NATURAL SUCCESSION OF SPECIES IN AGROFORESTRY AND IN SOIL RECOVERY

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August 1992

ABSTRACT

This paper describes a method for the rapid recovery of degraded soils and for sustainable agroforestry in the humid tropics. The method, in essence, is an attempt at imitating the natural process of species succession. I have devised means of accelerating the process through strategic interventions. The net result of these practices is that, in only five years of time, completely degraded soils now support highly productive and diverse agroforestry systems. Evidence is presented that, even in regenerated soils, the dynamics of natural species succession play an important role in ensuring the health and vigor of crops.

Key words: Agroforestrv; soil recovery; species succession; sustainable agriculture.

INTRODUCTION

Modern agricultural techniques (monocropping, usually combined with the use of herbicides and pesticides and mineral fertilizers) lead to a very rapid loss of soil fertility in the humid tropics. Similarly, shifting cultivation, the practice of traditional farmers, is no longer viable as, due to population pressure, soil recovery periods are becoming increasingly short, entailing a decrease in productivity. One possible alternative to conventional agriculture is agroforestry, the practice of combining trees with crops and/or pastures. Sustainable agroforestry has been practiced by many Indios in the Americas and by small farmers all over the world for thousands of years. In spite of attempts at adapting traditional agroforestry to modern agriculture, there has not, to my knowledge, been a breakthrough inthe development of a form of sustainable agroforestry capable of meeting the needs of the1990's and of the 21st century.

I outline below a method by which abandoned pastures with completely degraded soils can be turned into highly productive and biodiverse agroforests after only five years. The system allows for a high degree of exploitation while maintaining and even increasing biodiversity. The practices described below lead to a rapid recovery of poor soils without the use of fertilizers. Finally, costs are very low as neither pesticides or herbicides, nor heavy machinery are required and as the method is not labor intensive.

The method, in essence, is an attempt at imitating nature. In nature, most plants live in association with other plant species, and require these other plants for optimal growth. Similarly, in my agroforests crop species are planted in association with other plants similar to those with which they would normally occur in nature. Furthermore, in nature plant associations or consortiums succeed one another in a dynamic ongoing process called natural succession (see Table IV). Destroyed, depleted or leached out sites are colonized by pioneer plants. Pioneers are succeeded by secondary forest species which are, in turn, succeeded by primary forest species. Similarly, and as is commonly practiced, pioneer plants are used to recover soils in the initial phases of the plantation. More importantly, the dynamics of natural species succession are also used at later stages as a driving force which ensures the health and vigor of the plants.

DESCRIPTION OF THE PROJECT

Geography and organization of the farm

The site: the farm has an area of 480 acres in the South of Bahia, Brazil, in a region which used to be Atlantic rainforest but which has been significantly altered by timber extraction and shifting agriculture (primarily manioc, Manihot sp., cultivation). The site was selected because of two unique features: it contains the last stand of primary atlantic rainforest in the region and is a hydrographic basin with 25 creeks, 17 of which originate on the site itself.

Vegetation: As many native species are important in our agroforestry systems, I have listed and briefly described the most common species of the local natural vegetation in Table I.

When I acquired the land eight years ago. roughly 140 ha were reasonably well conserved primary forest. In the canopy, trees were 35 to 40 meters in height and adult trees had boles 70 to 100 cm in diameter, with the exception of one species which had boles up to 150 cm in diameter. Orchids and Bromeliads occurred in abundance in the crowns. Palm-trees, Jussara (Euterpe edulis Mart.) and Buri (Diplothemium caudescens Mart.), were frequent in the spring areas of creeks.

Another 140 ha were forest that had been heavily exploited for timber but had never been burnt. Eight years ago, the canopy of these secondary forests was dominated by one species, the fast growing pioneer tree mundururu (Miconia sp.) which reaches a height of up to 25 meters. The mundururu have since been substituted by tree species transitional to primary forest.

The remaining 200 ha were abandoned pastures and fields whose soils had been depleted and leached over a period of at least 120 years by repeated cycles of manioc cultivation, pasture periodically cleaned by fire, and brief abandonment for natural recovery. The poorest sites were covered, almost exclusively, with fern and two species of grass, Imperata bradiliensis and Antropogon bicornis, which are all indicators of acidic, aluminum-rich, nutrient-poor soils. Partially recovered pastures had turned into poor secondary forests. These secondary forests were composed of relatively few species of vines and herbs and mainly two pioneer tree species, fumo bravo (Aegiphila sellowiana Cham.) and capianga (Vismia guianensis Choisy).

