Perspectives for Sustainable Management of the Renewable Natural Resources of the Amazon Forest

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I - Introduction

In the last years of the 20th century a major world concern unites different research groups, social segments and governments - conservation of the tropical forests, meeting the requirements of the human population and the necessary economic growth. The initial outcome of this concern today is the notion that only by adopting a sustainable development project integrating technique and social improvement will it be possible to conserve natural resources, tropical forests all over the world and improve the quality of life for the human race.

Historically, the countries where the nature-society bionomial has high levels of degradation lie exactly in the inter-tropical areas, between latitudes 23° North and 23° South. Their histories demonstrate a sad relationship between colonization, exploitation of their natural resources, population growth, demographic implosion of autochthonous groups, method of production, technology and social exclusion.

The consequences of this relationship, considered today to be unsustainable, are the increase in geometric progression of the processes linked to incorporating land into the prevailing productive methods, always beginning at the deforestation stage; deteriorating living conditions in the rural and urban environment; and loss of autochthonous cultural roots.

In this sphere, the Amazon domain has been recognized as a matter of worldwide concern regarding its progressive natural and social deterioration and its potential and importance in maintaining the biosphere-atmosphere balance.

The Amazon, stretching across nine countries, Brazil, Colombia, Peru, Venezuela, Ecuador, Bolivia, French Guinea, Surinam and Guyana, comprises a total area of around 7.8 million km^2, 70% of which is in Brazilian territory, representing more than 60% (around 5.5 million km^2) of this country.

It is defined in Brazil, for political-administrative purposes, as the Legal Amazon, consisting of the states of Acre, Amazonas, Roraima, Pará, Mato Grosso, Amapá, Tocantins and most of western Maranhão (Fig.1)

II - General Ecology

In terms of river drainage, the Amazon region covers the Solimões-Amazon, Tocantins river basins and part of the Orinoco river basin. The 6,577 km long Amazon river is considered today the longest river with the largest volume of water in the world. It is the area with prevailing plant formations of tropical rain forests and savanna vegetation.

Alongside this apparent unity in terms of river drainage, a range of complex ecosystems have developed with different characteristics of relief, soil, flora, fauna and morpho-dynamic processes. In order to understand these different landscapes, it is necessary to go back to the history of the Amazon basin's physical geography and its beginning when the Andes mountain range emerged around 68 million years ago (Cenozoic Era).

This new mountain range inverted the previous drainage pattern, creating today's vast depression between the arch at the foot of the Andes mountains, the Guyana and Brazilian plateaus, and is considered one of the largest inland lowland amphitheaters on Earth. Fluvial-lacustrine deposits prevailed for some time in this depression. Another slight uplift sloping generally eastwards determined the Amazon river and its western tributaries. In this sense, then, the Amazon is a geologically young river.

Today the relief system consists of a broad amphitheater opening eastwards and limited in the West by the Andes, by the Guyana plateau in the North and Brazilian plateau in the South. This physiography and its latitudinal position, cut by the Equator - influenced the prevailing warm rain-carrying winds blowing from the East to eventually give rise to a hot wet climate which permitted the development of the current climatic conditions.

Moreover, numerous recent studies show that the continuing prevailing climatic conditions and ecological dynamic balance itself are determined partly by the existing forest. This fact confirms the hypothesis that over time, under the prevailing hydrological conditions, plant-animal interactions gradually changed the conditions of climatic behavior until the present.

From the paleoclimatic viewpoint, the many studies performed on the Cenozoic in Brazil have shown that the evolution and development of the relief systems existing today resulted from the recurrence of the alternating dry and wet climates.

An increase in and better distribution of the rainfall, predominance of chemical alteration of the rocks, soil formation, spread of forest vegetation and development of the river basins were associated with the rainy eras. In the river basins erosion was under control, and only occurred in a linear fashion. These were the times when biological life developed and diversified.

On the other hand, a decrease in and concentration of rainfall were associated with the dry eras, which reflected immediately on the forest vegetative cover that tended to diminish in favor of the expansion of open vegetation (grassland, steppe, savanna, scrub land). The outcome is the removal of soil by the action of rainwater and filling up of valley bottoms, obstructing the flow of the rivers, since the increase in debris was much higher than the capacity of the rivers to carry it. During these dry seasons, slope erosion processes prevailed, ranging from surface run-off to mass movement, increased rates in the mechanical alteration of rocks, a drop in the river water volume and widening of the river beds. These are the times when biological life diminished and the general degradation of the landscape increased.

The many studies already performed to define the role of the alternating climates have revealed the occurrence of considerable paleo-hydrological fluctuations on a regional basis, between 21,000 and 12,500 years ago, and around 7,520 years ago, when dry or semi-arid climatic conditions prevailed.

In the studies on the Legal Amazon carried out by Brazilian Geography and Statistics Institute (IBGE and FBDS,1994) the mapping of natural landscape systems on a scale of 1:2,500,000 revealed this complexity, and 104 systems and 224 subsystems of natural landscapes were identified. These studies showed the importance of the presence of dichotomic natural landscapes (that is, in imbalance) between the hydrological and flora and fauna behavior, considered overall as tropical, and the abiotic landscape (relief, soils) with characteristics that differ from those of today. Such a fact confirms the hypothesis that the wet tropical conditions for the Amazon were recent and calls attention to the recentness and fragility of its biodiversity and, thereby, its ecosystems.

III - Population Growth

On the other hand, the same Brazilian Amazon today has a population of over 20 million inhabitants, representing around 15% of the whole Brazilian population, of which around 55% live in urban centers. The remaining indigenous societies total approximately 100,000 inhabitants.

The regional society is formed by Indians, mestizos, small farmers, homeless groups, urban workers, large and small landowners, traditional and modern entrepreneurs. Most of these social players comprise the groups of immigrants who at different times moved there, adding to the diversity which is so characteristic of this area. This no longer includes merely its physical-natural and biological diversity but also the diversity of the social, economic and cultural colonization.

In short, the change in the ecological and cultural mosaic of the Brazilian Amazon may be considered the result of four landmarks: the Portuguese spread in the 17th century; the Marquis of Pombal's policy in the 18th century; the rubber boom in the 19th/20th centuries; and the developmentalist policy of the second half of the 20th century.

The 1990s, however, seem to bring with them a new referential regarding the role of this region, caused by global economic and political changes. A new phase appears now with reference to the scientific-technological revolution, environmental crisis and social movements.

Meanwhile, countless projects for organizing and integrating this geographical area have been proposed and implemented. The sixties, however, may be considered the major landmark that was the basis for the changes which caused the most dramatic ecological and cultural transformations. In the early years of that decade the population was 2.6 million and by the end of the eighties had reached around 17 million (figure 2).

As a result of these changes, for the period between 1960 and 1991, in demographic terms, there was an increase in the population of 14 million inhabitants, which means a total growth rate of 550%. In terms of vegetative cover, taking into consideration the forest and non-forest vegetation, in 1991 a total of 14.07% of Brazilian Amazon territory was impacted and/or deforested (Ferreira, 1996).

To discuss this incorporation and "humanization" of the Amazon area entails discussing the different stages of devastation undergone by this region during its occupation. This expropriation of man and nature, mostly a result of the idea of "the great frontier of resources", when it acquired gigantic proportions, caused the idea that there were inexhaustible resources and almost an obligation to exploit them.

On the other hand, the "demographic void" slogan transmitted the idea of the need to occupy an area of continental dimensions. And so this region began to be compulsively colonized, on a three-pronged basis of the need for progress, search for national and international integration, and economic growth.

IV - Land Transformation.

These are transforming agents generated most frequently in areas outside the Amazon and the continent. The extent of these forces creates demands that can exert so much pressure on the social groups living there that they become local agents of the devastation

In fact, this progressive devastation, educational and cruel at the same time, is responsible for different external and internal demands for raw materials and inputs necessary for the prevailing form of production, as well as the need to solve social issues in different regions beyond the Amazon (Northeast, Mid-West and South). The answer lies in the penetration and consolidation of the control of the territory, gradual privatization of land, mines and forests and the economic and political organization of the region.

The First Changes.

Since the arrival of the indigenous nations in the Amazon, at an unknown date, until the decline in the rubber boom at the end of the 1940s, anthropic changes had little effect on the landscape. The demand for food (pirarucu, manatee), oil for lighting (manatee oil for candles and turtle oil), leather, skins and feathers for the fashion industry (alligators, monkeys, wild cats, egrets and other colored birds) and aromatic woods for perfumery (rosewood and cinnamon), was responsible for the extermination of large contingents of regional fauna and flora. Even today the pirarucu, manatee and turtles are still being destroyed and their populations have diminished greatly.

The loss of biodiversity in the region can be followed throughout its history. The first devastation was that of the gallery forest along the navigable river routes. The intent was to find "drugs from the *sertão* (inland)" (cinnamon, clove, indigo, cacao, aromatic roots, oleaginous seeds, timber, sarsaparilla, etc.) used in food, seasoning, shipbuilding and the pharmacopoeia of western Europe of the 17th and 18th centuries, as well as to expand Portuguese territory. Settlements were based on the military and colonial centers and religious missions (São Gabriel da Cachoeira, Barcelos, Tefé, Santarém, etc.). Market pressures and potential led to the metropolis tentatively starting a move from collecting to cultivating these drugs.

The need for manpower forced the settlers, mainly from Maranhão, to capture Indians as a labor source. The clash between the Jesuits who defended the Indians and the Maranhão settlers who produced sugar, tobacco and other products caused a further move inland by the settlers who discovered new potential products, that is, spices. This period is called the "inland drug boom".

In the 17th century an enormous quantity of smoked or salted manatee meat or *mixira* (preserve of young manatee in its own oil) was sent to Europe. Every year more than 20 vessels laden with manatee meat sailed from the port of Gurupá. By the 18th century it was hard enough to fill even one vessel with this cargo. Veríssimo, who was an encyclopedia of knowledge on Amazon matters, in 1895 spoke of the disappearance of the turtle and manatee populations from Marajó bay and the lower Tocantins. Between 1885 and 1893 the average pirarucu fish production was 1,283 tons, corresponding to 2,500 tons of fresh fish. Between 1933 and 1936, at the same port, the average annual production of dried pirarucu was 563 tons, that is, around 1,130 tons of fresh fish. These depleted resources in the 19th century were caused by the food requirements of the contingent of rubber soldiers who were the work force on the rubber plantations.

The second major devastation occurred between the last decades of last century and the first two of this century as a result of two major demands: Europe and the United States demanded a massive volume of rubber to manufacture domestic appliances, tires, war material and for shipbuilding; and the other was the need to solve problems in the Northeast due to the prolonged drought between 1877 and 1880. This was the time when Southwest Amazon was invaded and integrated, and from this period dates the incorporation of what is today the state of Acre. This was the "rubber boom".

