CHAPTER 12

POSSIBILITIES FOR SUSTAINABLE AGRICULTURE DEVELOPMENT IN THE BRAZILIAN AMAZON: AN EMBRAPA PROPOSAL

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INTRODUCTION

The Brazilian Amazon has been the centre of world attention in the last two decades and, in particular, in the last five years, due to present and potential ecological implications related to the use of its natural resources for development purposes. In this context, the development of agriculture has been the most important factor in environmental disturbances during the last three decades. About 40 million hectares of forest have been cleared for the implementation of land-use systems which, in general, have proven through time to have low levels of sustainability from an ecological, economic and social point of view.

Figure 12.1 shows the various ways in which the Amazon forest ecosystem has been utilized for agricultural and forestry development, especially during the last three decades.

The question of sustainable agricultural development in the Amazon has been a controversial issue. On the one hand, there is the ecological argument in which large-scale deforestation degrades the environment. On the other hand, there is the development argument where there is a real need to produce food, fibre and other needs of a growing Brazilian population, mainly that of the region. The search for sustainable agricultural and forestry development in the Amazon is the greatest challenge of governmental and non-governmental institutions involved in the process.

Logically, for each degree of agricultural development, there is some degree of environmental loss. What is necessary is that these losses be reduced

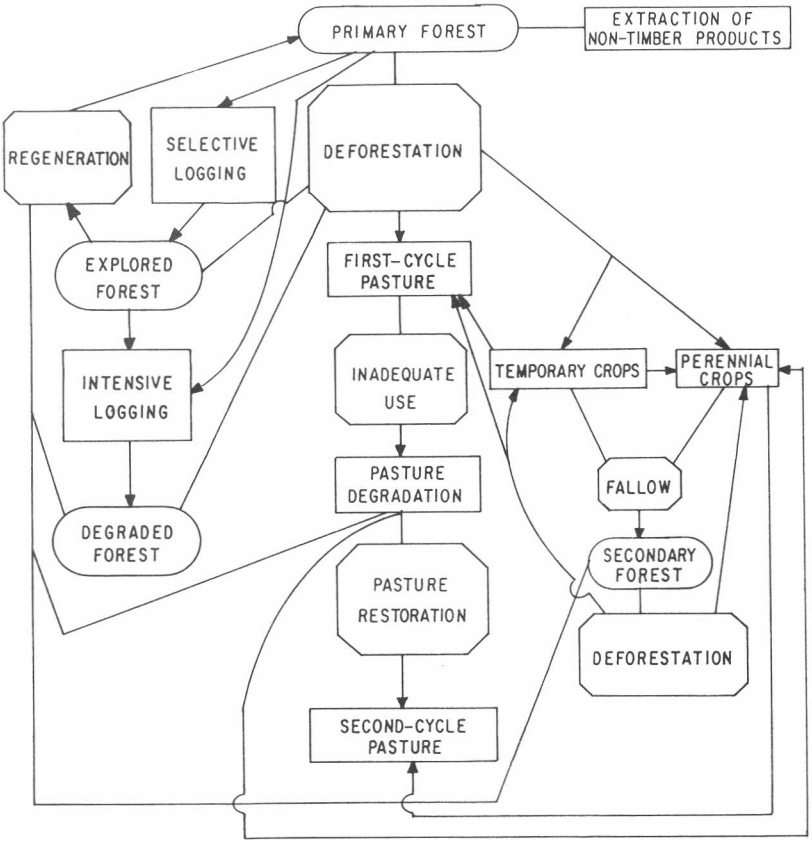

Figure 12.1 Flow diagram of present use of upland forest for agricultural development purposes in the Amazon; rectangles, economic activity; octagons, process; ovals, substrate; taken from EMBRAPA/CPATU, 1992, with permission

as much as possible. In this context, agricultural and forestry research has a role of the greatest relevance and EMBRAPA, through its agroforestry research centres located in the region, in association with other similar institutions, has been trying to generate knowledge and technologies for the purpose of effectively supporting the development of land-use systems which are more sustainable from a socio-economic and ecological point of view than those presently in use.

This chapter presents a proposal for sustainable agriculture and forestry development in the Amazon, based on the technical and scientific information accumulated to date and on the experience of agricultural development itself, mainly during the last twenty years. It also indicates the research needs for the implementation of the proposal.

THE BASES FOR AGRICULTURAL SUSTAINABILITY IN THE AMAZON

EMBRAPA's point of view (Flores et al., 1991) is that the development of sustainable agriculture does not mean returning to the horse and plough and to subsistence agriculture models, or to a type of agriculture using soil fertilization based only on organic matter. The central idea is the use of technologies adequate for the conditions of regional and even local environments, and of the forecasting and prevention of negative impacts, whether they be social, economic or environmental. Such technologies may include machinery, chemical products (fertilizers, pesticides), satellite images and computers, use of biotechnology, integrated pest management (IPM), conservation of water in the soil, organic matter management, nutrient cycling and other management alternatives.

EMBRAPA's proposal implies that one has the final guarantee that agro-ecosystems are productive and profitable with time, securing a certain stabilization of production factors, which are difficult to manage since they are influenced by market, sociocultural and environmental conditions. Thus, through the diversification of production in space and time, the association of plants with animals, use of natural and less toxic chemical pesticides, of biological control, and other production methods and factors which propitiate, at the same time, increased productivity and sustainability, there will be greater perspectives for success. This should be possible since agro-ecosystems will tend to get to the point where their mechanisms of self-control will start to act in an efficient manner in maintaining a dynamic balance which will be acceptable for both production and environmental quality (Flores et al., 1991).

Proposals for agricultural development in the Amazon must take into consideration the need to promote sustainable land use. Sustainability has to be the basis for analysis and implementation of alternative agricultural and forestry development models in the region.

The possibilities for developing sustainable agriculture in the region depend on its permanence, as much as possible, in the same area, with increasing increments in productivity, not only that of the land, but also of the labour force as well, thereby reducing the pressures for further deforestation.