The terrain had formerly been occupied by small farmers who raised pigs in the lowlands and cultivated manioc on the hill slopes. On both sides of the public road they had a belt of 100 to 200 m of pasture. Due to the decreasing productivity and, in their words, "poor soils", the small farmers left the site.

Soils: in this region, oxisoils predominate at lower elevations near the creeks whereas ultisoils predominate on the slopes and hill-tops. Both types of soils are very acidic, with pHs between 4.2 and 5.0.

Life-zone: the climate is characteristic of tropical premontane moist forest. The average rainfall over the last five years was 1400 mm. The average temperature is 25 C in January and 21 C in July.

Actual situation: 100 hectares of the farm have been cultivated. These parts were mostly abandoned pastures and fields with degraded, nutrient poor soils with a low pH, trace amounts of available phosphorous, and low contents of Ca and Mg. The 65 ha of the plantation which were planted first are now taken care of by eleven small farmers, each running a parcel of 5 to 6 ha and living from his operation. 90% of each farmer's production is his and 10% is the share of the farm. The farmers receive continuous training and assistance to ensure that they adequately apply the methods and strategies developed on the farm. The oldest 65 ha of agroforestry systems are highly productive and economically viable, in spite of the present economic crisis in Brazil and, in particular, the recent drop in the price of cocoa.

Crop species are listed in Table II. Native and crop species are listed in Table III in the sequence in which they would occur in the process of natural soil recovery.

Alternatives to the use of fertilizers, herbicides and pesticides

No external fertilizers are introduced into the plantation, but all efforts are made to recycle and to increase the amount of organic material produced by the plantation itself. When plants are pruned, cut back or removed, the dead material is placed on the ground as mulch, which both protects and enriches the soil. An additional practice is the use of certain plants which have multiple beneficial effects on the soil. The herbaceous species capeba (Pothomorphe umbellata L.), for instance, stimulates earthworms to reproduce and to increase their activities, which in turn improves the structure and pH of the soil as well as its capacity to retain water.

"If soil scientists were to rank factors crucial to the maintenance of the fertility of deeply weathered and leached tropical soils, organic matter would likely head most lists." (Ewel 1986).

To diminish the share of spontaneously occurring species in the total vegetation normally plant at a high density, and also introduce polycultures which, in time, will fill all the available spaces. Furthermore, some so called "weeds" are, in fact, beneficial for the I crops and are not removed (see selective weeding, below). Paradoxically, although we neither mow nor cut weeds indiscriminately, nor do we use herbicides, we do not require more labor per unit area than do conventional cocoa farmers (compare one worker for three to four hectares in conventional plantations as opposed to one worker for four to five hectare in our agroforests).

As insects prefer native species to crop species and weak plants to vigorous ones, one of the most effective weapons against insect attack is to ensure the vigor and health of the plantation. Additional strategies aimed at keeping insects away from the crops include planting a number of species which either repel or attract insects. The native tree Pau Pombo (Tapirira guianansis Aubl.), for example, attracts insects because of its tender, palatable and abundant leaves and thereby keeps them away from crop species. As another example, the bean feijão de porco (Canavalia ensiformis L.) serves as a very effective repellent for the notorious leaf cutter ants, keeping them away from entire plots.

THE RECOVERY OE IMPOVERISHED SOILS BY IMITATING AND ACCELERATING NATURAL SUCCESSION

Establishment of the method by trial and error

The development of the above outlined method for soil recovery and for sustainable agroforestry in the humid tropics is the result of a long process of trial and error. I first came into contact with the humid tropics 16 years ago, upon arrival in Brazil. I was disturbed by the contrast between the stark poverty of the cultivated lands and the wealth of the nearby tropical rainforest. This contrast moved me towards my first attempts at designing and planting agroforestry systems in central Europe.

I then came to Costa Rica (1979-1982) and developed a program of reforestation employing the strategy of alley-cropping. I planted rows of leguminous trees such as Leucaena, Inga and Erythrina, alternated with rows of fruit trees such as banana, Governor palms, Caimito, Zapote, etc. The space between the rows of fruit trees and alleys was used to cultivate annual crops (corn, beans, manioc, and vegetables). This system was not entirely successful in that it relied on the use of fertilizers and in that, in the second and third years, the trees inhibited the growth of the annual crops in their immediate vicinity without substituting for them in terms of productivity.

I therefore made a second attempt at agroforestry, combining mainly four fruit trees -bananas, cocoa, avocado and pupunha - together with Erithrina, Inga and other leguminous trees for shade. This system, forest/orchard plantation, did reasonably well in the fairly rich soils of Costa Rica and of Itabuna, Brazil, but did not function in the poor soils of abandoned pastures of this farm.