The association of these national and international external demands caused a substantial increase in the number of the local population. The human contingent increased from 127,000 in 1823 to approximately 1.4 million inhabitants around 1920. They were additions to the lines of workers who spread out over those areas of thick rain forest, which has the largest occurrence of *Hevea brasiliense* (rubber tree). Of these areas, Acre had the largest influx of immigrants.

The 1920s and 1930s saw the start of the invasion of the cattle raising and mining forerunners who penetrated through the wide gaps left by the rubber and nut extractivist organizations. The latter activities satisfied predominantly local and regional demands, resulting from the need to attend a local consumer market then and to complement the resources of those who lived on subsistence and/or plant extractivist farming.

During the rubber boom, biodiversity was endangered by hunting for the rubber tappers' food. As most of the work force was busy with latex extractivism, there were few extensively cleared areas in the western Amazon for farming. Most farm products were imported from other regions.

Although the cropland frontiers had existed for a long time in the Amazon, they had the boundary of the forest against farther penetration. The whole rural spread ascertained until then occurred in areas of savanna and cropland. This farming activity put little pressure on the Amazon forest area until the 1960s because of its characteristics of expansion on natural pastureland and its secondary role, which demanded little in terms of the number of workers.

Decades of Devastation – 1970-980s.

But the arrival of the 1970s inverted this situation. From that moment, the "discovery" of mineral wealth and poverty of the soils made these two "frontiers" responsible for a new "boom" in changing this ecological mosaic.

The opening up of the Belém-Brasilia highway in the 1960s formed a North-South axis joined by the pre-existing secondary roads or those to be built. This redefined the whole system of access to the region, the circulation of the expanding frontiers and merchandise in the East-West direction.

The construction of this highway led to a faster advance of cropland fronts following the highway, moving towards Araguaia and the Xingu, the first signs of considerable changes in East Amazon. These changes, however, were only to be deeply felt ten years later when the Transamazonica and Cuiabá-Santarém highways were built. At the same time, during this period, there was a sharp rise in the number of small farmers expelled from the Northeast, who had been "advised" and "encouraged" to move onto the fore-Amazon and Amazon lands where, according to the propaganda, there was plenty of "free land".

The rate and intensity of this occupation meant, as a rule, a dramatic break from the activities that were being reproduced in the "demographic void", within a social and economic diversity that basically sheltered a population formed of Indians, riverside dwellers and some Northeastern immigrants, many of whom were mestizos, attracted by the successive booms in the extractivist economy.

From 1960 to 1980, the Amazon population grew from 2.6 to 11 million. The population boom is again the result of migration.

In an attempt to improve the organization of this occupation process, INCRA (National Institute of Settlement and Land Reform) was created in 1970 in order to organize and undertake land reform and to organize, coordinate, control and carry out colonization. According to IBASE (1985), INCRA would have moved around 400,000 settlers to the Amazon region between 1970 and 1974.

Directed settlement appeared as one of the most significant forms during this intense occupation process over the last twenty years. In general, settlement projects do not have a uniform pattern, differing from each other in terms of area occupied and the nature of the enterprise.

Although they have the same government policy, they have different aspects of access to the land through settlement.

The official settlement projects undertaken by the government were scattered over East Amazon (Altamira, Itaituba, Marabá, Carajás II and III, in the state of Pará; Barra do Corda in Maranhão), while in West Amazon they tend to concentrate in Rondonia. They may be of three types: integrated colonization projects, directed settlement and joint settlement. They covered 73.4% (7,104,285.3 hectares) of the land appropriated for this purpose.

Private colonization projects, however, by private enterprise occur predominantly in Mato Grosso, such as, for instance, those in Sinop, Alta Floresta and Juína. These projects cover 26.6% of the whole area (2,573,485.6 hectares).

If, on one hand, in terms of land penetration, land, mines and forest ownership, and economic and political organization of the region, it can be considered as the last devastation, it may, on the other hand, mean a new beginning.

The Pressures Continue – 1980-1990s.

A new phase appeared in the early 1980s as a reflection of the new world economic order, dictated by a structured raw material market on a worldwide scale. The commitment of this economy caused the retrieval of resources which have now become scarce (timber, hydroelectricity), use of other resources in a growing demand for modern technology (aluminum), in addition to the lower costs of abundant traditional raw materials in the area (iron ore).

From a Brazilian viewpoint, the 1980s represented the implementation of a modernization policy of this territory, with a view to industrialization of the Amazon and exploitation of its mineral resources on updated bases. It was in the eighties that the Grand Carajás Project (PGC) was installed, considered in terms of both physical area (900,000 km^2) and projected investments as one of the largest integrated development projects ever begun by a developing country (Hall, 1990).

Basically this new project led by the State brings demands for timber, hydroelectric power, organizes the opening of areas for mineral exploitation and provides new mobility for the population in the Amazon area.

In the wake of these demands comes the new mobility of the population inside the Amazon region itself, especially from immigrants from Maranhão. They are encouraged to move to areas where they are needed as manpower in the building of the infrastructure (Carajás railroad, mining area, steel mills, etc.) and for future industry.

Interaction between demands, exploitation of resources and need for labor caused a spatial "disorganization" of the deprived social segments who eventually consider the exploitation of this asset as an alternative for survival. Groups of migration were seen within and outside the Amazon (Mid-West and South). This was seen in the gold rush (prospectors and small companies), of which the best known example is Serra Pelada. This boom reached its peak in 1985 when more than 500,000 people converged on this area, crammed together in towns, such as, Marabá, Eldorado do Carajás, Curionópolis, Parauapebas and Rio Verde. This is the second major ecological and human change in eastern Amazon.

As an outcome of these induced geographic organization projects in the Amazon (Ferreira et al, 1995, 1996), it was found that between 1976 and 1991 around 35.61% of the area where the vegetation is seasonal and rain forests and 20.41% of the contact areas were rain/seasonal forest, was impacted and/or deforested. If we take into account the other non-forest vegetation, in 1991 we have a total of 14.07% of the Brazilian Amazon territory impacted and/or deforested (Fig. 3).

These figures correspond to the total percentage of the Brazilian Amazon area converted into pastureland, farming areas, lumbering, mining, prospecting, plant extractivism and urban areas.

New Economic Pressures and Deforestation – 1990s.

The nineties seems to bring in its wake a new reference point regarding the role of this region, caused by further changes of a world economic and political order. This is a new phase now in relation to the scientific-technological revolution, environmental crisis and social movements.

The transforming forces, previously exclusively external, now blend with the national and local internal demands. The Amazon is becoming the product of local, regional, national, international and planetary demands. Its future is the world's future.

In this new context where the technical-ecological vector characterizes the production methods, the Amazon has become the center of a worldwide debate. According to Becker (1996), "all elements in this vector are present in Brazil and much more clearly in the Amazon, which has become the contradictory synthesis of the prevailing industrialist and eco-developmentalist models at the end of the millennium. For this new production method, nature is valued as capital with future returns for native populations and environmentalist movements. Nature is valued as a source and means of life, while it is still the essential basis of resources for productive segments and Brazilian society in general".

However, although the technical-ecological vector emerges as a debate that seems to permit the preservation of this geographical area, it is found, on the other hand, that there are accentuated external economic demands for staple raw materials (principally timber) and primary products (cereals) that again put heavy pressure on this region because of the exhaustion of other areas.

The rise in deforestation rates disclosed by INPE (figure 4), principally in 1990 and 1991, and IBGE's mapping of human development seem to indicate that these new demands are already in the pipeline.

If we look at the deforestation rate per state (figure 5), we will see that the states of Rondonia and Mato Grosso showed a progressively higher rise in deforestation rates for the 1990-1994 period. The progressive increase in rates in the state of Mato Grosso can be explained by the advance of the soybean agribusiness that is already moving into the southern areas of Pará and Maranhão.

On the other hand, when we look at the graphs on urban and rural population growth (figures 6 and 7), we see that since the 1980s both West and East Amazon have undergone an increasing urbanization process of their populations, headed by the states of Amazonas and Mato Grosso, followed on a lesser scale by Rondonia and Acre.

If we compare the graphs on urban and rural population growth and the deforestation rates in the Amazon we will see that a population growth in rural areas does not correspond to this substantial increase in deforestation rates.

This offers us the hypothesis that progressive deforestation is not a product of direct demographic pressure but rather of transforming economic forces entailing technological packages which exclude large quantities of manpower. Such transforming agents represent pressure groups at local, regional and international levels.

This hypothesis is confirmed by the types of international and national demands (Figures 8 and 9) that exert more pressure on this region. The products in most demand are represented by timber, cattle raising and cereals, activities which absorb little manpower but with a high spatial capacity for destroying the ecological mosaic. Grain farming, although representing a recent demand, has been encroaching on the remaining savanna areas in northern Mato Grosso and southern Pará since 1988 as the IBGE mapping reveals (1995). Today this cereal production is already encroaching on the forest-savanna transition areas.

This new order of devastation is currently reflected in the disordered growth of the towns that, in some places in the Amazon, have even had a relative growth of 7,000% between 1980 and 1991 (IBGE, 1995). These towns have become the locus of a cultural and ethnic disruption, with the consequent loss of identity by native segments who have for centuries adapted to the regional ecosystems.

Questions of health arise in this complex urban scenario and this last decade has seen a substantial increase in the incidence of endemic diseases, principally malaria, cutaneous leishmaniasis, typhoid, leptospirrose and leprosy (IBGE, 1995).

The figures undeniably demonstrate the importance of the different social segments in the progressive transformation of the Amazon domain and the external transforming agents that are able to engender processes hard to control at a regional and national level.

It is, however, necessary for us to identify as early as possible the new pointers of the human dimension that now emerge and those that may potentially arise with a view to being able to supply not only past but future models of scenarios of changes in the biosphere-atmosphere.

Lastly, it is important to remember that at the end of this millenium, the Amazon domain is at the same time one of the last vast and wealthy sparsely populated areas on the planet and one of the world's most complex and vulnerable ecosystems which "makes its development an incognito and a challenge to world and national sciences" (Becker, 1996).

V - The Evolution of the Scientific Knowledge of Amazonia.

The First Descriptions

The stories of the first conquerors who traveled as far as the Brazilian Amazon attest to their wonder at the sight of such natural abundance. The presence of adventurers from many European countries was a sign that this territory was coveted by n means few European powers, and that, on beholding such tropical lushness and biodiversity, they believed that they had found in the Amazon a fortune that would make each common conqueror a wealthier man than the Portuguese king himself. They believed that this land was part of the earthly paradise or the mythical Renaissance cities (El Dorado, Land of the Amazons).

We owe the first accounts of this region to the Dominican friar, Caspar de Carvajal, who wrote in detail of the expedition of Francisco Orellana, Spanish conquistador, who founded Guayaquil and brother of the cruel Gonzalo Pizarro, who annihilated the Inca empire. The first journey along the Amazon river was made following the waters eastwards from the West. Friar Carvajal's writings are the first descriptions of the general characteristics of the river with the largest volume of freshwater on Earth. This navigation took around eight months and ended in August 1542.