This concept of sustainability implies a balance in time between agronomical and/or zootechnical, economic, social and ecological feasibility (Figure 12.2). A certain agricultural land-use system may have high levels of agronomic and ecological sustainability but, at the same time, have low levels of economic and social sustainability. The majority of plant extractivism (mainly that of non-timber products) is included in these types of situation, for example (Homma, 1989). Other systems may have satisfactory levels of agronomic/zootechnical and economic sustainability but have low

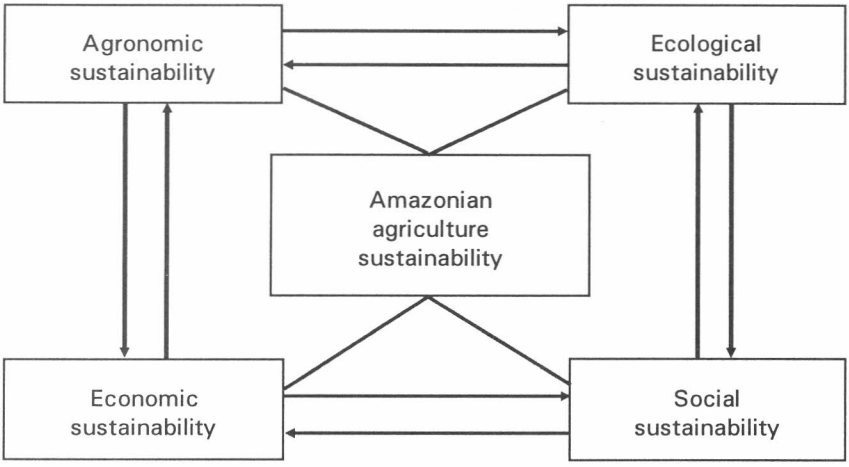

Figure 12.2 Simplified diagram of the sustainability of Amazonian agriculture, taken from Serráo and Homma, 1992, with permission

levels of ecological and social sustainability. Here, one can include extensive cattle-raising and shifting agriculture (Serráo, 1992; Serráo and Homma, 1992).

In fact, with present technological standards, one can say that, in Amazonia, there are no land-use systems in existence today for agricultural purposes which fulfil all the prerequisites for sustainability mentioned above at fully satisfactory levels. In practice, based on experience with agricultural development processes *per se* and the generation of knowledge and technologies which are more compatible with the regional socio-economic and ecological environment, the search for and implementation of land-use systems with higher levels of sustainability than those presently in practice should continue.

Another aspect which should be considered in proposing sustainable agricultural and forest development models in the Amazon is the present stage of agricultural development in relation to the extensive area of already altered forest land in the region. From a technical point of view, it is appropriate to say that there is already more than enough deforestation for agricultural and forestry purposes. From this point of view, one can suggest that in about 50% of the already deforested areas of the region (including in the productive system segments of less fragile ecosystems such as well- and poorly-drained savannahs and alluvial floodplain – *várzea* grasslands) it is possible to produce food, fibres and other products to supply the demands of the region's population (today about 17 million inhabitants) at least until the beginning of the next century. This means that future agricultural and forest production in the Amazon will depend on higher levels of land-use

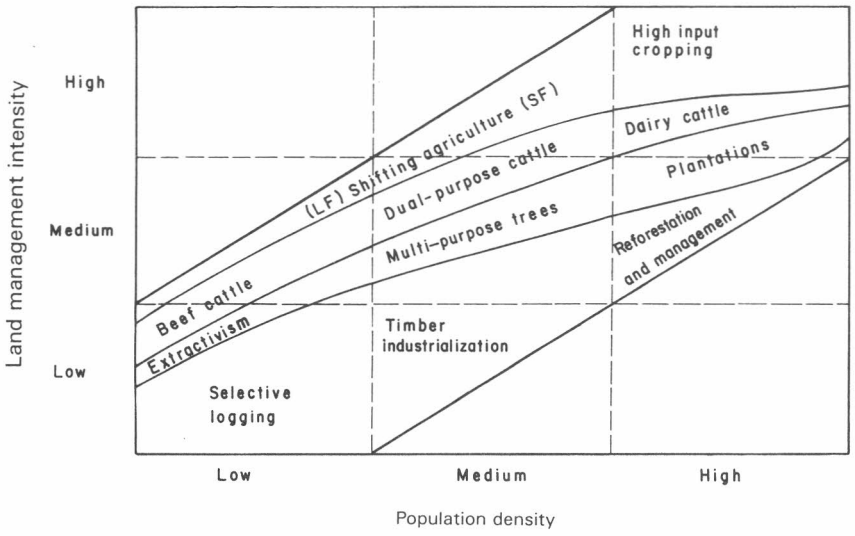

Figure 12.3 Land use as affected by population density in the Brazilian humid tropics; LF, long fallow; SF, short fallow; adapted from Serráo and Toledo, in press

intensification (Figure 12.3) in a scenario of decreasing deforestation rates – due to ever increasing national and international pressure for conserving the rain forest and the development of an environmental consciousness on a regional level – increasing population density and, consequently, increasing land prices in presently existing development poles.

Still another aspect which should be taken into account in the question of sustainable regional agricultural development is the growing socioeconomic and ecological development of regional agroindustry and bioindustry, mainly with the utilization of regional products, in virtue of its comparative advantages.

Undoubtedly, *productivity* and *sustainability* will have to be the foundation of future development of agriculture in the region. From now on, more than ever, scientific knowledge and agricultural, forestry, agro- and bioindustrial technology will play a role of the greatest relevance.

MAIN DIRECTIVES FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN THE AMAZON

The model for sustainable agricultural development in the Amazon should consider the following general directives:

(1) Towards the end of the first decade of the third millenium, agricultural and forestry development should be concentrated in already

altered forested areas and in segments of ecologically less fragile ecosystems, such as the well- and poorly-drained savannahs and the *várzea* floodplains.

(2) Agriculture should be developed with its main base linked to integrated land-use systems with emphasis on developing feasible agroforestry systems.

(3) Regional biodiversity and genetic resources should be efficiently utilized in agricultural development, for which domestication of plants, mainly, and of animals having present and potential socio-economic interest should be of the utmost importance.

(4) Agroindustry and bioindustry of regional products should be fully developed, profiting from their comparative advantages.

(5) The emphasis on research and development and efficient diffusion of technologies should be the main strategy of research institutions to support the development of sustainable agriculture and forestry in the region.

PRINCIPAL LAND-USE SYSTEMS IN THE AMAZON: PRESENT SUSTAINABILITY AND MORE SUSTAINABLE MODELS

Serráo and Homma (1992) recently evaluated the sustainability of agriculture in the Amazon based on the analysis of the main land-use systems existing in the region. Based on this and other recent papers and in a summarized form, some of the information which characterizes the importance and present sustainability of the land-use systems are presented below, as well as indications as to how they should be developed in order to have greater levels of sustainability than those they have today and how research should be directed to support this development.