I then worked to improve these impoverished and depleted soils by first planting four pioneer species (manioc, cow peas, Erythrina and Inga) known to do well in the poor soils of the region. Of these, only the manioc successfully established itself, but still developed poorly.

A large number of native pioneer plants, however, grew vigorously in the new plots. I therefore chose to be selective with respect to those plants which I weeded out. I removed only those grasses, herbaceous species and vines which had come to mature or which had been substituted by cultivated species. All other native herbs, trees and palm-trees were allowed to grow and to fulfill their important function in improving the soil. The cultivated plants now grew well in the presence of the native species. This is how I came to the practice which can be described as **selective weeding**.

I now try to take full advantage of the biological and genetic potential of the flora and fauna which occur spontaneously on the plots. Many invading native plants are, if properly managed, excellent companion plants, as they are well adapted to the existing edaphic conditions. When young, they stimulate the growth of the crop species and fend off pests and diseases. They also protect and improve the soil, or indirectly correct its pH, as in the above example of capeba. In addition, they increase the organic matter of the soil, constituting a valuable source of fertilizer.

After two years of selective weeding, however, I observed that the cultivated plants showed signs of decreased growth. It appeared that the maturing native tree and shrub species which had germinated in the plots two years back were now inhibiting the growth of the crops. This proved to be the case as, once mature pioneer trees and shrubs were cut back entirely (if substituted by crop species) or pruned by (1) cutting all mature plant parts and (2) thinning out crowns by cutting 50% or more of the branchlets, the entire plant community was invigorated and burst into new, rapid growth. This is how I came to the practice of **pruning**.

Pruning has multiple effects on the plantation:

• The most important one is that it accelerates the rate of growth of the whole plantation by rejuvenating maturing plants. (I have observed that, in its phase of vigorous growth, a plan stimulates neighboring ones to grow and that, once a plant of the dominant plant consortium within the succession matures and senesces it induces others around it to exhibit signs of maturity, such as yellow leaves and growth arrest, and eventually of senescence, such as increased susceptibility to fungal and microbial infection, or to pests [the reason for this the subject of further research]).

• The dead material generated by pruning is placed on the ground as mulch which both protects and fertilizes the soil.

• Pruning indirectly produces beneficial changes in the soil, as monitored by changes in soil texture and in the abundance of earthworms.

• Pruning also increases the amount of light available to the future generation of plants.

• Pruning also serves, as an instrument for speeding, intervening and directing the organic process of succession by the possibility it offers to influence each plant individually in term of access for light, space and leaf area.

Finally, periodic rejuvenation by pruning prolongs the lifetime of short lived pioneer species, thereby enhancing their ability to improve the soil.

The current practice, in summary, is as follows: on the one hand, maturing trees shrubs are rejuvenated by pruning and mature plants which have fulfilled their function in improving the soil are cut back or removed altogether. On the other hand, potentially each plant of the community is pruned in order to influence and control access for light and space on an individual basis.

Species composition, plant density, and the timing of the introduction of each species

"A successional crop system is not just a chronological sequence of crops. As in natural succession, each successional crop stage produces the physical environment required by the next successional process." (Hart 1980).

When the new cacao trees which I had first planted began to bear fruit I observed, to my surprise, that those plots which initially had richer soils were less productive than those which initially had poorer soils and vegetation. In sites with initially richer soils, the cacao and banana trees had grown vigorously during the first three to four years in the shade of the abundant and vigorous corindiba and imbauba branca. Once these secondary forest trees had matured and therefore been cut back, however, the cacao did not bear fruit and the banana died back. Furthermore, both showed signs of increased susceptibility to insect and pest attack. Those cacao and banana trees that occasionally were in the shade of a tree transitional to primary forest or a primary forest tree were healthy and highly productive. (These future shade trees had been planted at what was to be their final distance from one another, taking into account the diameter of the crown of the adult tree, i.e. 12 to 18 m).

By contrast, on the plots with initially poorer soils, bananas did not establish themselves, nor did their counterparts in the natural vegetation such as Corindiba and Imbauba branca, come up spontaneously. On the plots with poorer soils, the poor vegetation and open spaces had challenged me to plant, at a high density, a large number of species known to do well under similar conditions: I planted pioneers to improve the soil and fruit, nut and timber species to ensure medium and long term yields.

This operation was highly successful, but only in those places where we had heavily pruned or cut back the bigger individuals of the already established vegetation before introducing the new ones. There the whole plant community began to thrive and now represents the most productive parts of the plantations.

It therefore appeared that the critical factor in determining the health, growth rate and productivity of the system was not the initial quality of the soil, but rather the composition and density of individuals of the plant community and the presence of a future generation of plants.