One of the interesting facts mentioned by Carvajal is the existence of the Amazons, described by him as women who courageously fought with bows and arrows, were naked and wore their hair very long, in plaits entwined around their heads, and that they were organized socially in groups of villages. Even today we are not sure if this people had light skin, if they really existed, if Carvajal had mistaken them for long-haired men, or if he unwittingly adopted the Greek myth of the Amazons. The fact is that this is why the great river along which they sailed became known as the river of the Amazons. The accounts of all these journeys tell us that there were people living in organized communities along the Amazon, under the command of a chief, with large tracts of land and remarkable buildings, but we are not sure how many there were. (Oliveira, 1983)

These indigenous peoples had sophisticated in-depth knowledge of the ecosystem and farming and several species were domesticated for food or otherwise by the Amazon nations, and which are still used by us today. These Indians, living in the floodplains or forests (mainland), were knowledgeable about and used a large variety of plants such as: tubers, bulbs, seeds, fruit, nuts and other plant products. The vegetation also supplied poisons for hunting and war, in addition to medicinal products and drugs used to cure some diseases and in religious rituals. The forest was also the source of timber for firewood, to build utensils, weapons and cabins, as well as a source of material for basketry, clothes, resins, oils and pigments. The fauna supplied food, especially meat, eggs, insects and honey, as well as ornamental and building material for instruments and weapons.

Between 1637 and 1639, the Portuguese captain Pedro de Teixeira led an expedition from Belém to Quito and back to Belém. On the return journey, from Quito to Belém, Pedro Teixeira is assisted by Father Acuña, who in 1641 publishes the *Nuevo Descubrimiento del Gran Rio de las Amazonas* in Madrid, the most detailed treaty until then on the nature of the tropical region and the uses and customs of the Indians.

In 1743, Charles Marie de La Condamine, entrusted by the Science Academy of Paris to set the exact coordinates of the land Equator, sails up the Amazon river and, after enduring a series of hardships on his expedition, returns to Paris and leaves a vivid account of the aspects of nature in the tropics.

However, the best account of the Amazon is found in the report of two emissaries from the Portuguese court. The report by Francisco Xavier Ribeiro de Sampaio, in 1774-75, as justice of the peace and General Overseer of the River Negro administrative division, covers vast regions, as he visited indigenous villages to find slaves. The most detailed and only report written by a naturalist is still consulted today by scientists and students of the Amazon, and we owe it to a Brazilian, born in Salvador, who studied Natural History at Coimbra University. Alexandre Rodrigues Ferreira (1756-1815), when 27 years old, was commissioned by the Portuguese court to write a scientific report on the river Negro. Between 1785 and 1791, Rodrigues Ferreira collected animals and plants, visited Indian villages, where he gather ethnological material, drew numerous drawings on several aspects of nature and indigenous customs. On his return to Portugal, he wrote "*Viagem Filosófica pela Capitania do Rio Negro*" (Ferreira, A. R., 1792). He was a renowned scientist and became administrator of the Royal Botanical Garden in Lisbon. After the earthquake in that city and the Napoleonic wars, his collections and publications were scattered and few have survived.

The Classic Era

There is no doubt, however, that the 19th century is the era of the great naturalists. We have from this time the best collections and studies of Amazon plants and animals. The systematic and taxonomic studies, on which scientific knowledge of this forest's biodiversity is based, was undertaken by Humbold and Bonpland who spent the years from 1799 to 1800 sailing along the Cassiquiare channel between the Orinoco and Negro rivers. Then, between 1817 and 1820, two other great German scientists, Spix and Martius sailed down the Amazon, exploring the Juruá and Madeira rivers.

There were several other accounts by military men and priests during these years, with the main focus on indigenous problems, with nature on a secondary plane. Some examples are that of Major João Henrique de Mattos, in 1825, who mentions the decadence of the Indians in the upper Negro river. By Navy Lieutenant Henry Lister Maw, in 1828, who arrived in Brazil at Tabatinga, and traveled as far as Belém, leaving us accounts of civilized Indians. Sir Robert H. Schomburgk, from Prussia, who visited between 1838 and 1842, employed by the Royal Geographical Society of London, explores and maps the region between Brazil and Guyana. His numerous collections are kept at the British Museum and his cartographic studies were used, at the International Court of The Hague, to arbitrate in favor of Brazil, the dispute on the boundary lines between Brazil and former British Guiana.

In the mid-19th century, four outstanding naturalists broadened and founded the tropical taxonomic science. Alfred R. Wallace, entomologist, gathered his Amazon collections in the 1849-1852 period. He visited and collected mainly fauna from Belém in Pará to the upper river Negro. His notes, drawings, articles and most of his collections were lost in a fire on the ship that carried Wallace back to England. His friend and also entomologist, Henry W. Bates, also visited the Amazon and explored the Amazon river tributaries. He stayed for eleven years (1849-59) in the region and his vast collection reached England safe and sound.

Turtle Oil

The Spanish and Portuguese conquistadors told how the Indians, during the ebb tide, would capture a large number of turtles. They were left imprisoned in small lakes to fatten and were then used as food when they reached adulthood. This primitive management system can still be found in remote communities. The oil taken from turtle eggs started with the Europeans, as there is no record of the Amerindian peoples using this oil since they were only interested in the fresh meat and eggs as food. The oil is obtained by breaking thousands of eggs under the hull of a canoe, crushed and mixed with the oar until a mixture is obtained from which the fat is removed and placed in large mortars for purification and reduction. Henry Bates calculates that to fill a pot (unrecorded volume) 6,000 eggs would be needed and that, in the region of the upper Solimões and Madeira rivers, 48 million eggs were destroyed every year. This corresponds to 400,000 turtle nests.

From his entomological collections, it has been possible to describe 3,000 new species of insect. Richard Spruce, an American naturalist, who between 1849 and 1855 followed in the steps of those two above, formed an important collection on the regional flora. There is no shadow of doubt that these three men were the forerunners of taxonomic knowledge of the biodiversity of the tropical rain forest. The American ichthyologist couple Agassiz traveled the Amazon rivers and gathered the largest collection of fish ever. By the end of the century their publications were the bible of taxonomic studies on Amazon fish.

In the late 19th century (October 6, 1866), Brazil founded a Research Institution that is now called the Emilio Goeldi Museum in Pará. For the first time, scientific research was now based in a local institution. In addition to studies on birds by Goeldi himself, mention should be given to the work on fish and fishing by Verissímo, which is still being quoted. From the studies carried out by the Goeldi Museum, scientific research was consolidated as an ongoing activity of the Amazon intelligentsia.

The prosperity from the rubber monopoly since 1880, reaching its peak in Brazilian production between 1910 and 1912, brought significant improvements to the region but this did not reflect in scientific research. However, since 1914 with the decline in the Brazilian monopoly, the Brazilian government took a series of measures to save the rubber and look for alternatives for farming development. Some of the programs amplified the basic knowledge on the regional nature as they focused on research. This phase includes the Rubber Defense Plan, 1912, in the government of Hermes da Fonseca; the Rondon Commission, 1907-1917, started by president Afonso Pena, extended studies on the indigenous communities; land concessions to the Japanese for exploiting jute and then black pepper coincides with the formation of farming cooperatives and the creation of the Northern Agronomy Institute in 1941, to undertake research on plant production, species acclimatization and soil and forest identification. The Emílio Goeldi Museum of Pará and Northern Agronomy Institute together have performed the best scientific research every done in the Amazon to date. The specialists and researchers working there have formed the basis for undertaking future investigations that today are spread throughout the universities and public institutions in all Amazon states.

Organized Research

With the end of the Second World War and continuing signs of internationalizing the Amazon, especially with the American proposal to create the International Institute of Amazon Hylea in a town in the Amazon region as the headquarters for international scientific research in the region, the nationalist government of Getúlio Vargas reacted and in 1952 created the National Institute of Amazon Research (INPA), based in the city of Manaus.

In contrast to the Emilio Goeldi Museum of Pará, who focused for decades on systematic and anthropological research, from its early years INPA concentrated on studies of the relations between the environment and biological systems that would later lead to important research on how ecosystems are structured and operate.

This new point of view originated the primordial work of Professor Sioli on the river system in the region. The division between white, black and clear waters proposed by these researchers from the studies of their physical, chemical and biological characteristics were the pillars of the limnological studies on the whole Amazon region. Since the 1960s, a significant research effort has been made to establish scientific bases of the dynamic processes to maintain the ecological balance of the Amazon.

By the end of the sixties two major lines of work had emerged. The first endeavored to discover the importance of the forest in the water cycle, especially investigating if large-scale deforestation could be an influence on climatic changes in the region. This line of work was first adopted by Eneas Salati and eventually established the Amazon water cycle (Salati & Vosse, 1984).

The second line of work sought to discover the importance of nutrient recycling in maintaining the primary productivity of the forests, that is, the continuation of the forest biodiversity. This kind of work was undertaken in the laboratory by Herbert Schubart and his results were summarized in two important publications (Schubart,1983; and, Schubart,1998).

The Forest and the Water Cycle

The work performed since the end of the sixties to date shows that the forest vegetation plays a relevant role in the influence of the water and solar energy balance (Salati & Marques, 1984; Salati et al, 1978; Salati et al 1979; Salati and Volsen, 1984; Salati et al, 1990; Salati and Nobre, 1991).

Many papers have been published stressing the importance of the Amazon rain forest and the maintenance of the climate within this region, as well as the areas around the Amazon and even global climate changes.

The main functions of the rain forest affecting the climate balance in the Amazon region are listed below:

- due to its structure, the forest intercepts the rain causing direct evaporation and returning water vapor to the atmosphere. The amount of water vapor generated thus depends on the structure of the forest, and this figure varys from 17%-25% of precipitation for dense forest areas;
- trees within the forest structure act as "pumps" carrying water from the soil to the atmosphere. During this transpiration process, the energy needed to transfer the water from the liquid to the gaseous state comes merely from sunlight. In dense forests, this process represents approximately 50% of rainfall;
- the forests avoid surface run-off as the soil is covered by a thick layer of organic matter with a large water infiltration capacity. This means that the forest increases the length of time during which the water remains in the ecosystems, allowing the plants to act as systems transporting water from the soil to the atmosphere through transpiration;
- the forest controls the energy balance of the ecosystem. Studies show that some 75% of solar energy is used in a dense forest to evaporate water through direct evaporation of water retained in the canopy and plant transpiration. Deforestation alters this energy balance, as well as the water balance.

Based on this information and mathematical modeling, the forest system has been shown as an important factor for maintaining both regional and global climates. Deforestation could well result in climate changes at the local, regional (Gash et al, 1996) and global levels.