Extraction of non-timber products

Plant extraction of non-timber products in the Amazon presently represents 10–20% of the regional primary sector's income, involving at least 100,000 families, in general small farmers, representing 14% of the socio-economically active population of the primary sector (Homma, 1992). It is an important land-use system, mainly in the states of Acre, Amapá, Rondônia and Pará, which exploits mainly rubber, Brazil-nuts, heart-of-palm, native fruit, medicinal plants, oils, resins and other products.

Extraction of non-timber products has low levels of productivity but high levels of agronomic, ecological and cultural sustainability. This type of

extractivism is characterized by low technological intensity, not only from the point of view of the use of capital, but the use of technical–scientific knowledge as well.

In the last few years, the extraction of non-timber products has appeared as an important theme within the context of regional development, but does not represent a general solution for poverty or for environmental degradation in the Amazon (Homma, 1992)

Potential for increasing sustainability and expansion

According to Serráo and Homma (1992), in the short and long term, there are only moderate possibilities for increasing the socio-economic sustainability for extraction activities of non-timber products, and their potential for expansion as land-use systems is limited.

A more sustainable model

The extraction of non-timber products alone cannot be considered an alternative model for increasing the sustainability of forest lands in the Amazon, but rather should be considered a component of a more ample model, based mainly on the development of intensive agroforestry systems in already altered forest areas. Within this context, it is important and necessary to promote the diversification of the base of the extractive economy of already established extractive reserves.

In spite of the low expansion potential of the extractivism of non-timber products, if new extractive reserves were to be created, they should be connected with those populations having strong extractive traditions and their own social organization, and should take into consideration the heterogeneity of the community's economic activities.

Research support

To support the development of non-timber product extraction at more acceptable levels of sustainability, research should be aimed at selecting annual and perennial crops and forest species which are easy to establish, require low levels of input and are highly valued for the enrichment of the extractive reserve and for its integration within sustainable agroforestry systems which would also include a small-scale animal production component, such as poultry and dual-purpose (milk- and meat-producing) cattle (Serráo and Homma, 1992).

Timber exploration

The extractive exploration of timber in the Amazon is an important economic activity, not only for the region but for the country, as well. It has been developed throughout the Amazon Region, having greater concentrations in the states of Pará, Rondônia and Mato Grosso, mainly by small- and medium-sized enterprises, and involving about 25,000 loggers. The Amazon is presently extracting about 50% of the total amount of lumber produced in Brazil (Silva and Uhl, 1992) and the State of Pará responds for about 85% of the region's production.

Presently, lumber industries in the Amazon rely almost totally on the native forest as their source of timber, whether it be from selective extraction itself or from deforestation for other purposes, such as for extensive cattle-raising and shifting agriculture.

In the Amazon, the effort to conserve the productive wood potential in native forests or generate stocks to replace the volume of wood extracted in plantations is, if not negligible, very much short of actual needs (Silva and Uhl, 1992).

Extractive timber exploration, as practiced today, can be considered to have moderate levels of ecological and social sustainability and low to moderate levels of economic sustainability. Present economic sustainability is satisfactory and would only be threatened if resources were to become scarce. The activity's technological intensity, from a technical/scientific viewpoint, is low; however, it is high from the point of view of use of capital, with very low productivity per area, medium per capital and very high per person.

Potential for increasing sustainability and expansion

On a short-term basis, extractive timber exploration has moderate potential for increasing its sustainability from technical, ecological, economic and social points of view but, due to the present and potential economic importance of timber products at national and international levels, the potential for expanding this activity is very high. To be sustainable, the lumber activity must adopt sustainable management technology. Then, and only then, will it not be an extractive activity but a productive activity. Potential for expansion only depends, practically speaking, on the depletion of African and Asian resources.

A more sustainable model

Some knowledge and technology already exists in the region, not only for timber exploration from the natural forest, but for planting native species as

well (Silva, 1989; Silva and Uhl, 1992). However, the use of sustainable management for timber exploration in the region has not yet become a reality. Nevertheless, on a commercial level, sustained forest management practices and the plantation of native species must be initiated. For this to happen, the government must provide for the establishment of an adequate forest policy.

The sustainable model includes the creation of forest reserves in dimensions capable of guaranteeing the preservation of the main forest ecosystems, as well as providing for the present and future timber supply in the region (Silva and Uhl, 1992). The agro-ecological zoning of the Amazon is indispensable for establishing this policy.

To overcome the limitations of sustainability from the economic point of view, it is necessary to alter the tax strategies of the market, seeking to benefit those producers who use sustainable extractive exploration models or developing forest plantations. To accompany this process, it is of fundamental importance that the regional timber industry be modernized in order to propitiate greater levels of sustainability to this important land-use system.

Research support

In order to provide support to the achievement of higher levels of sustainability for the regional timber exploration activity, forestry research should concentrate its efforts on natural forest exploration and management techniques, on the identification and domestication of timber-producing species of present and potentially high economic value, on the enrichment of already explored areas where the natural regeneration is too poor or in secondary forests having low forest value, on reforestation of altered areas with forestry and agroforestry systems, and on the industrial utilization of timber products.

Shifting agriculture

Upland shifting agriculture is probably still the most important agricultural land-use system in the Amazon, not only from an economic point of view – it is responsible for at least 80% of the region's total food production – but also from a social point of view because the large number of people who directly or indirectly depend on it. Shifting agriculture is practiced in almost all of the region by at least 500,000 small farmers, producing mainly beans, cassava, rice, corn, malva, fruit and cotton.

Shifting agriculture is also very important from an ecological standpoint. Large areas in the Amazon have been deforested to develop shifting agriculture. In spite of the small individual areas used in the practice of this activity (between 10 and 50 ha), the 500,000 farmers, who on the average plant two

hectares for two consecutive years, with a fallow period of about ten years, presently need a total area of at least 10 million ha in a process which can be called 'silent deforestation' (Homma, 1989).

