area had been surveyed and divided into plots, the growth form types of the spontaneous vegetation of all 90 plots of the trial were assessed quantitatively, i.e. on the basis of their respective area coverage. The patterns are the result of the historic use of the sites and of differences between sites within the experimental area.

A preliminary analysis of the data reveals very heterogeneous vegetation patterns within the plots (on a m^2 scale), but clearly distinguishable patterns in a north-south direction (from block A to block E). The following growth forms show dominance in the blocks of the experimental area as shown in Table 4.

Table 4: Growth form structure of the spontaneous vegetation in the different blocks four months after clearing

Growth forms		dominant in block(s):
Trees		A, B
Shrubs		nowhere dominant
Herbs	Tussock grasses	B, D, E
	Stolon grasses	nowhere dominant
	upright growing dic. herbs	D
	creeping, dicotyl. herbs	C, D
	Ferns (bracken)	E

A more detailed analysis of the data will be carried out later. So far the patterns are interpreted as patterns of different intensity of use or as differences in intensity and frequency of disturbance. Although these differences will in part be canceled out by subsequent management measures, the vegetation differences observed are important as they represent the starting conditions of the experiment and must be included as site differences in the final trial evaluation.

The spontaneous vegetation which regenerates or colonizes the space between the plantation crops can, on the one hand, constitute competition for the crops (light, nutrients, space), in which case it must be suppressed. On the other hand, the wild vegetation can be an important store of nutrients, which become available to the crops after dieback and mineralization of the biomass. Whether these two opposed processes can be optimized in favor of the crops by appropriate control of the wild vegetation, is a question that is to be examined.

Basically there are three ways of controlling growth of wild vegetation (Fig. 2). First, the secondary vegetation is allowed to regenerate, but is occasionally cleared from the space immediately around the crop plants. In this case mainly trees, i.e. long-lived growth forms, would benefit. The species spectrum would be compressed owing to the occasional disturbance. The second way, the cultivation area is kept free of taller growth forms, i.e the regeneration of secondary forest species is frequently disturbed. In this case the long-lived herbs and grasses would benefit. Third, the herb species with creeping growth forms are sown, e.g. Pueraria. This would lead to a dense undergrowth of one or very few species.

The three different ways of treating the undergrowth favor different eco-morphological plant types or strategy types. According to Grime (1979, 1988), sowing favors fast-growing types with a high nutrient requirement (Competitive Ruderals), frequent cutting and hoeing favors short-lived herbaceous species and species which can regenerate quickly from the buds at the soil surface (Ruderals and CSR strategy types) and minimum management favors regeneration of part of the species spectrum of the secondary forest.

In the field experiment cover plants will be sown in most of the test variants, because of the positive farming experience that exists with this method. The exception is System 4, where secondary vegetation will be tested as cover crop.

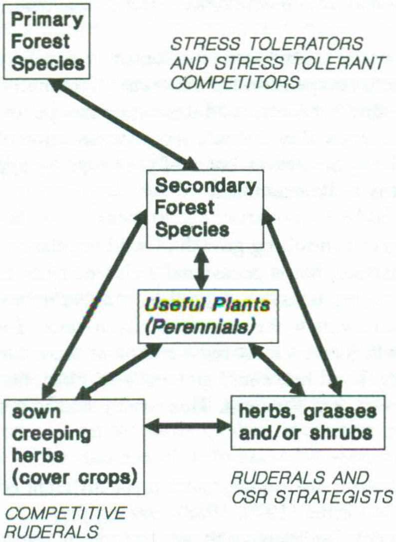

Fig. 2. Three ways of controlling wild vegetation in the plantation. The arrows indicate different competitive situations due to management

3.3 Control of plant diseases

Perennial mixed cropping systems favor conditions similar to those prevailing in primary forest, where non-host species act as a barrier to the spread of pathogen spores by wind and rain.
The species used in the experiment, in particular Seringueira, Cupuaçu, Citrus and Urucum are affected by diseases requiring control measures. In the mixed cropping and monoculture systems established in the field trial, the course of the main diseases will be assessed, unknown pathogens isolated and identified, and the occurrence of hyperparasites recorded.
Fungicides will be used as little as possible. Disease intensity will be monitored in order to decide when protective measures must be taken to ensure the survival of the plants.
The main diseases affecting seringueira are South American leaf blight (*Microcyclus ulei*) and target leaf spot (*Thanatephorus cucumeris*), which can be controlled with Triadimenol (7.5 g a.i./100 l water). Crown budding will be carried out when the plant stems (brown part) reach a height of 2.20-2.50 m, i.e. the crowns of the Fx 4098 clone will be replaced by PA31 crowns, thus eliminating the need to use fungicides.
Cupuaçu is susceptible to witches' broom (*Crinipellis perniciosa*), which will be controlled by periodic pruning. Urucum can be infected by *Oidium sp.*, which has to be treated with Benomyl (50 g a.i./100 l water). The main problem in citrus is the fungus *Phytophthora spp.*, the active agent of foot rot. The plants die if action is not taken. Preventive measures such as pruning to improve ventilation, and painting of the trunk with copper-based fungicides in the period September-November, must be taken.