It also appeared that the order in which crops were planted was important, for most species only grow vigorously if they enter the flow of species succession in such a way that they can come to dominate (see Tables III and IV). This is illustrated by the following example in which four species were grown together on the same plot:

1) Manioc (Manihot sp.), a herbaceous annual pioneer plant with a life cycle of one to two years;
2) Corindiba (Trema micrantha), a pioneer tree with a life cycle of four to six years;
3) Inga (Inga sp.), a leguminous pioneer tree transitional to the virgin forest with a life cycle of 20-80 years; and
4) Caimito (Chrysophyllum cainito), a virgin forest fruit tree with a life cycle of 200 years.

These four species grew vigorously if they were planted in the order in which they are listed, which is the order in which they would succeed each other in nature, and if each species was planted when the preceding one was established and in the beginning of its phase of vigorous growth. If the four species were planted simultaneously they did fairly well, but the inga and caimito had difficulties establishing themselves. A caimito could successfully be introduced beneath fully established manioc, corindiba or inga trees but the reciprocal combinations were not successful. Inga, for example, did not establish itself beneath a fully developed caimito, though it grew well in the shade of a vigorous manioc plantation or a corindiba or both combined. Similarly, the corindiba failed even to germinate under a fully developed inga or caimito though it thrived in the shade of a vigorous manioc plantation. In conclusion, the critical factor for the establishment and development of a plant is not as much the factor light as the order and timing of its introduction in the natural succession.

I concluded from these observations, since repeated numerous times, that the most successful plots were those in which I had best imitated the natural process of species succession, described below.

The above observations suggest that natural **species succession is the driving force in natural systems.**

Species succession in nature

Diverse forms of flora and fauna have occurred and developed on our planet in the course of time. They have adapted to every situation and occupy the maximum amount of space. The living beings of each place and in each situation form consortiums in which each member contributes with its particular capacity to improve and to optimize its conditions as well as those of members of its consortium to grow, prosper and reproduce. Each consortium gives birth to a new consortium, different in composition. At a given place, the different consortiums function as a macroorganism of high complexity undergoing a process of continuous transformation. Each consortium within this macroorganism is determined by the preceding ones and will determine the following ones. This ongoing process is called natural species succession. (This is illustrated with a few selected species in Table IV).

Plants in their phase of exuberant growth stimulate and activate all members of the plant community-in their vicinity. Similarly, mature and senescent plants of the dominant consortium induce all neighboring plants to stop growing and to mature, and to show signs of senescence atypical for their stage of development.

When, as is often the case, two plants of different consortiums in a community germinate simultaneously, that of the dominant consortium will direct the growth of the other one, which will only come to dominate when its consortium becomes the dominant one. Only when the dominant consortium has matured and died will the succeeding consortium dominate land will a new cycle of growth and death begin.

In nature, pioneer species capable of growing in poor soils colonize open spaces such as forest clearings or abandoned pastures. These pioneers, mostly grasses and herbs, improve the soil, making it possible for secondary forest species to grow. The secondary forests undergo several cycles, during which the life time of the dominant species gradually increases from 3 to 15 to 30 and up to 80 years. The secondary forest species create soil conditions conducive for the growth of longer lived virgin forest species, with life cycles of roughly 200 years (see Tables III and the vertical axis of Table IV).

In the recovery of poor soils the dominant species in the succession are generally ones which have a high content of lignin and which produce small seeds and large amounts of organic matter which does not readily decompose. Such species are listed to the left in Table IV. Once these species have died, they are replaced in the next cycle by species with a higher protein content and whose carbohydrate, instead of being fixed primarily in lignin, is also stored as starch or sucrose. As a result, such species are preferred by animals ,as they often also have larger fruits and seeds) and are overall characteristic of a lusher vegetation. This natural progression in the succession (represented along the horizontal axis in Table IV) is favored and accelerated by the effects of herbivores, wind, lightning and flooding and are duplicated in our agroforestry systems by practices such as selective weeding and pruning.

Natural succession as a driving force in agroforestry

"One way to develop sustainable agroecosystems may be to imitate the structure and the function of natural communities" (Ewel 1986).

"A crop system designed by the natural ecosystem analog approach must include successional stages analogous to natural succession" (Hart 1980).

In nature the recovery of depleted soils by species succession may take up to centuries, but may exceptionally occur in a much shorter lapse of time in the same type of soil and climate. The critical factors in determining the speed at which natural recovery occurs are:

• the composition of the plant community,
• the order in which species appear,
• the timing of the appearance of these species for each cycle,
• the nature of their interactions with microorganisms and wild animals,
• and climatic factors.