In spite of its importance in the region's economy, traditional slash-and-burn shifting agriculture is tending to decrease with the decline in the expansion process of the agricultural frontier due to the restrictions on deforestation, and with the increase in demographic density and consequent increase in food demands and in the rise in the region's land prices (Figure 12.3). In these circumstances, the long fallow periods – a necessary condition for maintaining agricultural sustainability of this traditional system – may not be as stable as before and, in the medium to long term, shifting agriculture will naturally and necessarily be substituted by more intensive land-use systems.

This form of traditional agriculture, so adequate for the environment in other historical contexts, is today faced with serious problems of sustainability. Present levels of agronomic, sociocultural and economic sustainability are low to moderate, with low levels of ecological sustainability. Technological intensity, both in terms of technical–scientific knowledge and of capital investment, is low, resulting in low productivity per unit of land. However, it can offer relatively high returns in productivity per unit of capital investment and per person.

Potential for increasing sustainability and expansion

There is some potential for increasing the levels of sustainability in shifting agriculture with the increase in the amount of time cultivated areas are utilized, through the adoption of technological procedures which allow for cultivating the same area for three or more years instead of two, which could reduce at least 30% of the present deforestation of primary and secondary forest caused by farmers who practice this system of land use.

In spite of their low levels of sustainability and the tendency to disappear with the passing of time due to increasing demographic pressures, the need for environment conservation and other factors, shifting agriculture, as such, should probably continue to exist for some time in the Amazon, although at increasingly lower levels. Consequently, it is necessary that the socio-economic level of the farmers who practice this type of land use be improved.

The most sustainable model

The development of land-use systems as an alternative to shifting agriculture is extremely important for contributing to the reduction of deforestation and to increasing the socio-economic sustainability of those who practice them.

The models which should be used are those systems of integrated agriculture which take advantage of the benefits of diversified production in the rural establishment, based on the association of long-cycle crops together with subsistence crop and livestock production (da Veiga and Hebette, 1992). Some components to be followed are particularly important, such as home gardens having agroforestry characteristics which are so important to the subsistence and health of the farmers and their families (Fernandes and Serrao, 1992).

Raising small, medium and large animals as an integrated part of these systems is of the greatest importance, as they function as economic and financial security, minimizing the risks (biotic pressure, climatic adversity, market fluctuations, etc.) so frequent in traditional regional shifting agriculture.

Increased sustainability of present shifting agriculture activity should pass through a transition process in time, with typical slash-and-burn agriculture evolving towards integrated agroforestry systems for which small-scale farmers have greater affinity than large-scale farmers.

Research support

For various reasons, shifting agriculture is probably the agricultural activity which has received the least support from research in the Amazon. Research support should be looking towards the gradual transformation of typical shifting agriculture in feasible agroforestry and agropastoral systems in order to keep, as much as possible, small farmers on the same small land modules, thus reducing 'silent deforestation' and avoiding their displacement from their land in the future. Research should, in a participatory process with the farmers, concentrate its efforts on developing varieties of annual, semi-perennial and perennial crops to be integrated into agroforestry systems, on the management of organic matter, on the recycling of nutrients, on the control of pests and diseases and on livestock raising and management for the purpose of integrating them into the system.

Cattle-raising in deforested areas

Within the context of agricultural development in the Amazon, cattle-breeding replacing forests is a very important economic activity being developed throughout the region where approximately 5,000 medium and large producers are involved mainly in beef production. Extensive cattle-breeding in forested areas replaced by pastures is the land-use system which has contributed to the greatest amount of deforestation in the region and has been seriously questioned due to its negative socio-economic and ecological implications and, consequently, low levels of sustainability.

Technological intensity, from the point of view of utilizing scientific knowledge, has been low to moderate and, conversely, high from the point of view of capital investment. In spite of this, productivity has been low, not only per unit area but per unit of capital investment, and medium to high per person.

Cattle-breeding on first-cycle pastures (those formed after clearing and burning the primary forest) has had low levels of sustainability from various points of view: agronomical (pasture degradation), economic (reduced profits due to low productivity), social (low levels of employment, land ownership problems, high meat prices for the majority of the population); ecological (at least 20 million hectares of deforestation, widespread burning to form and manage pasture, loss of biodiversity, edaphic losses, climatic changes, among other negative implications). However, it achieved relatively high levels of zootechnical sustainability (beef-producing breeds well adapted to the regional environment).

Potential for increased sustainability and expansion

Low levels of cattle-breeding sustainability in deforested areas have mainly been related to the extensive exploration models adopted in the frontier opening process (especially in the 1960s and 1970s) based on first-cycle pastures.

Beginning in the mid-1980s, with increased scientific knowledge on the interrelation between pasture degradation factors and some positive experiences of the productive sector itself, cattle-breeding in these already explored areas began to improve in its levels of sustainability. In this context, the recuperation of degraded areas with the use of improved forages and pasture and animal management practices, has been having an increasingly relevant role.

These developments make it possible to infer that reasonable potential exists for increasing sustainability of cattle-breeding on pastures formed in already deforested areas. This activity's potential for expansion into new segments of forest is reduced for technological, socioeconomic and, especially, ecological reasons (Serráo and Homma, 1992; Serráo, 1992).

A more sustainable model

With the scientific and technological knowledge available, in spite of still being insufficient, cattle-breeding production in already deforested areas is feasible for meeting the demand of the region's population, at least until the year 2000, using only about 50% of the area already deforested for this purpose. In this process, intensification of land use is of utmost importance (Serráo, 1992).

In already deforested areas, in the medium to long term, the extensive cattle-breeding model still predominant today should gradually evolve into models of more sustainable production systems such as the *semi-intensive beef cattle model* for medium and large producers, the *intensive dual purpose cattle-breeding model* (for beef and dairy production) for small to medium producers, and the *integrated agro-silvo-pastoral model* for medium producers (Serráo, 1992).

This gradual transformation of the present extensive cattle-breeding systems based on monoculture pastures should offer higher levels of sustainability from an agronomical point of view (reduced risks due to pasture pests and diseases; improved cycling and, consequently, improved utilization of soil nutrients), as well as economic (different sources of income), social (production of different products, greater direct and indirect employment, improved levels of specialized labour) and ecological (higher levels of biomass accumulation, improved hydrological balance and soil conservation), and improved environmental conditions for macro- and microflora and fauna (Serráo and Toledo, 1990).