The appearance of global climate changes deriving from deforestation in the Amazon is particularly related to:

- quantitative alterations in the transportation of energy and water vapor from the Equatorial regions to higher latitudes;
- the emission of greenhouse gases produced by deforestation and burn-offs with CO_2 taken into consideration. Another aspect that should be recalled is the emission of nitrogen oxides produced during burn-offs.

Due to deforestation, direct CO_2 emissions in the Brazilian Amazon are estimated at some 0.3 GtC. These figures have prompted countless discussions due to relative uncertainty over deforestation rates and the quantity of biomass associated with cleared ecosystems.

The Forest and the Nutrients Cycle.

Schubart, in 1998, made an excellent summary of the role of the forest in recycling nutrients. The problems of establishing sustainable agriculture in the Amazon region are mostly the result of the break in this dynamic process with the forest ecosystem. Shubart summarizes as follows:

In the Brazilian part of the Amazon, the vegetation types of the vast Hylaea of about 3.7 million square kilometers are divided into 89% of non-flooded dense tropic rain forests, 2% of flooded forests, 6% of open vegetation types like savannas and *campinaranas*, and 3% of aquatic vegetation, rivers and lakes (Braga, 1979). The non-flooded dense rain forests are, therefore, by far the most representative forest cover of the region and will be thus specially considered here.

The two most conspicuous aspects of the structure of these forests are certainly the high biomass and the extremely high biological diversity. A complete sampling of a 2,000 square meters plot (0.2 hectare) of dense rain forest, growing on an oxisol near Manaus, found an amount of about 500 metric tons per hectare of plant biomass (dry weight), 14% of which was root biomass. This sampling also established the presence of 502 different tree species between one and 40 meters in height, distributed among at least 60 plants families (Klinge, 1973; 1976; 1983). None of these species showed any particular dominance over the others.

The thick forest around Manaus is clearly stratified in four stories: trees taller than 15 meters; trees between 12 and 15 meters; small trees and shrubs between 7 and 12 meters; and seedlings, saplings and shrubs less than 7 meters tall. The highest story has less individuals and species. There are not many emergent trees higher than 30 meters (about 4 to 10 trees per hectare). Twelve species in this area exceed 35 meters height, among which *Dinizia excelsa*, a legume tree, which is reported as the tallest tree in Amazonia, with a record of a 55 meters tall specimen. The diameters of the tree trunks of most species are not very large, at below 85 centimeters. Only 10 species were found with trunk diameters of more than 85 centimeters, including one tree of *Dinizia excelsa* with two meters. Other structural elements of the vegetation include palms, lianas, ferns, mosses and epiphytes. Their biomass is not quantitatively important, but they do represent an expressive share of the forest biodiversity and are functionally very important.

A study of the distribution of fine roots (diameters < 10 millimeters) and soil fauna (mainly arthropods), in two soil profiles to the depth of 1.6 meters, showed that about 85% of the dry weight of less than 2 millimeter roots and 66% of the roots between 2 and 10 millimeters are found in the top 10 centimeters of the soil. The same trend is true for the distribution of soil fauna: 84% of the total catch (expressed in number of individuals) in the mentioned profiles also occurred in the top 10 centimeters (Chauvel, Guillaumet and Schubart, 1987).

There are no really large animals in the Amazon rain forest. Of course, some of the world's largest insects and spiders do live a hidden existence in its shade. Among the large vertebrate predators are the jaguars and pumas, bush dogs and other dog-like species, the harpy eagle and several hawks, falcons and owls, besides a variety of snakes, toads and frogs. The largest herbivore mammal is the tapir, followed by several other groups of herbivorous or omnivorous animals, like deer, peccaries, agoutis and smaller rodents, opossums and other marsupials, the edentate armadillos and the tree climbing sloth, monkeys and marmosets, many insect or fruit eating bats, and a multitude of birds.

A long term research project being carried out North of Manaus to assess the impact of forest fragmentation on plant and animal diversity (Lovejoy *et al.,* 1983) has inventoried the vertebrates occurring in the area as follows: 44 species of amphibians, 89 species of reptiles, 300 species of forest birds and 51 non-flying mammals. It is interesting to note that the bats - flying mammals - are more species-rich than all other mammals together in the same area, amounting to between 60 to 65 species.

Then, there is a host of insects. The high diversity of plants seems to be at the origin of the high diversity in insects, due to the generally tight species-specific relationships between plant-eating insects and their feed plants. As a matter of fact, the number of species of these insects, and of their predators and parasites, can be very high indeed, as studies of the forest canopy insect fauna have shown. According to these estimates, the number of species of insects in all tropical forest could be as high as 30 to 50 million (Erwin, 1988).

However; the total animal biomass in the dense rain forest ecosystem is not so high when compared with plant biomass. A rough estimate of these biomass figures, expressed as fresh weight per hectare, reads as follows: 1,000 tons of living plants, of which 20 tons are leaves; 30 kilograms of herbivorous animals; 15 kilograms of carnivorous animals; 165 kilograms of soil fauna; an unknown amount of soil fungi biomass; and 100 tons of dead organic matter, mostly of plant origin. Most of this animal biomass consists of invertebrates, especially insects. The importance of the soil fauna, especially ants and termites, is particularly remarkable.

In terms of food chains, the rain forest ecosystem may be separated into two sub-systems. The first is based on the direct consumption of leaves, fruits, nectar and parts of other living plants by insects, birds, bats, monkeys and other herbivorous animals, which in their turn fall prey to predators or carnivorous animals. The energy flowing through this so-called autotrophic food chain is only about 10% of the total solar energy fixed by the green forest plants.The remaining 90% of solar energy stored in plant tissues – leaves, flowers, fruits, bark, wood, etc. – as the leaves or the whole plant die, is transferred to the dead organic matter of the soil as leaf litter, dead tree trunks, rotten fruits, and the like. This raw organic matter store is the starting point of a very important food chain, in which the soil fungi and bacteria play an essential role as organic matter decays. This basic function is enhanced by the activity of a myriad of mites, springtails, millipedes, termites, wood lice, earthworms, ants, pseudo-scorpions, spiders, nematodes, protozoans, and so on, which constitute a complex food web of detritivorous and fungivorous organisms and their predators. All the biological activity in this so called heterotrophic food chain results in the breakdown and humification of the raw organic matter, the release of mineral nutrients to the plants, and the building up of porosity along the soil profile by the activity of soil animals, especially termites, ants and earthworms.

The mean yearly production of dead leaves and other fine debris by the forest trees varies between 6 to 8 tons per hectare around Manaus, and 10 tons per hectare around Belém. This litter fall is greatest during the drier months of the year; when leaf litter builds up on the soil. The breakdown of this leaf litter; on the contrary, is more intense and very fast during the rainy season, when the dead leaves may completely decay in about one month.

These lush dense rain forests thrive on the very mineral-poor soils described in the previous section, a situation that at first seems a paradox. The explanation is, nevertheless, simple: these rain forests store in their biomass, and recycle, all the mineral nutrients. The concentrations in the water of the forest streams and rivers that drain these systems, are minor and comparable to the small mineral inputs from the rainfall and from the weathering of the already impoverished soil parent material.

The conclusion is that the Amazon rain forest ecosystem is very efficient in retaining and recycling its essential mineral supplies under a regime of very high rainfall. Actually, these forests have been described as biological mineral filters, in which the complementary and finely tuned functions of a multitude of trees and their fine roots, epiphytes, animals and microorganisms, together, help to find and consume any remaining small piece of nutritious food, or any leaking droplet or mineral concentrate. In this model, therefore, the reportedly high biodiversity of the rain forest plays a very central role, which is schematically shown in Figure 3. Without attempting to explain every relationship depicted in this diagram, it is worthwhile pointing out a few of them. First, the tropical climate conditions are very favorable to plant production. However, these same conditions also favor the year-round development of insects, fungi and bacteria as plant pests and disease agents, and also cause the intensive weathering of clay mineral and leaching of soil nutrients. Both of these last mentioned consequences – pressure of plant predators and parasites, and impoverished soils – favor the increase in plant diversity by different means. The first, by decimating any clustering of a single species – "natural single crops" – which could occur in the forest as, for instance, all the seedlings germinating under the mother tree. Isolated individuals are statistically harder to find by their natural enemies and are, therefore, less vulnerable).

As a result of this pressure of phytophagous insects and disease agents on plant populations, the forest ecosystem develops a higher plant diversity in equilibrium. Here, the importance of seed dispersal by birds, bats, agoutis, monkeys, etc. to maintain the plant diversity of the rain forest becomes evident. The second consequence – impoverished soils and their role in plant diversity – can be explained by the growth rates of different plant species under different soil nutritional status. In fertile soils, some species grow very rapidly and occupy all the available space, to the exclusion of many other species. In more mineral-impoverished soils, no species can grow fast enough to exclude the others. Once again, the outcome will be a more species-rich plant community.

Recent International Cooperation

Since the eighties, a series of projects began in INPA in cooperation with international and Brazilian institutions outside the region, which introduced an integrated view of the importance of the Amazon for the planet and the effects of global anthropic changes on the region. Integrated projects are also underway to investigate the ecological relations established during the evolution process of the Amazon biota.

Two lines of research started in the late seventies consolidated the knowledge about the structure and functioning of the non-flooded and floodplain ecosystems. Since then, with growing international concern for the effects of deforestation on the biodiversity of the non-flooded forest, a research team was created in INPA to study the effects of fragmentation on the ecosystems through the Biological Dynamics of Forest Fragments Project (Projeto Dinâmica Biológica de Fragmentos Florestais - PDBFF). This program, now more than 20 years old, trained 39 new Masters and Ph.D. researchers, and every year holds a course on tropical ecology for students from the whole of Latin America, as well as producing vast literature on fragmentation issues. Based on 11 forest fragments close to Manaus, this project is the result of a bilateral cooperation agreement between INPA and the Smithsonian Institution. The results already obtained from basic research help towards drawing up social integration policies and developments more suitable to ecological relations.

With regard to the floodplains, the projects by INPA and the German Max Planck Institute on the influence of the ebb and flow pattern on the ecology and biology of the floodable areas, were also the basis of the ecological and anthropic relations of this Amazon ecosystem, which have historically been most impacted by man since the Indians set up home along the rivers (Junk, 1997). This line of work led to the application of basic research studies on a proposal of sustainable development for the Amazon floodplains, through German-Brazilian cooperation that produced the Program of Studies of Human Impacts on Tropical Forests and Plains - SHIFT.

Now at the end of the 1990s, awareness that the global climate changes are the result of anthropic actions and that the impacts of these changes can affect continuing economic development, creates the need to set up research programs that strive to model the anthropic effects on bio-geochemical cycles, especially with regard to the carbon cycle. From this latest point of view, Brazil and the international community have set up a research program called "Large Scale Experiment on the Biosphere-Atmosphere in the Amazon". This experiment attempts to answer two major questions: how does the Amazon currently operate as a regional entity and how will the changes in the land and climate affect the biological, chemical and physical functioning of the Amazon, including its sustainability and influence on global climate. These questions will be answered through studies on the carbon exchange and storage, bio-geochemistry of trace gases and nutrients; chemistry of the atmosphere; surface hydrology and chemistry of the water and changes in land use and vegetative cover. The results will help towards the development of public policies for the sustainable used of the natural resources in the region.