I have therefore devised ways of optimizing the contributing factors and of accelerating the process, as follows:

• First, I identify the optimal species, consortiums and successions of consortiums that occur in similar soils and climates. I plant these species or substitutes thereof in their natural consortiums.

• Second, I introduce species which have (a) have beneficial effects on the soil, (b) help keep insects away from the crops, or (c) do both (examples are given under the heading "Alternatives to the use of pesticides, herbicides and fertilizers").

• Third, I identify the optimal timing of the initiation of each cycle, i.e. the planting of a new consortium, so that each species will find optimal conditions to establish and grow, and finally to come to drive the growth of the community.

• Fourth, I accelerate the growth-rate and the progression of the succession by pruning and removing plants once they begin to mature and therefore have accomplished their function in improving the soil (see Table IV).

Each step is an attempt at entering and being carried along by the stream of life called the natural succession of species.

If we want to imitate the natural process of species succession, or to successfully intervene in natural forests, we need to have an intimate knowledge of the biotope in which we wish to interfere. We need to identify the niches of the plants we intend to cultivate as well as those we wish to remove, and we must strive to understand the interactions of these crop and native species with all other elements of the community.

It would be difficult to design and to plant an optimal consortium of plants in which all parameters are taken into account. Help comes from the local species, often called "weeds", that come up spontaneously in the plots. These fill in many of the niches which have, either temporarily or permanently, remained unoccupied by the cultivated plants. By pruning or removing only those plants which are maturing or which are being substituted by ecophysiologically similar species of the future generation, we can intervene in the succession at each location and at all points in time. Natural local species and invading plants, therefore, complement the cultivated species and help us to overcome many a weak point in the plantation (see Table IV).

CONCLUSION

My experiences in the development of agroforestry systems have reconfirmed the critical importance of understanding and duplicating the model of natural succession in the! design of long term sustainable agricultural systems as well as in recreating natural forest areas.

In order to apply the above method to other regions of the humid tropics, an intimate knowledge of the local flora and fauna is required. It is my experience that many older members of rural communities and small traditional farmers are familiar with native species of their regions. They still have remnants of the knowledge indigenous peoples had of the uses of plants for food, medicine, construction and various other purposes and are familiar with the nature of interactions between different plants.

Proximity to a virgin forest fragment was beneficial for this work but is not an indispensable requirement for the success of the method, as most native species can be substituted by ecophysiologically similar cultivated ones.

In order that the extraordinary potential of native species be available, alternative technologies must be developed and adapted while islands of preserved forests still remain, and seed banks must be developed.

ACKNOWLEDGEMENT

This work was made possible by the investment of the generous Swiss architect Hans Koella. I am especially grateful to Farhah Assaad for stimulating discussions and for her active participation in writing and organizing the text. Thanks to Michael Jenkins for useful suggestions and help with the terminology and to a number of friends for critical comments on the manuscript. I am very grateful to many local workers, especially Carlos Mora of Costa Rica and Braulino Alves da Cruz and Alwino Hilario de Jesus of Brazil who taught me a lot about the local vegetation. Thanks to Dr. Tosi and Dr. Holdridge for their support and encouragement throughout my time in Costa Rica. Klaus and Monica Nowotny, Dr. W. Schaumann, Christof Kremp, Thiery Arnault and Didier Bloch have been of great assistance in writing about and disseminating our work. I am grateful to many visitors for their work on the farm. I am especially grateful to Peter Hinn for his active participation in our work and for his research on measuring the productivity of the farm. Thanks to Mme. Dianne Perrot for her commitment and assistance. And thanks to my wife, Renate, and children, without whose efforts and support this work would not have been possible.

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EPILOGUE

Upon observing the growth of plants in my agroforest systems and natural forests, I have come to understand that natural succession is a force intrinsic to life; The nature of life is to grow, to occupy a maximum amount of space, and finally to propagate itself, transforming itself from one form to another. The succession of species is but the means by which life moves through time and space as one life form gives birth to another.

TABLE I: Native plant species of the region.