Research support

The development of cattle-breeding systems in already deforested areas should be based on land-use systems characterized by high levels of technical–scientific knowledge and low input levels, with greater attention given to small- and medium-scale farmers. Consequently, basic research is essential and should concentrate on studies of the ecology of pasture weed community, biotic and abiotic mechanisms for the regeneration of degraded pastures' native vegetation, and cycling of nutrients. With regard to applied research, emphasis should be given to the selection of food and forage crops, trees and animals for developing feasible integrated systems of the agro-silvo-pastoral type.

Exploration of long-cycle agricultural crops

Long-cycle agricultural crops have been considered the ideal land-use model for agriculture for the Amazon, as a means to minimize environmental disturbances and maintain ecological balance (Alvim, 1992). From an ecological point of view, perennial crops, as well as forestry and agroforestry plantations, are the systems which are most like the natural forest in efficiently protecting the soil against leaching, erosion and compaction. The lower demand for soil nutrients by perennial crops is mainly due to their efficient nutrient cycling mechanisms which, in some manner, approximate to those of the natural forest.

Long-cycle perennial crops are, to a greater or lesser degree, the activity of about 20,000 small-, medium- and large-scale farmers, mainly in the States of Pará, Rondônia and Mato Grosso.

Long-cycle perennial crops of greater economic importance are African oil palm, rubber tree, cocoa, and robusta coffee. Among the fruit trees, orange (especially the *pera* type) and lemon (especially the *Tahiti* type) are the most important being cultivated with reasonable success, especially in the proximity of some of the large urban centres.

Long-cycle crops have generally had reasonable levels of technological intensity from the point of view of technical–scientific knowledge and use of capital which results in good levels of productivity per unit of area, per capital investment and per person. In general, their levels of agronomic, ecological and social sustainability are satisfactory, although, in some cases, and in certain situations, agronomic (mainly due to biotic pressure of diseases and pests) and economic levels of sustainability (due to market saturation and/or fluctuation and other related problems) may be low.

Potential for increased sustainability and expansion

There is good potential for some increase in the levels of productivity and sustainability of long-cycle crops, especially from an agronomic point of view. Nevertheless, large-scale expansion of long-cycle crops whose economic value is high, may run into the problem of market fluctuations and saturation (except, perhaps, for rubber production in most cases), lines of credit incompatible with the cycle and the nature of production systems.

A more sustainable model

Playing an important role in the development of agriculture with higher levels of sustainability in the region, in addition to perennial crops of present economic importance, are many other forest plants (fibre producers, fruits, oils, resins, medicinal products, etc.), which are presently and potentially important and need to be domesticated for future crops in homogeneous plantations or, preferentially, in agroforestry production systems (to reduce biological risks and market fluctuations). These regional plants, due to their comparative advantages, will certainly contribute to a longer-cycle crop model with higher levels of sustainability than present ones.

Research support

Research will be a decisive factor in developing more sustainable models of land use with long-cycle crops. Basic and applied research should give

priority to control of diseases and pests of economic importance to these crops and should emphasize, as well, the domestication of perennial plants of high potential value and the definition of agroforestry systems for their inclusion.

Agroforestry systems

Agroforestry systems – land-use systems where arboreal and non-arboreal plants are cultivated simultaneously or in sequence, in planned association with annual crops and/or pastures for animal production – have been seen as systems which will make more sustainable use of land resources in the Amazon and which should gradually substitute or be associated with land-use systems presently in effect, such as cattle-breeding systems based on pasture, upland shifting agriculture and extraction of non-timber products.

The agroforestry systems are still little known in the region. In all probability, no more than 500 small- and medium-scale farmers practice them and, typically, they occur on a larger scale in the state of Pará, especially in its eastern part, in areas of more intensive agricultural development.

They are the land-use systems considered of greatest sustainability from a biophysical, socio-economic and ecological point of view, presenting medium to high levels of productivity per unit of land, of capital investment, and per person, due to the use of medium to high levels of technological intensity, both from the point of view of technical–scientific knowledge and use of capital.

Potential for increased sustainability and expansion

There are good perspectives for increasing agroforestry-system sustainability because, among other benefits:

(1) They can increase agricultural land productivity where productive capacity has been reduced due to inadequate management resulting in soil compaction and loss of fertility;

(2) They allow for the combination of species with different energy requirements, resulting in more efficient use of this input due to the vertical stratification of associated plants;

(3) Their diversification reduces biological risks and is more efficient in facing market fluctuations; and

(4) The introduction of the tree component in present extensive systems of shifting agriculture and extensive cattle-breeding can considerably increase the sustainability of these systems.

Despite not being a panacea, but in virtue of their favourable levels of present and potential sustainability, agroforestry systems have a great potential for expansion. In future regional monocultural agricultural development, there will be room for monoculture agriculture even with intensive capital investment. Nevertheless, agroforestry systems should play an ever more important role in increasing agricultural sustainability in the region, for the most part involving small- and medium-scale farmers.

A more sustainable model

There are no specific agroforestry models to be recommended. However, there are many possible models of agroforestry systems resulting from the combination of annual, perennial, arboreal, bush-type and herbaceous plants and small and large animals in various arrangements (Figure 12.4). Most important is that the components be mutually compatible from an agronomical and ecological point of view and that the resulting products be competitive on the market, offering economic security for the farmers who produce them (Fernandes and Serráo, 1992).

Typical agroforestry-system models with reasonable levels of sustainability presently in use in the north-east of Pará are those developed by Nippo-Brazilian farmers in the region of Tome-Açu (Subler and Uhl, 1990). These farmers have been substituting their monoculture crops of black pepper for diverse agroforestry arrangements which include perennial crops (such as cocoa, rubber tree, cupuaçu, graviola, papaya, avocado, Brazil-nut and mango, among others), palm trees (such as açaí, coconut, African oil palm and peach palm), bushes and vines (such as Antilles cherry, coffee, passion fruit, black pepper, guaraná and urucum) and annual plants (such as cotton, cow-peas, manioc and a variety of fruits and vegetables). These models are, on the average, grown on only about 20 ha per property which vary between 100 and 150 ha. The remaining area is generally left for regeneration of the secondary forest after previous use in shifting agriculture activities, or is constituted of uncleared forest areas.

Research support

Success in the increase of agroforestry-system sustainability depends, largely, on constant experimentation with innovative techniques and the exercise of co-operative market systems. As land-use systems, the agroforestry systems have such a high level of priority for research that, recently, beginning in 1991, EMBRAPA transformed all of its six agricultural research units in the Amazon into Centres for Agroforestry Research (Figure 12.5). Research efforts for developing more sustainable agroforestry systems

EMBRAPA

should be concentrated on the introduction, selection and domestication of native and exotic multi-purpose plants with good economic value and comparative regional advantages for the development and maintenance of integrated agro-silvo-pastoral systems.