Obviously, the development of scientific research in the Amazon has always had international cooperation and, although still quite fragmented and with major gaps even in such basic subjects as taxonomy and systematics, it has reached a level of integration and global thinking that permits the establishment of major multidisciplinary projects in the latest international scientific investigations.

VI - Factors that limit sustainable development in the Amazon

Sustainable development projects in the Amazon are limited by a number of environmental pressures, which are as follows:

- low productivity originating from the actual bio-geochemical cycle, as in the example in the following item;
- variation in available resources, typical of the flooded areas where the water supply cycle varies widely between seasons;
- biological pressure, namely pests, disease and predators that attack plantations, the clearest example being the fungus that attacks rubber trees, against the cultivation of single *Hevea* crops in the Amazon.

In addition to these environmental pressures are the limiting factors relating to the expression of the political and economic culture, that are of a technological, institutional and market origin. In this chapter we have endeavored to show how the biological and cultural factors limit the success of economic ventures and that identifying the factors is a key to implementing sustainable development projects in the Amazon (Salati et al, 1998).

Factors that Limit Biological Productivity in Natural Ecosystems

Environmental limiting factors can be easily described through understanding the primary productive process. The basis for establishing a food chain in the Earth's major ecosystems depends essentially on the possibilities of organic matter production through photosynthesis. During this basic process of nature, carbon dioxide assimilated by the plants during the day produces simple organic compounds that, by biochemical processes, become more complex organic compounds. In order for this phenomenon to occur, that is, for "primary production", some conditions are necessary, such as water, light, inorganic chemical elements, suitable temperature conditions and the existence of organisms that can produce photosynthesis.

With the exception of the polar regions, there is always some plant species that can survive and produce organic matter, which accumulates for some time and then is fully or partly oxidized. This basic process, occurring on Earth for at least the last 3.2 billion years, permits the accumulation of a large quantity of carbon in the form of organic compounds.

The animal kingdom depends for its survival on basic organic matter that is the start of quite a complex food chain in the various ecosystems on the planet. This ability to produce organic matter, that is, biochemical fixation of carbon, depends on numerous factors that define and determine the "exuberance" of the ecosystem under study.

The lack of conditions for plant growth can be described by limiting factors that hinder or prevent efficient photosynthesis of a certain species or plant community.

When addressing a farming ecosystem, that is, the production system in which man utilizes the photosynthetic conversion to supply his food requirements, the appearance of limiting factors should be avoided. This is possible by using farming techniques where, for instance, only selected crops adapted to the local ecological conditions are planted. The development of the root system should be maximized, in order for a more efficient absorption of mineral nutrients and water required to increase production. Selected crops have the advantage of resisting local diseases.

In some natural ecosystems, the limiting factors in the cultivation of farming species are so obvious that no attempt is made to do so. Thus, for example, in the desert regions like the Sahara, for instance, the obvious limiting factor is water. Thereby, before any farming activity or plan of action is adopted, it is necessary to find out if there are water sources in order to cancel out the most important limiting factor.

In other regions, the limiting factor for farming cultivation is the temperature. In large regions, such as, Siberia and some very high plateaus (Tibet, Chile), the average temperatures during the year discourage the growth of exotic crops in the open air. In this limiting situation, some kind of farming activity can be performed by using artificial systems, including greenhouses, which permit the cultivation of some plants of economic interest.

Another limiting factor in tropical, temperate or semi-arid climates is soil fertility. The reason for low fertility can sometimes be related to the origin and evolution of the soil; at other times, the degradation of the ecosystem by anthropic action accelerates erosion and the leaching process, resulting in barren soil, unproductive in farming terms. In this case, the problem is solved by using specific techniques, such as, proper soil management, cultivating pioneer species, using nitrogen-fixing plants and artificial fertilizers, including macro and micro-nutrients.

The productivity of various natural ecosystems in the Amazon is closely linked to the characteristics of the soils. Evidence of this fact is the existence in the Manaus region of very different ecosystems with a variable biomass from a few dozen to 400 t/ha. When studying these ecosystems, it is found that the wide variation is related to the soil characteristic, for example, too much aluminum or sand, since the climate and topographical conditions are practically identical.

The thick mainland forests grow on clay soils and the vegetation becomes more sparse as the clay content diminishes until reaching the "campinas" (savanna) conditions where the trees show evident signs of xerophytism. This scenario is repeated in parts of the river Negro, mainly in its upper course, where savanna land prevails. The particular features of this associated flora and fauna are the result of the soil's fertility and variables, such as the groundwater level and slopes.

Also in the flooded forests, the flora characteristics are associated with the availability of nutrients from the river waters flooding the area. Along the Amazon floodplains, flooded periodically by white water rivers, such as the Solimões and the Amazon itself, there is a large quantity of organic matter in the water and consequently a high total biomass for the gallery forests. In the areas flooded by black water rivers, poor in nutrients, there is little organic matter, and, therefore, less total biomass in the forests in these flooded areas, or *igapós*. Flooding time is longer in the flooded forests, and the trees are under water for a long period in some places, while the seeds are under water for up to 6 months. This water "stress" is a selection factor and only some species have adapted. This limiting factor also explains the smaller diversity of the *igapó* flora.

In general, in the case of the tropical rain forests, with special emphasis on the Amazon forest, the lushness of the vegetation depends fundamentally on the soil and climate conditions. The humidity, temperature and light levels are excellent for the plants. It is mistakenly believed that there are no limiting factors for intensive and/or extensive farming. This simplistic view has pushed visionaries or men with a developmentalist mentality to establish large settlement projects in the Amazon. However, the experience of some decades of settlement has shown that in the rain forests the limiting factors make intensive farming a thankless and unproductive task and it most often depends on the use of techniques, which is practically impossible given the socio-economic reality in the region.

Factors that limit the Implementation of Sustainable Productive Systems

In order for a project to be sustainable, it must adopt basic guidelines of economic sustainability, ecological adaptation and social justice. To date and for various reasons, these guidelines have not been achieved by the development projects in the region. A complete study of this topic would be of great value to learn about the limiting factors that exist and that have challenged the public or private authorities and the scientists or politicians that endeavor to equate and solve the problems of the Amazon.

Some specific examples have been analyzed, with special mention to those relating to the implementation of cattle raising projects. One of the examples was setting up farming villages along the Transamazonica highway.

It was expected that a region covered by thick forest could easily be transformed into an agriculturally productive area. In fact, it was exactly the opposite. The creation of estates for cereal crops and cattle raising came up against major obstacles. Another example was the installation of the Northwest Center Project when the Cuiabá-

Porto Velho highway was built. It was expected that the development model, based on building housing schemes and encouraging the building of farming villages, would in a relatively short time make the region economically independent. Today, 15 years after the start of intensive colonization in those areas, agricultural production and consolidated sustainable productivity are still a dream.

The projects implemented by small farmers and those with heavy capital investments, using all available technology, are examples of the failures to be expected when the Amazon territory is exploited using a technology foreign to its own ecosystem.

The Jari Project is a typical example of how planning and expected success were very far from the real achievement. Despite these examples and hardships, other programs and projects are being implemented in the region, such as, the production of pig iron in the region covered by the Carajás iron railroad. In this case, iron ore is transformed into pig iron, using charcoal as a source of energy and reducer. There are strong indications that this project is not sustainable from an ecological viewpoint, since the sparse natural forest resources and forest planting will probably make the project economically unfeasible. Despite this study and the experience already gained in the Minas Gerais region, several industries are still setting up their plants in the region. The analysis of this problem shows that, despite the willpower, enthusiasm, hope and efforts of government agencies and private institutions, there are environmental factors that, in themselves, or by interacting with other causes, are detrimental to the project's implementation.

Technological Limiting Factors against Primary Production

When an economic activity is based on farming or cattle raising this implies that there must be a capacity for primary production. In other words, plants grow and from this growth some product destined for human activity must result, such as: food, fibers, medicaments and other products used for agribusiness purposes. Some factors are essential for the growth of plants, as follows:

- existence of a soil with a certain level of fertility;
- available water at the stage required for plant growth;
- solar energy for photosynthesis and a suitable temperature to complete the biological cycle of the species.

When studying an Amazon forest ecosystem, especially in the case of the dense forests, the conditions of development exist and continue over the years. The tropical rain forest, by its very nature, has numerous species of animals and plants that, in an interacting process, maintain the soil's characteristics, recycle the nutrients of the dead plant tissues, regulate the moisture in the soil and establish conditions of dynamic balance favorable to energy and water processing. On a scale of small river basins or on larger regional scales, the forest maintains the bio-geochemical cycles in dynamic balance in benefit of its own survival. The forest also controls the other cycles necessary for stabilizing the conditions of water balance and sunlight.

When the forest is cleared and the soil is then used for farming, this causes a drastic change in the ecosystem, altering the balance existing until then. The replacement of forests by another plant formation with less species per hectare completely modifies the dynamics of the bio-geochemical cycle. The decay of organic matter and re-use of the nutrients by the plants is totally changed. In addition to these changes, others vary with the specific characteristics of the ecosystem, such as the nature of the soil, for instance.

The Amazon plateau has irregular relief, principally around Manaus, where the topography, like half an inverted orange, is typical. Experience has shown that soil management is quite difficult on rough terrain. After deforestation, these areas show a rapid process of erosion and reduced fertility. The soil becomes compacted, hindering water seepage and root growth.

On the microclimate scale, it is found that the temperature of the soil and air rises. These factors modify the behavior of the water process at a local level with influence at a regional level, as mentioned in Chapter 1.

The observations, taken from several scientific investigation projects, show that in order for the limiting factors to maintain a high productivity in farming and livestock farming are as follows:

a) chemical and structural nature of the Amazon soils;

b) distribution and intensity of rainfall;

c) relative humidity in the air;

d) existence of pathogens in the soil, principally fungi and nematodes;

e) increase in attack by insects, fungi, bacteria, virus and others harmful to intensively cultivated crops.

There are others, besides the natural factors, relating to human activities at the various stages of anthropization of the ecosystems under study. Some of the limiting factors arising from human activities are as follows:

a) type of soil management;

b) the farming techniques used, and

c) the species and varieties of crops cultivated.

In this group of limiting factors, it is important to mention that there has never been, at any time whatsoever, a technological cattle raising package that can be used without risk in the tropics.

Current recommendations have been tree farming in which the annual crops are developed jointly with the formation of forest groups, including fruit trees, forest species of timber economic interest or otherwise, plus fruit or oil producing species.

When implementing intensive farming systems, for instance, at the start of colonization in Rondônia, the harvested produce could not be sold due to the absence of an efficient transportation system. Farm produce transportation and storage is also a determining factor in successful trade.