VULGAR NAME	DESCRIPTION	USE	FAMILY	NAME
Aderno	tree	hardwood	Icacinaceae	Emmotum nitens Miers
Aderno-de-caipora	tree	construction wood	Pretaceae	Roupala sp.
Assa-peixe	herb	pioneer, medicinal	Asteraceae	Verbesina macropbylla Blake
Baunilha-da-Bahia	climber	spice	Orchidaceae	Vanilla palmarum Lindl.
Bomba d'agua	tree	furniture wood	Tiliaceae	Hydrogaster trinerve Khulm.
Brede-de-reado	herb	edible leaves	Phytolaccaceae	Phytolacca thyrsifolia Fenil.
Buri	palm tree	oil seeds	Arecaceae	Diplothemium caudescens Mart.
Calumbi-vermelho	climber	pioneer	Mimosaceae*	Mimosa sp.
Caminho-de-roca	herb	pioneer	Asteraceae	Vernonia scorpioides Pers.
Capeba	shrub-like	benificial for soil, medicinal	Piperaceae	Pothomorpbe umbellata L.
Capianga	tree	pioneer, firewood	Clusiaceae	Vismia guianensis Choisy
Cipo ferra	vine		Sapindaceae	Paullinia termata Radlk.
Cipo verdadeiro	climber	aerial root for construction	Araceae	Philodendron sp.
Coarana	shrub	pioneer	Solanaceae	Cestrum laerigatum Schlecht.
Cocao	tree	construction wood	Erythroxylaceae	Erythroxylum sp.
Corindiba	tree	pioneer	Ulmaceae	Trema micrantha Blume
Fetao	herb	pioneer	Dennstaedtiaceae	Dennstaedtia circutaria Moore
Fidalgo	tree	pioneer, construction wood	Verbenaceae	Aegiphila sellowiana Cham.
Fruto-de-paca	tree	medicinal	Flacourtiaceae	Carpotroche brasiliensis A. Gray
Gameleira	tree	benificial for soil	Moraceae	Ficus sp.
Imbauba-branca	tree	pioneer	Moraceae	Cecropia hololeuca Miquel
Imbauba-vermelha	tree	pioneer	Moraceae	Cecropia cinerea Miquel
Imbirucu	tree	soft wood	Bombacaceae	Bombax macrophyllum K.Schum.
Inga-mirim	tree	pioneer	Mimosaceae*	Inga marginata Willd.
Ingaucu-preto	tree	construction wood	Cesalpinaceae	Sclerobium chrysophyllum Poepp. & Endl.
Inhaiba	tree	hardwood	Lecythidaceae	Holopyxidium sp.
Jacaranda-violeta	tree	timber	Fabaceae*	Dalbergia nigra Fr. Allem

VULGAR NAME	DESCRIPTION	USE	FAMILY	NAME
Janauba	tree		Apocynaceae	Himatanthus lancifolius Woodson
Jangada-preta	tree		Annonaceae	Rollinia sp.
Jequitiba-rosa	tree	noble wood	Lecythidaceae	Cariniana legalis O.Kuntze
Juerana-branca	tree	soft wood	Mimosaceae*	Pithecolobium pedicellare Benth.
Jussara	palm	heart of palm	Arecaceae	Euterpe edulis Mart.
Louro-graveta	tree	soft wood	Lauraceae	Nectandra sp.
Louro-tapioao	tree	noble wood	Lauraceae	Persea sp.
Mamao-de-veado	tree		Caricaceae	Jacaratia sp.
Marcela	herb	pioneer	Asteraceae	Achyrocline satureoides D.C.
Mundururu-vermelho	tree	pioneer	Melastomataceae	Miconia calvescens DC.
Pati	palm	oil seed, construction wood	Arecaceae	Barbosa pseudo-cocos Becc.
Pau-d'alho	tree	construction wood	Phytolaccaceae	Gallesia scorododendron Casar
Pau d'arco bico de saracura	tree	noble wood	Bignoniaceae	Tabebuia sp.
Pau-oleo-copaiba	tree	medicinal, construction wood	Caesalpinaceae	Copaifera multijuga Hayne
Pau-pombo	tree	insect fodder	Anacardiaceae	Tapirira guianensis Aubl.
Pequi-amarelo	tree	construction wood	Lythraceae	Lafoensia pacari St.Hil.
Pequi-de-capoeira	tree	construction wood	Melastomataceae	Tibouchina elegans Cogn.
Pequi-preto	tree	construction wood	Caryocaraceae	Caryocar edule Casarreto
Piinenta-malagueta	shrub	spice	Solanaceae	Capsicum frutescens
Pindaiba	tree		Annonaceae	Guatteria sp.
Pororoca	tree	pioneer	Myrsinaceae	Rapanea sp.
Rabo-de-raposo	herb	pioneer	Poaceae	Andropogon bicornis L.
Sape	herb	pioneer	Poaceae	Imperata brasiliensis Trin.
Solteira	tree	pioneer	Melastomataceae	
Tararanga-lisa	tree	fruits	Moracea	Pourouma acutiflora Trecc.
Tritica-fino	herb	pioneer	Cyperaceae	Scleria pterota Presl.