Agriculture on *várzea* floodplains

Várzea agriculture, developed mainly along the banks of the Amazon River and its muddy water tributaries, rich in organic sediments and minerals, have some features in common with the upland shifting subsistence agriculture practice discussed above, such as the practice of slash and burn, and the preponderance of annual food crops used mainly by small farmers in a similar socio-economic environment.

The main differences are: in general, *várzea* floodplains have less heterogeneous vegetation, soils are generally more fertile, fallow periods are shorter

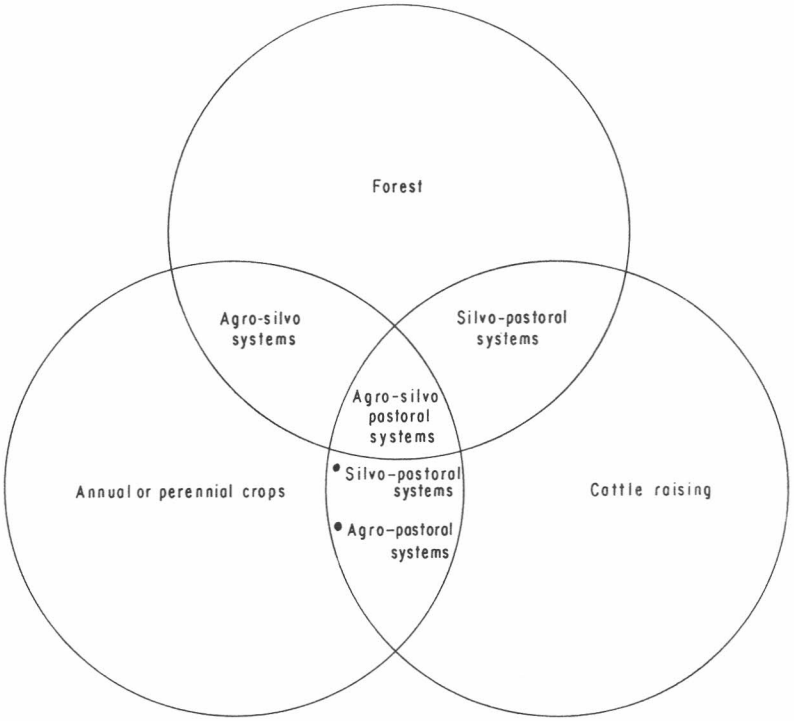

Figure 12.4 Possible combinations involving annual and perennial crops with trees and cattle-raising; taken from Homma and Serrão, 1992, with permission from *Sustainable Agriculture and Environment.* Copyright 1993 by the National Academy of Sciences, courtesy of the National Academy Press, Washington, D.C.

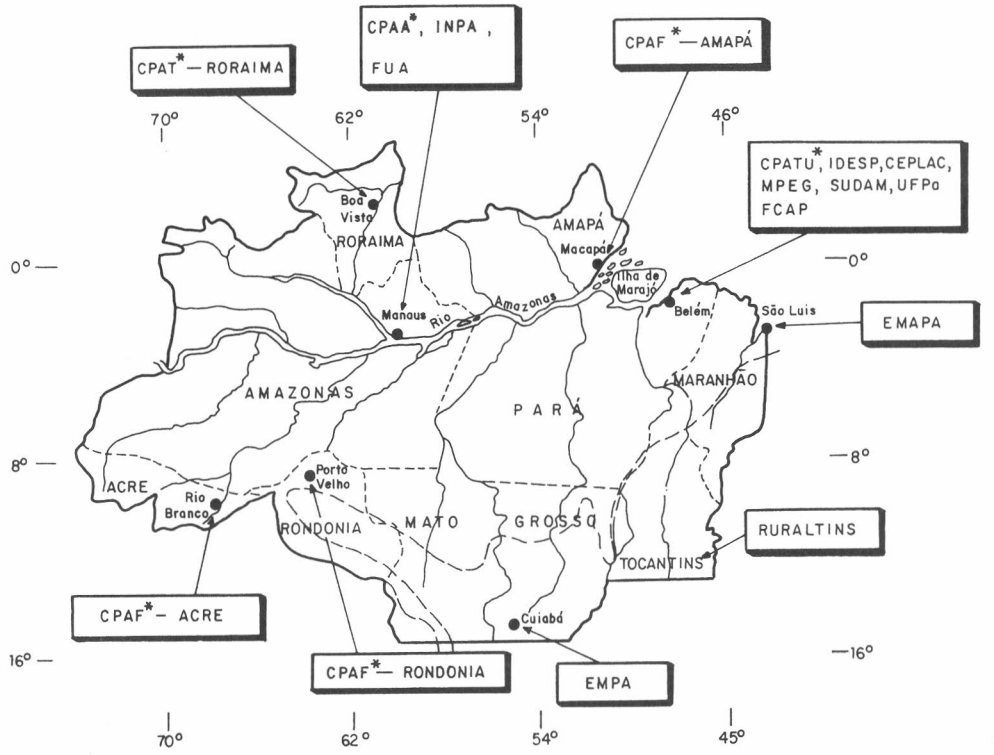

Figure 12.5 Governmental research institutions directly and indirectly involved with agricultural development in the Amazon; *, EMBRAPA's Agroforestry Research Centres

due to the higher fertility of the soils; flood risks – the *várzeas* are subject to an annual flood cycle; fishing plays an important role as a complementation of the agricultural activity; and jute fibre has been an important product in *várzea* floodplains.

Várzea agriculture, due to its potential, has been considered an alternative for intensive agricultural production (mainly of short-cycle food crops), thus reducing the pressures of 'silent deforestation' in upland shifting agriculture.

It is estimated that about 50,000 small 'river bank' farmers practice *várzea* floodplain agriculture, mainly in the regions of the lower and mid-Amazon River regions, in the states of Pará and Amazonas, and produce mainly fruit, jute, cassava, corn and beans (Serráo and Homma, 1992).

This system of land use involves very low levels of technology dependent on capital and technical–scientific knowledge, but has medium to high levels of productivity per unit of land, per capital invested and per person. Agronomical and ecological sustainability levels, in general, tend to be higher, but socio-economic levels are even lower than those of upland shifting agriculture.