Due to the distances between producer and market, the sale of a certain product did not have continuity, the supply was interrupted and the economic sustainability of the producer became more difficult.

Technological limitation is a determining factor in the success of tree farming in the tropics. However, in order to have a technological leap in this activity it is not necessary to start from zero.

Research of the tree farming systems has been based very much on the farming experience of the local populations. The different ethnic groups living in the tropical forest band around the world have, through their cultural evolution, developed farming practices that have permitted survival of their descendants in a sustainable manner.

All those groups have a fact in common that is to imitate the structure and functioning of the natural forest in their fields or plantations, consisting of:

- A wide diversity of species planted with few individuals per species.
- Planting of species that bear fruit alternately, providing different harvest dates throughout the year.
- Selective choice of the adult height of each crop, to take best advantage of the photosynthetic capacity, imitating the vertical pseudo-disorganization of the native forest.
- Short crop rotation cycle, with fruiting species in a long cycle; in some cases, planting species with delayed fruiting to be used soon after abandoning the place.

These characteristics are common to most of the different ethnic groups, whether they live in Tropical America, Africa or Asia. Cultivating plants is necessary to supplement the products extracted directly form the forest. Crop selection varies greatly between the different ethnic groups, at both the species and variety levels. After the post-Columbus period, some exotic species were introduced but the indigenous fields continued to be farmed with Amazon species. The major diversity of crops are the energetics, rich in starch or saccharoid: manioc, corn, sweet potato, different varieties of banana, *pupunha* (a type of palm), *açaí,* yams, arrowroot, etc. But indigenous farming does not stick to food production alone but is combined with an enormous variety of medicinal plants, spices, such as different species of pepper, drugs for religious ceremonies and social events, plants for pigment, poisons, etc.

Manioc and indigenous technology

The different South American ethnic groups domesticated some of the plants that are most used by mankind, such as: potato, corn, cacao, tomato, peanut and some beans, e.g. which are part of our daily meals. Cultivating manioc and the technology to remove the highly toxic prussic acid is an example of the technological processes developed by the South American Indians. There are two varieties of manioc, *Manihot esculenta*, one toxic and "harsh" and the other "sweet" that may be eaten after cooking. Every indigenous nation in the Amazon maintains, classifies and selects manioc crops in their fields and changes them for others from farther afield. Ethnobotanists have devoted their time to the selection processes of these crops that until a few years ago were ignored. A piece of harsh manioc has toxins that could kill several people. This toxic variety is used in daily meals. The change to flour ensures the extraction of prussic acid. The roots are first scraped and put into running water over night, then are grated and this pulp is placed in a press (*tipiti*) where the water mixed with the acid is removed. The remaining solid part is still not suitable for eating, is heated in a pan under a controlled temperature so that it does not burn, to remove the rest of the toxins. This is when the manioc in flour form is ready for consumption. An extra advantage is that it can be stored for years without attracting fungi, bacteria or insects, which seems impossible in this hot wet climate.

Twenty-seven different cultivated species were used by the Way-Way of Guyana. Fifty-four species were found in the fields of the cultured Sion-secoya in Ecuador. The Amerindian ethnic groups cultivate native forests and secondary areas. Ethnobotanist Possey has widely published the management techniques of the Kayapo Indians. In an inventory in Gorotire village, the flora used by the Kayapos, in their secondary areas, records 185 planted trees representing 15 different species; 1,500 cultivated medicinal plants and 5,500 individual plants for food, some still unknown by science. Other eminent scientists have shown that there are already ecologically balanced systems of forest occupation, but all at a subsistence level.

For some anthropologists there is, in the indigenous concept, no difference between a cultivated and natural forest. In handling the tropical ecosystem, the indigenous populations presume a continuum between the domestic species on their farms, the semi-domestic, which are manipulated and what we call the wild species. Each of these species plays its role in the group's subsistence or in the social calendar. In some areas that were and continue to be itinerant zones of the indigenous communities, what to us seems a natural forest is the result over thousands of years of cultivation and co-evolution between the ethnic groups, plant and animal species that form the ecosystem. The basic know-how has already been acquired from years of adaptation to the tropics by these men and women who, like the forest, are also threatened with extinction.

It is possible to set up small farms based on tree farming developed from the Amerindian technologies, although further scientific investigation and experiments are necessary, so that these farming practices can become a tool for sustainable development, on a market and subsistence scale. More control over the environmental limiting factors is necessary by using techniques that permit an increase in productivity.

Population growth and resulting environmental exhaustion is also a limiting factor in fragile ecosystems. What we see today and in the near future in the Amazon is a trend towards concentration of populations in large urban centers. Manaus, Belém, Santarém, Porto Velho, for example, already have more inhabitants that they can support. This trend towards megacities is a third world trend, where the rural zones are still poor and the dream of wealth and quality of life is associated with opportunities found in an urban center. How can these megacities live in a world based on the concept of sustainable development? or how can a society based on sustainable development meet the consumer demand of megacity populations? So far, there are no answers to these questions.

What is apparently clear is that there is a level for sustainability of development when based on Amerindian models, that are effective on a small scale but need a technological leap to be able to supply the demand of the growing Amazon population.

THE MAYAS AND ENVIRONMENTAL EXHAUSTION

The Maya civilization flourished over 22,715 Km^2 between the Yucatan peninsula in the Campeche-Quintana Roo zones (Mexico) as far as the Petén region (Guatemala) and mountains of Belize, and was the only one to fully occupy a tropical rain forest, with standards comparable to that of the ancient Egyptians. The monuments, writings and archeological discoveries attest that the Mayas were the only neotropical nation to leave history engraved in stone.

What are the reasons that led to the extinction of this tropical sedentary civilization? The main factor was the increase in population. In 1,000 BC the population was estimated at 161,000 inhabitants, that is 7.09 persons/Km^2, in 300 BC the population was already 242,000 (10.65 persons/Km^2). By 300 AD there were 1,020 million inhabitants (44.90 persons/Km^2), the peak was in 800 AD with a maximum of 3,435 million persons (151.22 persons/Km^2). At the time of the conquest of the Mayas they were already in decline with 104.00 person/ Km^2. It is presumed that by 300 AD, 75% of the land had already changed. The central lands of the Mayas were drastically altered, forests cleared and floodplains destroyed for farming purposes. Ecological models used by the Mayas explain that the sharp increase in population growth reduced the stability and increased the resilience of the ecosystem. This agrees with Holling's principle, according to which complex systems fluctuate more than simple systems. With the drop in population the forest returned, with its altered flora composition. Today the forest is more lush than at the time of the conquest, but the Mayas were already culturally dispersed.

Institutional Factors

Another group of limiting factors is linked to the lack of policies in favor of sustainable development, which is reflected in the lack of facilities of the local institutions. An improvement in institutional performance is important since they are institutions, public or otherwise, that should make the binomial efficient: competent human resources and proper financial resources in implementing development projects. This point is of some importance when we consider that the institutions are not a neutral factor in the development process but represent values that, in their turn, are related to interests of some political or social group, and therefore greatly hinder the process of implementing sustainable development in the Amazon. In order to exclude the institutional limiting factor it is first necessary to ensure that the values are in the correct position and that institutional guidelines are in tune with the goal to be achieved. Only after this point should more technical matters, such as the use of resources, transfer of scientific, technological or managerial know-how to a certain institution, be discussed. Even then, this capacity building must be correctly measured so that the organization can effectively handle its new institutional level.

One way of visualizing an efficient institutional scheme when implementing sustainable development is to create an institutional flowchart with the participation of organizations that work at a micro, medium and macro level.

The micro level is that at the level of the community. Here organizations represent ideas and needs of the people living in the community who have entrusted them to represent their interests and be able to communicate with the higher organization levels of the authorities. For this level of action to exist, they presume that the community has access to information on regional and national development policies. This also requires that the country assume a certain decentralization and accept the right of community leaders to participate in the decision-making process. This is the preferable scenario for the work of grassroots non-government organizations. The various sections of the National Rubber Tappers Council that are present in the extractivist reserves, Land Pastorals linked to the Church, fishing villages, scattered through the Amazon hinterland, indigenous organizations, to mention the better known, are institutions of this kind. According to a study by the United Nations Development Program (UNDP) on the third world, the largest number of grassroots organizations are in India, focusing on mostly social questions, then environment and class. The World Bank, UNDP, Global Environment Facilities (GEF), United Nations Program for the Environment (UNPE) and several large international NGO programs have created financing to support projects of these grassroots institutions.

The middle level is intermediary, between the goals of grassroots organizations and the central authorities, and is the prevailing area of the NGOs. They are more sophisticated organizations with a blend of technical, managerial capacity and political pressure, and their principal strength is the ability to work with information. An example of institutions between the micro and macro levels are: cooperatives, unions, research and training institutes, organizations which represent the medium-sized company, religious groups, non-profit foundations. In order for these NGOs to be effectively able to achieve their goal, they must create the skill of coordination between the opinion makers and grassroots organizations. The process of implementing sustainability requires the transfer of responsibilities from the central government to the communities, the working scenario of the NGOs, that can assume such a task, principally in those poor regions where many municipalities and towns do not have the public institutional equipment for such a purpose.

On all continents, over the past two decades, NGOs have become the principal political and executive act at this medium level. They have shown to have more capacity, speed, efficiency and responsibility in dealing with the issues that concern society than the public institutions themselves. NGOs have already demonstrated to be outstanding substitutes for the role of the state.

The capacity for international mobilization of these institutions, especially those in the northern hemisphere, have prevented continued crimes against the environment, very often against the interest of the national governments and major corporations. This feat caused a movement of counter-information against these organizations, accused of defending exotic interests, with the intent to discredit the politically correct work of the NGOs. Many forget that the institutions working at the medium level are identified with the environmental issue and not with the government policies of their home countries. In the Amazon, the work of non-government organizations at a regional level is still in the early stages. The NGO role is more political and preferably outside the Amazon. Organizations that do field work in the region are extremely rare. It is expected to see an increase in the number of South American NGOs on the international scene in the near future.

The macro level is that of the governments, which, in the past 20 years, have been forced to redefine the role of the state, very often traumatically. The southern hemisphere, under pressure of its foreign debt, has been obliged to climb down from its dominant role in national development, very apparent in the spate of privatization that the governors have announced throughout the third world countries.

Society's further participation in running public matters and the renewed democracy of the South American countries in the 1980s provided political foundations to create public institutions that cooperate with non-government organizations in implementing sustainable development.

At a macro level the public institutions created developmentalist policies for the Amazon that hastened the deforestation process and aggravated the environmental limiting factors. The two examples below show how government institution decisions can drastically alter the Amazon ecosystem:

- **Tax incentive policies —** independent of size, a company could register a cattle raising project with SUDAM, in order to receive tax incentives by deducting income tax or having subsidized credit. The sole requirement was that the project would provide improvements to the purchased land. The law recognized any land clearance as an improvement. Therefore, a variety of projects for deforestation, blocking river islands, opening up pasture land, intensive plantations and rubber, cacao, eucalyptus and other crops were awarded tax incentives. This policy was aiming at destroying the forest and any project that proposed to create a reserve or prospect biodiversity for the pharmaceutical industry would never receive a tax incentive.