*: legume

TABLE II: Crop species

VULGAR NAME	DESCRIPTION	USE	FAMILY	NAME
Abacate (avocado)	tree	fruit, oilseed	Lauraceae	Persea americana
Abacaxi (pineapple)	herb	fruit	Bromeliaceae	Ananas comosus Merril.
Banana da prata	herb	fruit, beneficial for soil	Musaceae	Musa sapientum L.
Batata-doce (sweet potato)	creeper	tuber	Convolvulaceae	Ipomoea batatas Poir
Baunilha-bourbon (vanilla)	climber	spice	Orchidaceae	Vanilla planifolia Andr.
Biriba	tree	fruit	Annonaceae	Rollinia mucosa
Cacau (cacao)	tree	almonds	Sterculiaceae	Theobroma cacau L.
Cacau-tigre	tree	almonds	Sterculiaceae	Theobroma bicolor Humb. & Bampl.
Caimito	tree	fruit	Sapotaceae	Chrysophyllum cainito L.
Capim elefante (elephant grass)	herb	fodder plant, pioneer	Poaceae	Pennisetum purpureum Schum.
Chuchu	climber	vegetable	Cucurbitaceae	Sechium edule Sw.
Cupuacu	tree	fruit pulp	Sterculiaceae	Theobroma grandiflorum K. Schum.
Eritrina	tree	Nitrogen fix, shade	Fabaceae*	Erylhrina poeppigiana O.F. Cook.
Feijao-de-porco	creeper, vine	pioneer, repels lf. cutter ants	Fabaceae*	Canavalia ensiformis D.C.
Inhame	vine	tuber	Dioscoreaceae	Dioscorea sp.
Inga metro	tree	pioneer	Mimosaceae*	Inga edulis
Jaca	tree	fruit, wood	Moraceae	Artocarpus integrifolia L.
Jambolao	tree	fruit	Myrtaceae	Eugenia jambolana Lam.
Kudzu-tropical	vine	fodder plant, pioneer	Fabaceae*	Pueraria phaseoloides Benth.
Laranja-da-terra (orange)	tree	fruit	Rutaceae	Citrus aurantium L.
Lima (Lime)	sm.tree	fruit	Rutaceae	Citrus limertioides Tanaka
Limao boi (Sweet lemon)	tree	fruit	Rutaceae	Citrus aurantifolia Sw.
Mandioca (Manioc)	sm. shrub	tuber	Euphorbiaceae	Manihot ultissima Pohl.
Mangostao	tree	fruit	Guttiferae	Garcinia mangostana L.
Mapati	tree	fruit	Moraceae	Pourouma cecropiifolia
Mostarda	herb	leaves,spice	Brassicaceae	Brassica integrifolia O.E. Schulz
Noz-moscada (nutmeg)	tree	spice	Myrtisticaceae	Myristica fragrans Houtt.
Pimenta-do-reino	climber	spice	Piperaceae	Piper nigrum L.
Pupunha	palm	fruit/oilseed	Arecaceae	Bactris speciosa Korst.
Quiabo	herb	vegetable	Malvaceae	Hibiscus esculentus L.
Rabanete	herb	vegetable	Brassicaceae	Raphanus sativus L.

VULGAR NAME	DESCRIPTION	USE	FAMILY	NAME
Sombreiro	tree	shade/pioneer	Fabaceae*	Clitoria racemosa D.Don
Taioba-branca	herb	vegetable	Araceae	Alocasia antiquorum Schon.
Tangerina	sm.tree	fruit	Rutaceae	Citrus reticulata Blanco
Tomate (tomato)	herb	vegetable	Solanaceae	Lycopersicon esculcntum Mill.

abbreviations: fix.: fixation; If.: leaf; sm.: small. *: legume

TABLE III: THE ORDER OF APPEARANCE OF SPECIES IN THE PROCESS OF SOIL RECOVERY

NATIVE SPECIES	CULTIVATED PLANTS
1. FIRST PIONEERS (herbs and subshrubs)	
Assa peixe Verbesina macrophylla	Abacaxi (pineapple) Ananas comosus
Caminho de roca Vemonia scorpioides	Capim elefante Pennisetum purpureum
Marcela Achyrocline satureoides DC	Feijao de porco Canavalia enslformis
Rabo de raposo Andropogon biconiis	Kudzu-tropical Pueraria phaseoloides
Sape Imperata brasiliensis	mandioca (manioc) Manihot sp.
2. SHRUBS AND TREES OF EARLY SECONDARY FORESTS	
Capianga Vismia guianensis	
Coarana Caestrum Laevigatum	Coarana also planted due to its extremely beneficial effect on the soil
Corindiba Trema micrantha	
Fidalgo Aegiphila sellowiana	
Imbauba vermelha Cecropia cincrca	Banana da prata Musa sapientum
Pororoca Rapanea sp.	
3. SPECIES OF THE SECONDARY FOREST i	
Aderno de caipora Roupala sp.	Chuchu Sechium edule
Calumbi venmelho Mimosa sp.	Inga metro Inga edulis

Capeba
Pothomorphe umbellata L.