Potential for increasing sustainability and expansion

Due to its natural potential and due, mainly, to higher levels of soil fertility, the possibilities of increasing present sustainability are good for *várzea* agriculture. The main impediments from an agronomical point of view are biotic pressures (pests, diseases, weeds) which, to some extent, could be minimized with water control and with the development of adapted cultivars. There is potential for improvement in socio-economic sustainability through the improvement in means of transportation, education and sanitary conditions in the river bank regions.

For the same reasons mentioned above, there is good potential for expanding this system of land use. However, its expansion should include higher levels of land-use intensification.

A more sustainable model

A more sustainable model of *várzea* agriculture should necessarily include technological improvements, especially the development of cultivars more adapted to the system of production, wherein conditions should be created that would allow the farmer to control the effects of the floods or to synchronize with them, as well as a socio-economic environment more in tune with the needs of those who practice this type of agriculture in the region.

The model for sustained *várzea* agriculture development should envisage integrated agricultural production, which should include crop production

(mainly annual crops), animal production (mainly buffalo and bovine), and fishing (Marques et al., 1992).

The intensification of land use, which should be part of a more sustainable model, should take into account that an inappropriate use of chemical products can affect the quality of the water, an essential component of the *várzea* floodplain agriculture.

Research support

To support the sustainable development of *várzea* floodplain agriculture in the Amazon, research should give priority to the development of integrated production systems with minimum input (with the inclusion of the use of traction animals) with a minimum of damage to the aquatic ecosystem.

Cattle-breeding in non-forest ecosystems

Before the advent of extensive cattle-breeding development substituting forests, in the 1960s, livestock production in the Amazon was practiced almost exclusively in natural pasture ecosystems.

Presently, with the results at the moment more negative than positive for cattle-breeding on pastures replacing forests in the region, and with the present need to the minimize pressure from this activity on new segments of forest, the importance of cattle-breeding in non-forest ecosystems tends to increase as a present and future complement of cattle-breeding in already explored areas in forest ecosystems.

According to Nascimento and Homma (1984) and Serráo (1986), in Brazil there are between 50 and 75 million hectares of Amazonian ecosystems with variable gradients of herbaceous/bushy/arboreal vegetation having potential for cattle-breeding. It is estimated that a herd of about 6 million bovines (mostly) and buffaloes is grazing on this land at the moment, but there is a capacity for stocking at least 30 million head of cattle (presently, the cattle population in the Legal Amazon is estimated to be around 18 million head).

From an economic point of view, the main and most important ecosystems of native pastures are: well-drained savannahs (*cerrados*), mainly in the states of Amapá, Roraima and Rondônia; poorly-drained savannahs, with varied gradients of flooded areas, mainly in the states of Pará, Mato Grosso and Maranháo; and alluvial *várzea* floodplains, mainly in the states of Pará, Amazonas and Amapá (Serráo, 1986). Almost 10,000 small-, medium- and large-scale farmers carry out cattle-breeding activities on natural grasslands in the region where beef cattle are the main product of this system of land use.

In spite of their inherent low productivity, the well-drained savannahs, as such, have relatively high levels of ecological and agronomical sustainability, due to their adaptation to the effects of burning, to prevalent conditions of low soil fertility and adverse climatic conditions of the ecosystem.

The alluvial *várzea* floodplains have high agronomic sustainability due to the edaphic/hydrological conditions of the *várzea* floodplains and similar ecosystems which favour high forage production and quality resulting in high levels of cattle performance, mainly in the dry period, contrary to other ecosystems of native and cultivated pastures. Ecological sustainability is high, but levels of socio-economic sustainability are only moderate.

The poorly-drained savannahs, typical of the Island of Marajó, in the State of Pará, have high levels of agronomic sustainability due to their adaptation to edaphic, hydrological and management conditions prevalent in the ecosystem. Typically, cattle-breeding on these savannahs is developed on large properties whose owners reside in large urban centres and offer few jobs to cowboys who, with their families, have low socio-economic standards which result in low levels of socioeconomic sustainability for the system.

Potential for increasing sustainability and expansion

Cattle-breeding developed on well- and poorly-drained savannahs, and alluvial *várzea* floodplains show moderate levels of potential for increasing sustainability, mainly the savannahs which allow for and respond to greater technological intensification, both from the point of view of technical–scientific knowledge and use of capital. Their productivity can be considerably increased with the adequate use of technology; however, their expansion is restricted to the natural dimensions of the ecosystems themselves.

A more sustainable model

Increased sustainability for cattle-breeding in non-forested ecosystems should be based on greater management intensification of well- and poorly-drained savannahs *per se*, associated with cultivated pastures with adapted forage crops in selected segments of those same ecosystems.

In the case of the alluvial *várzea* floodplains, the model should consist of grazing on them during drought periods and on cultivated pastures (formed with adapted forage species in adjacent upland areas) during the rainy season when the former are flooded. This integrated system approach allows for high levels of livestock production, mainly of beef cattle.

Research support

The contribution of research to increasing the sustainability of cattle-breeding in non-forested ecosystems has been reduced. Additional research is necessary, mainly in relation to increasing sustainable pasture productivity. Thus, in relation to the well- and poorly-drained savannahs, research should be concentrated on:

(1) Selecting better adapted and more productive grasses and vegetables;

(2) Pasture establishment and management;

(3) Fire control and mineralization of native pastures; and

(4) Physical and biological characterization of native pastures.

With regard to alluvial *várzea* floodplains, research should be concentrated on finding more efficient management methods for native pastures and in the selection of adapted and more productive forage species for establishing and grazing cultivated pastures in adjacent upland areas.

Agroindustry and bioindustry

Agroindustry and bioindustry of regional products show great potential for development in the Amazon and will certainly contribute to sustainable agricultural and forestry development.

Development of agroindustries represents a feasible alternative in view of its capacity to create new jobs, keeping workers on the land, aggregating value to agricultural and forest products, increasing regional income, decreasing social tensions and generating and incorporating technologies.

The rational utilization of existing natural resources, together with the establishment of agroindustries supported by the generation of appropriate technical–scientific knowledge, will contribute to sustained development by better utilizing already altered areas, stabilizing agriculture, improving better-paid labour and, consequently, contributing to environmental conservation/preservation (Melo and Guimaraes, 1992).