- **Increase in the farming frontier —** credit facilities led several farmers in the South and Southeast to exchange their crops of rice, beans, corn and food products for export crops like soybean, wheat, cacao, coffee, etc. It became harder for the small producers to get loans and they sold their land, attracted by the colonizing companies that were starting to cultivate the Amazon. The largest group of migrants since the 1970s came from South and Southeast Brazil. People from Paraná, Rio Grande do Sul, São Paulo and Minas Gerais sold their small and medium-sized properties to the planters of soybean, wheat and other mechanized crops. The increase in the Amazon population was the result of migration and not from the increase in the local birth rate. As long as real consequent land reform is not carried out in South and Southeast Brazil, this outside pressure will continue to increase the exhaustion of the Amazon ecosystem.

Throughout Amazon history, the role of the state has been dominant in encouraging development. At the macro level, therefore, it is essential to identify the limiting factors present in the public institutions.

The lack of environmental policies, dissemination of technical know-how and financing for sustainable development, is reflected in the executive agencies of environmental overseeing, in the agencies in charge of financing projects and in those for rural advance, especially with regard to the small farmer. We could identify the following limiting factors in the public institutions:

- reinforcement in applying environmental laws, increase in supervision and punishment for crimes against the environment. Brazilian environmental law is one of the most modern in the world but is constantly being broken due to the absence and/or disregard in supervision. The overseeing and legal agencies are unprepared to enforce the law;

- lack of appropriate adequate farming transfer of know-how relating to the specific problems of the Amazon area, which range from fishing activities, plant extractivism, selective lumbering and small scale farming. We are talking about farming transfer policy in its most traditional concept, which is the transfer of technical-scientific know-how generated by the research institutes to the rural zone;

- lack of a proper structure for the environmental and planning agencies to be able to interact on an ongoing basis with the communities, NGOs and official agencies, in order to implement ecologically suitable and economically sustainable projects;

- lack of a farming loan structure focusing on sustainable projects with regard to the quantity of resources required and the overseeing of approved projects;
- lack of regional planning based on ecological-economic zoning for the Amazon, with the intent to implement sustainable development projects;

It is the task of the central government to encourage its own institutions to draw up policies that reflect the interest of the local communities through:

- more equality at the negotiation tables of the international cooperation, credit and trade agencies;
- enhanced Brazilian ability to formulate policies for sustainable development, as a way to minimize the dependence on international experts who very often area unaware of the demands of local communities, cultural traits of the nation and Brazilian peculiarities;
- improving the public institutions so that claims from medium and micro levels can reach the central government, facilitating partnerships with non-government organizations in promoting sustainable development.

We believe that sustainable development projects can be established in the Amazon, as long as scientists, environmentalists, decision makers, those who draw up regional policies and the local communities are aware that limiting factors exist at different levels, making it necessary to have a change in people's awareness about the occupation of this territory.

The first step in this awareness is to understand that nature imposes limits on farming and cattle raising in this ecosystem. We must also bear in mind that the available technologies for use in other ecosystems are not suitable for the Amazon and that the empirical technological knowledge, already developed by the local ethnic populations, is appropriate for occupation of areas that can be farmed on a small scale. On this particular point, it is important to strive for efficiency through technological enhancement. In environmental terms, efficiency means the decrease in environmental exhaustion caused by the incompetent use of raw materials and energy.

The various institutional players must work together so that the research and public development institutions and non-government organizations also work as a team. An important role is also expected form the international community, specifically by creating new business opportunities for the countries that invest in conserving biodiversity and carbon dioxide sequestration, services that have clear global effects.

VII - How does the conservation of the Amazon combine with the sustainable use of its natural resources?

Throughout history, settlement attempts in the Amazon have been an ongoing and constant challenge. The experiences of livestock farming settlements, either through government or private programs, have shown the inability of its sustainability over the years. So the major tree farming projects, both those undertaken in the past and those in recent decades have led to the increase in environmental exhaustion, in addition to investors' losing money due to the deforestation encroaching into new primary forest areas. Today the areas where these projects were installed are degraded.

Despite the disastrous results of such attempts to develop the region through projects which had not considered the existence of limiting environmental, social and institutional factors, the problem continues. The current land distribution policy for family allotments repeats the same mistakes of the past settlement attempts. In the latest government land distribution policy, there is no sign of implementing demonstration projects of sustainable use of natural resources.

The increase in scientific know-how in the Amazon region and wet tropical regions today permits a different focus on accepting this challenge, that is: implementing projects for sustainable use of the resources in the Brazilian Amazon, which guide and demonstrate to the settlers that it is possible to ensure long term farming production in the same area without needing to open up new areas of primary forest. (ALMEIDA-VAL, et al, (eds) 1991; BARTHEM, R. B. 1992; NEPSTAD, D. and SCHWARTZMAN, S. (eds). Non-timber products from tropical forests. *Advances in Economic Botany,* Volume 9. p. 79-86)

The literature on the Amazon, outcome of scientific meetings on regional development and experience of students concerned with the Amazon **STRONGLY SHOW THAT:**

- Previous settlement experiments confirm, without a shadow of a doubt, that if nothing is done to include scientific know-how in the planning of land use in the region, serious social problems will arise.
- It will be impossible to maintain sustainability of the settlements, both in degraded and virgin lands.
- Land exhaustion and the consequent environmental degradation will lead the settlers to occupy new natural landscapes still untouched by man.
- These new occupied lands, in their turn, will be degraded in a few years, thereby perpetuating the cycle of destroying the wet tropical rain forest, as the history of Amazon settlement has been demonstrating.
- There is already enough criticism and scientific know-how to draw up sustainable development projects.
- Among other options, using the state-of-the-art know-how on the tree farming systems, the deforested areas of the Amazon will permit the survival and continuity of human settlements, as long as they are based on social, economic and ecological sustainability.
- It is possible to set up experiments to act as demonstration and multiplier projects of the correct use of the potential of the already deforested Amazon ecosystems, ensuring the permanence of settlements and preservation of this huge tropical rain forest for future generations.

VIII - Future Research

Based on this background, a future agenda to continue the research in the region should include in-depth studies on:

Sustainable Use of Natural Resources with emphasis on:

Sustainable Forest Management - MFS including in the exploration process the economic value of forest-intrinsic biodiversity and showing if MFS proposals should be considered as an economic activity for the region or should be abandoned;

Fishing Management and Fish Farms, enhance the studies on fishing biology and ecology, as well as develop suitable techniques for fish farms;

Forest Farming Systems, develop and set up forest farming demonstration projects as models for regional development ;

Bioprospecting, develop prospecting rules and procedures in accordance with the recommendations from the Biodiversity Convention and the Brazilian law on the matter, in order to create model procedures in Brazil that will be used as an example for future prospecting activities of biodiversity.

Creation of Models:

Climate models that integrate the biosphere to the atmosphere showing the relationship between the global climate changes and the Amazon. Provide the decision makers with planning tools.

Socio-economic models that integrate changes in land use with the forces of social and economic transformation that put pressure on the occupation of the Amazon.

Planning and Control

Economic-ecological zoning, on a 1:250.000scale, of all Amazon territory, as a decisive tool in planning territorial management.

Amazon watch system, continuing with the physical installation of SIVAM and setting up databases and their interpretative tools for the end user.

Climate Control and Biodiversity Conservation:

Carbon sequestration through demonstration projects that integrate biodiversity conservation with reforestation by forest farming systems, using the clean development mechanism.

IX - Implementation of Demonstration Projects on Sustainable Development in Degraded Areas in the Amazon: a FBDS Framework

The definition of a series of projects on sustainable use of natural resources based, among other technologies, on the advanced know-how of tree farming and clean energy. Such projects shall be implemented in settlements located in critical areas, where there are basic data at a suitable level and with settlers ready to go ahead with this experiment.

I. BASIC PREMISES

- the project shall, from the beginning, involve the local community since it is ultimately responsible for actually adopting the proposed measures;
- the work shall be carried out in both the urban and rural areas and permit an exercise to implement sustainable development through the joint action of the

local communities and their interactions with the "outside world" at home and abroad;

- the municipalities shall be studied regarding the urban outline, material used in the buildings, basic sanitation, water supply, energy sources, health and education and the economic activities, such as transformation industries, mining exploration and commercial activities;
- in the rural areas, special emphasis will be given to sustainable forest management, rehabilitation of degraded areas, tree farming and field activities of the farmers, health and education, rural electricity supply, enhanced communication and transportation systems and establishing loans to implement and enhance these activities;
- in all work to be carried out, priority will be given to programs which use "clean sources" to produce energy, provided that they are feasible. Techniques shall also be examined in the treatment of drinking water, urban sewage and solid waste, which are compatible with the social-economic reality of each place, seeking those most ecologically and economically self-sufficient.

II. STAGES

- Identify settlement areas close to medium-sized or small towns.
- Examine the environmental and socio-economic problems of the urban and rural areas.
- Identify the limiting factors in order to set up a sustainable development program based on the criteria of economic, social and ecological sustainability.
- Identify the players in the process and establish the relationship between the public and private authorities in order to implement specific projects.
- Establish an analytical and follow-up system which permits changes and adaptations as a result of the gained experience.

III GOALS TO BE ACHIEVED

- Reduce the anthropic pressure on primary forests.
- Renew and expand biodiversity which is endangered during the deforestation process and installation of farming activities.
- Increase the residence time of peasants in the same place, giving small communities time to settle and establish feasible production and commercial lines for the local conditions.
- Increase the stock of carbon in the biosphere by growing secondary forests.
- Set up tree farming and cattle raising processes which are feasible in these extremely fragile systems.
- Re-establish the water and bio-geochemical cycles of the ecosystems, since they are radically modified during the deforestation process.
- Re-establish the inter-relationships between offshore and onshore ecosystems which maintain the productivity of the offshore fauna and very often survival of the onshore fauna. This point is of the utmost importance along the floodplains and banks of the *igarapés* (river islands).

IV. METHODOLOGY

- The formation of a small group of specialists from such institutions as EMBRAPA, INPA, IMAZON, Goeldi Museum and FUNTAC, to urgently define a pilot-model for sustainable use of natural resources, on a real scale.
- The basic function of this pilot-model would be to guarantee the settlement and permanence of settlers in the chosen regions. These settlements would be the predominant factor and responsible for preserving and maintaining the tropical rain forest. This would be the basic tool for future generations to inherit this priceless heritage of our land.
- Identify, by comparing data from the economic-ecological macro-zoning of the Amazon, priority areas for future settlement in regions already deforested and suitable for implementing feasible programs of sustainable use of natural resources.
- Identify sources of international resources and aid programs (preferably non-performable loans) which guarantee the implementation of such demonstration projects.