Inga mirim .
inga marginaia

Mundururu vermelho
Miconia calvescens

Pequi de capoeira
Tibouchina elegans

Solteira
Melastomataceae sp.

Mapati
Pouroma cecropiifolia

Sombreiro
Clitoria racemosa

Taioba branca
Alocasia antiquorum

4. SPECIES OF THE LATE SECONDARY FOREST, TRANSITIONAL TO THE PRIMARY FOREST

Buri
Diplothemium caudescens

Cipo verdadeira
Philodedron sp.

Cipo ferro
Paullinia termata

Cocao
Erythroxylumsp.

Fruto de paca
Carpotroche brasiliensis

Inguacu preto
Sclerobium chrysophyllum

Jangada preta
Rollinia sp.

Juerana branca
Pithecolobium pedicellare

Jussara
Euterpe edulis

Louro graveta
Nectandra sp.

Eritrina
Erythrina poeppigiana

Inhame
Dioscorea sp.

Laranja da terra
Citru sauranticum

Lima
Citrus limettioides

Limao boi
Citrus aurantifolia

Pupunha
Bactris speciosa

Tangerina
Citrus reticulata

Pati
Barbosa pseudo cocos

Pau pombo
Tapirira guianensis

Pindaiba
Guatteria sp

5. SPECIES OF THE PRIMARY FOREST

Ademo
Emmotum nitens

Baunilha da Bahia
Vanilla palmorum

Bomba d'agua
Hydrogaster trinerve

Gameleira
Ficus sp.

Imbirucu
Bombax macrophyllum

Inhaiba
Holopyxidium sp.

Jacaranda violeta
Dalbergia nigra

Jequitiba rosa
Cariana legalis

Louro tapioao
Persea sp.

Macaranduba
Manilkara data

Mamao de veado
Jacaratia sp.

Pau d'alho
Gallesia scorododendron

Pau d'arco bico de saracura
Tabebuia sp.

Abacate (avocado)
Parsea americana

Baunilha
Vanilla planifolia

Biriba
Rollinia mucosa

Cacau
Theobroma cacau

Cacau tigre
Theobroma bicolor

Caimito
Chrysophyllum cainito

Cupuacu
Theobroma grandiflorum

Jaca
Artocarpus int.

Jambolao
Eugenia jambolana

Mangostao
Garcinia mangostana

Noz muscada (nutmeg)
Myristica fragrans

Pau-oleo-copaiba
Copaifera multijuga

Pequi amarelo
Lafoensia pacari

Pequi preto
caryocar edule

Sucupira
Diplotropis sp.

Pimenta do reino
Piper nigrum

TABLE IV: Species succession in the recovery of depleted soils
illustrated with a few typical and representative species

		NATIVE SPECIES			CULTIVATED PLANTS
			PIONEERS		
Pioneer		Sape			Feijão de porco
		Rabo de raposo			Abacaxi
		Marcela			Mandioca
		Assa Peixe			Coarana
	consortiums of species with lignin production and small seed			Consortiums of lusher species with abundant fruit and big seeds	
			SECONDARY FOREST		
Secondary					
	Fidalgo	Imbauba vermelha	Imbauba branca		Bananeira
	Mundururu verm.	Solteira	Ingá sp.		Inga edulis
	Louro graveta	Pequi de capoeira	Jangada preta		Mapati
	Cocao	Pau pombo	Tararanga lisa		Eritrina
					Citrus
	Tiritica fina	Samambaia	Calumbi		Capeba
			TRANSITIONAL TO VIRGIN FOREST		
Transitional	Pati	Jussara	Buri		Pupunha
			VIRGIN FOREST		
	Pequi Amarelo	Maçaranduba	Bomba d'agua		Mangotao
	Juerana Branca	Inhaiba	Jequitibá rosa		Cacau
	Sucupira marreta	Louro tapioao	Mamão de veado	Abacate	
	Aderno	Pequi preto	Pau d'alho		Jaca
Virgin	Cipó ferro	Cipó verdadeiro	Baunilia da Bahia	Baunilia	

Transforming the local vegetation by planting, favoring and selecting lusher species