The development of agroindustry in the Amazon should take into consideration:

(1) The development of regional agricultural and forest exploration;

(2) The need to support already existing agroindustries through the development of new processes and techniques;

(3) The development of new technologies for better utilization of forest resources, be they timber or non-timber;

(4) The quantitative and qualitative evaluation of medicinal plants, insecticides, natural colouring products and oil extracts;

(5) The development and better utilization of methods and processes to increase and improve the quantity of milk, fish and regional fruit by-products; and

(6) Better utilization of agricultural residues and those of agroindustries themselves in manufacturing rations and organic fertilizers, as well as making more feasible the production of inorganic fertilizers and other soil-amendment products from mineral deposits existing in the region.

Bioindustry – which finds in the use of biotechnology one of the essential phases of production and which utilizes live organisms or functional parts isolated from them in its productive process – presently emerges with great potential for growth and participation in the world economy.

Bioindustry is practically non-existent in the Amazon as an industrial segment, except for a few units which utilize and manipulate live organisms in wood, food and pharmaceutical production with traditional technologies. Nevertheless, the Amazon has great potential for developing bioindustry, especially in function of its enormous biodiversity, an incalculable treasure for industrial use.

The region has a considerable wealth of medicinal, aromatic, food, oil and fibrous plants, in addition to an incalculable biotic wealth of fungi and bacteria which, if properly exploited through bioindustry, could provide an important contribution to the most important regional productive sectors, especially to those sectors with priority for sustainable development in the region (SUDAM, 1992). Regional bioindustry could become an important economic activity in the region if properly articulated with the agricultural and forestry sectors, with agroindustry and the pharmaceutical industry.

In the short and medium term, bioindustry may contribute to the sustainable development of the agricultural production sector (through techniques of clonal propagation and micropropagation, biological pest and disease control, among others), food and drink (for example, developing new strains of yeast for fermentation), fruit crops (for example, plant improvement for production of selected seedling material), medicinal plants, and poisons, among others.

Finally, due to its strong ties to biodiversity and genetic resources, bioindustry may also contribute to the region's environmental sustainability.

EMBRAPA, recognizing the growing relevance of agroindustry and bioindustry in the Amazon region in the last few years, through its research units in the Amazon, is making efforts to establish a foundation of competence and institutional capacity in the areas of genetic resources and biotechnology for the purpose of generating scientific knowledge and technologies to

support the development of these two important areas of agricultural production in the process of sustainable development of the region.

Biodiversity, genetic resources and biotechnology

Biodiversity encompasses the genetic variability of plant species, animals, and microorganisms and the ecosystems in which they are components (EMBRAPA/CENARGEN, 1991).

Preoccupation with and action regarding environmental questions indicate that biodiversity will have world priority in the last part of the twentieth century and the beginning of the twenty-first. The greatest part of biodiversity existing on earth is in regions of the Third World, mainly in humid tropical regions. The majority of this biodiversity exists in the Amazon Region.

Increasing scientific knowledge about Amazonian biodiversity should point to technological alternatives, mainly for utilization of native genetic resources in agroforestry projects which should be the main basis for sustainable agricultural development in the region, allowing for long-term environmental conservation (Castro and Santos, 1992). Consequently, it is necessary to establish units of biodiversity conservation which allow for, in the first place, knowledge of the complexities of Amazonian ecosystems and, in the second place, the characterization, economic value and rational use by man of the products of this biodiversity, mainly in agriculture, and in agro- and bioindustry.

Within the Amazon's biodiversity, there are genetic resources, or better, a variety of target species which should be conserved to be used mainly in genetic improvement and in correlated research for the purpose of economic exploration (EMBRAPA/CENARGEN, 1991).

In this sense, in order to increase stocks of genetic resources, high investments are needed in prospection, collection, characterization and cultivation techniques with environmental protection. In this way, plant and animal germoplasm will be developed which will contribute to sustainable agricultural and forestry development in the region.

In the context of evaluation and utilization of biodiversity and genetic resources for the purpose of agricultural and forestry development, biotechnology, undoubtedly, will play a role of great relevance through studies using molecular and biochemical methods of the genetic variability in natural populations, looking towards conservation *in situ* and *ex situ*, in programmes of genetic improvement and of Amazonian species with the quantity, quality and uniformity desired, beside their use in methods of biological control of pests and endemic diseases affecting regional agriculture (Castro and Santos, 1992).

EMBRAPA is developing research efforts with conservation and economic utilization of regional biodiversity in mind, mainly through research in genetic and biotechnological resources, trying to contribute, in this way, to the sustainable development of the Amazon.

Institutional capacity

Much more than before, research today is fundamental to the sustainable development of the Amazon Region. Limitations to agricultural and forestry production, to agro- and bioindustry, and the need to conserve natural resources require a research agenda which demands an enormous institutional effort (EMBRAPA, 1989; CORPAM/SCT, 1991).

Figure 12.5 shows the main governmental institutions directly and indirectly involved in agricultural and forestry research and evaluation and conservation of natural resources in the Amazon. Beside these institutions, in recent years, a reasonable number of non-governmental institutions have been contributing, in some measure, to the sustainable development of the region.

EMBRAPA, through its agricultural research centres in all of the states of the region, is undoubtedly one of the most important governmental research institutions for supporting agricultural and forestry development in the Amazon. In order to increase its efficiency in this sense, the institution has lately been re-evaluating its philosophy, mission, objectives, directives and research strategies for the region. Among other measures for sustainable development, all of EMBRAPA's agricultural research units in the region were recently transformed into Agroforestry Research Centres, for the purpose of emphasizing agroforestry development, probably the region's principal vocation. Great emphasis has also been given to the focus of research and development and to the diffusion of technology which favours development with conservation (EMBRAPA, 1991; EMBRAPA/CPATU, 1992).

Unfortunately and paradoxically, regional research institutions have stagnated during the last decade from the point of view of infrastructure, personnel (quantitatively and qualitatively) and, mainly, from the financial point of view, which has contributed to a considerable reduction in their performance.

At this time, it is difficult to foresee any improvement in the near future in the institutional capacity of regional research institutions. However, it is absolutely necessary that present tendencies of decline in the institutional capacity of regional research institutions be reversed as soon as possible. If this is not accomplished, this proposed sustainable agricultural and forestry development model for the Amazon will be difficult to establish.

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