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Science and the ethics to sustainability

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A New World

With the advent of the industrial revolution that followed the Age of Reason, the world population that was nearly stable till then started its exponential growth, the rate increasing three-fold from 1750 to 1850. At the end of the eighteenth century, Thomas Malthus in his *Essay on the Principle of Population* warned us that this rate was faster than the subsistence opportunities and that Mankind could head towards disaster. Developments like crop mechanisation, fertilisers, railway systems, steam engines etc that marked the peak of the *First Industrial Revolution* have shown that this pessimistic outlook, however, was not corroborated by facts. Rather, the outlook was that new developments in science and technology could always avoid disaster, fulfilling the increasing demand for food, energy and for more technological progress. As it left out the old supernatural and mythic cosmovision that prevailed in the Middle Age, Society was developing in the nineteenth century an optimistic view towards the future, building up a technical modernity marked by the faith on science as the solution to all problems. It was a renewed thrust on the *Scientific Revolution* initiated with Descartes *Discours de la Méthode* with the belief that Nature and Life could be reduced and understood through their mathematical expression and that "*the scientific knowledge could be used to render ourselves masters and possessors of nature*". It was, above all, a laic, pragmatic and utilitarian vision of the world, translated into a utopia focused on material prosperity and on the possibility of distributing and socialising the products of the technological progress.

Thus, we witnessed, at the beginning of the twentieth century, the acceleration of a productivity rush that was fed by another rush: the competition to advance science and to develop new technologies. Following this trend we also witnessed a progressive specialisation in every branch of science and the multiplication of techniques demanding more and more specialised scientists and high-skilled technicians and engineers. The broad, classic and universal education that prevailed until World War II moved, then, towards providing the professional competence demanded by the competitive job market, in the qualified fields of knowledge that fed the technological advances. The advent of the specialists that these changes brought about, brought also the fragmentation of knowledge (e.g. Morin, 1986; Capra,1982; Wilson, 1998). While there was a tremendous efficiency gain in the education and in the science/technology systems as measured by a variety of established indicators, there was a huge loss in the perception of our true objectives and what should be our overall efforts. The more we specialise in a branch of knowledge, the more we analyse a specific part of a problem without an equivalent effort to integrate it, the more we loose the perception of the whole. What is worse, we lost our critical sense, the conscience of the necessity and the usefulness of things. Specially, we became blind to the consequences of the use of a specific knowledge as we lost our broader knowledge and wisdom.

In recent times, this tendency for specialised science, for specialised education and for the parcelation of science into disciplines has increased dramatically. To some extent, we lost our broader references and the ability to distinguish means from goals. We do not know anymore what we want to achieve. We can only record that the current science-technology system is leading us to a whole new world and bringing some new deep worries. The perplexity and indignation registered in Bronowski's publications (e.g.1972,1978) is a clear example of this. A leading member of the *Manhattan Project,* this physicist who helped to make the atomic bomb, then confessed his unawareness of the destructive implications of his studies. Man had taken the role of God, he warned us, *a posteriori*.

But, even when widespread warnings were shouted before the tragedy, as in the case of Rachel Carlson 's *Silent Spring* (Carlson, 1962), the large-scale devastation promoted by the *Green Revolution* was not avoided. The power of the self-sustained and interlinked science-technology-economic system of this new world seems hardly affected, even when warning comes from the United Nations (1987), the National Academy of Sciences (1990) or from Al Gore (in Carlson, 1994,), the Vice-president of the powerful United States. We need some new way to develop.

The search for a new kind of development.

In feudal times changes were slow and unwelcome. Any advance or development was more the result of external and unpredicted events than of the wishes of people or of their rulers. The word *development*, teaches us *The Petit Robert Dictionary*, was only used with a meaning associated with the economy of a country or a region in the second half of the eighteenth century. It was only with the advent of industry that emerged a co-ordinated effort and a true Government concern to promote conditions for expansion and reproduction of the economic activities. In the process of pursuing progress and guaranteeing a continuous economic growth, nations started building up, at the turn of the century, more and more complex and specialised administrative structures to manage economic systems, to promote internal social peace and to secure foreign economic affairs for a sustained (economic) development.

In the twentieth century, we witness the economic dominance of nations who had massively invested in science and technology in connection with war efforts and the installation of defence systems. But after World War II, it became apparent that a country's economic success would not necessarily bring social justice nor prevent the relative impoverishment of other nations and regions. It became also clear that the present patterns of economic growth were promoting unprecedent ecological devastation and worrisome social changes. They are installing, according to Gunnar Myrdal, 1974 Nobel prize laureate on economics, a "vicious cycle of poverty". For Gore (in Carlson, 1994), 'the present system is a Faustian bargain. We get short-term gains at the expense of a long-term tragedy. And there is reason to believe that the short-term can be very short indeed'.

Regardless of our degree of hope and the gravity with which any of us see the present crisis, there has been a growing consciousness that our present system is breaking apart the sane relationships between man with his own self, his family, his society and the environment to which he belongs (e.g. Roszak, 1992; Boff, 1996; Mungall & McLaren, 1990; Gardner & Stern, 1996). It became clear that development cannot be achieved in economic terms alone and should not just reach a small part of Mankind. It is also clear that the present crisis is a crisis of the patterns of our development. Focussed on consumerism utopia, our so-called development has yielded appalling waste, social inequality and widespread irreversible damages to the environment. Many were the traumatic experiences and technological disasters denounced either by scientists, themselves, such as Bronowski and Carlson, or by the social movements, such us the Women's rights, Peace and Green movements. Man is becoming aware that through the indiscriminate use of science and technology he is excluding ¾ of mankind, extinguishing fellow species and modifying his own habitat regardless of its resilience. As he recognises that science can be an important tool to help him understand the world, he also perceives that the science-technology-education system has been used as an instrument of political and economic domination of a few at the expense of both the environment and the people it has excluded. He presses for changes.

Gathering a record number of 179 nations, the United Nations Conference on Environment and Development (Rio 92) prepared a 500 page-long consensus document called **Agenda 21**. It was the first global answer to the aforementioned pressure. Its 40 chapters offer the broad guidelines towards the achievement of ***Sustainable Development.*** This concept was based on the concept of Eco-development established in the *UN Conference on Environment* in Stockholm, 1972 (See also Sachs, 1980, 1993) and developed through many years of discussions by the Brundtland Commission. In its *1987 Final Report* the principle of the sustainability of future generations is internalised within the concept of development, opening a new horizon for mankind. Sustainable development is the development that supplies the basic neeeds of the present without risking the potential of future generations to supply theirs. The above reflections tell us that the logics of development must not obey the command of a *technical modernity* but should be subordinated to the principles of an *ethical modernity*. It is this ethics that should answer the new challenges confronted by Mankind. And this ethics should go beyond a mere 'social contract' settled with reciprocity and symmetry. It is a matter of setting, ethically, the asymmetry of power relations, even at its limits, with unilateral and non-reciprocal terms. This is certainly the case when we are faced with the vulnerability of the future life conditions due to the social and environment interventions carried out in the present reality by whoever has the power of action. We also need to consider the ethical frame of irreversible processes, as it is not always possible to amend in the future the undesired consequences of today's actions.

The sustainability principle

As the aim of ethics is the regulation of the power of acting, the threats posed by harmful technological interventions are, thus, growing in an "ethic vacuum". Recognising this, Jonas (1979) proposed the adoption of a new *principle of responsibility* where the highest rule be "let mankind exist!" The traditional concept of a "contract" *inter pares* as the ethical fundament fails at the present situation when we need to assure today, the quality of life of future generations. The *must exist* and the *not yet existing* are two essential points to impose on contemporary modernity the recognition of an objective *must be* (*at).* With that in mind, it is possible to deduce a commitment towards a responsibility for and the preservation of *the being* (Jonas,1979:102). This responsibility is, however, formal and its ethical and moral dimension only emerge with the existence of a *feeling* for doing goodness by its own inherent objective, as it shames on the selfishness of power (Jonas, 1979:175).

Hans Jonas proposal is to build an ethical modernity that is able to limit the human capacity as a destructive agent of the perpetuity or the sustainability of life. From that perspective, we can conceive sustainable development as a horizon within the framework of an ethical modernity, not only of a technical modernity. Therefore, the promotion of sustainable development requires not only wisdom and knowledge but also the ability to provide technical viable and ethically desirable solutions. Such know-how can also be defined as the knowledge and the skills that helps to promote the continuation of life. It should be expressed in terms of the different organised ways through which society acts or interacts (production processes, trade, profit standards, data processing, health prevention, water supply, garbage production, commodities consumption etc). As pointed out by Morin in several of his works (e.g.1977, 1986, 1990) and Wilson (1996) the approach to deal with complex and interacting systems, like life, society, the environment, economics and the World, must be transdisciplinary, so that the unity of knowledge is not lost. It must also not separate the observer from the observed or the object from the subject as they are intimately interconnected or one may belong or be part of the other.

Given technologies are sustainable and belong to an ethical modernity not because they resulted from the freedom of choice of economic alternatives but because they abide by the sustainability principle.

The philosophical meaning of modernity

The word *modern* is already present in medieval French in the XIVth century and *modernity* in the XIXth century. But according to the inspiring contribution of Brazilian philosopher Henrique Vaz (1992:85) "the concept is linked with the concept of philosophy itself, as we can state that there is a conceptual equivalence between modernity and philosophy: all modernity is philosophical or all philosophy is the expression of a modernity where it recognises itself".

This thesis, shown in such simple terms, needs some clarification. In the first place, we must bear in mind that the emergence of the meaning of modernity demands a clear-cut rupture with the representation of time. It needs to be emptied of the mythic-symbolic frame of the repetition and leave the logic of the identical to build a new home (*ethos*), in the dialectics between the identical and the different. The crucial matter being the emergence of the act of daring to philosophise, a move that attempts to disqualify the authority which is inherent to the ancient.

Through the exercise of the critical reason, the philosophical discourse bestows to the *times of the present* a new dignity, giving that moment a new quality. Modernity can be then installed as the readings of its time. As stated by Vaz (1992), the civilisations, which do not know philosophy, do not know a modern reading of its time, as they did not dare to judge their past during the present.

To Aristotle, *physis* and *ethos* are first forms of the presence of the *being.* The *ethos*, according to Vaz (1988:11), "...breaks with the succession of the *same*, which characterises *physis* as the domain of the necessity, through the advent of *the different* in the free space open by the *praxis*.

The term *ethos* is the transliteration of two different Greek words: the first is ethos beginning with the letter eta and, the second is the word *ethos,* beginning with the letter epsilon. *Ethos*(eta) means the home of man in the world as a biological and cultural being – a home that is supplied with shelter and material and immaterial conditions of survival and which is constantly built and rebuilt. *Ethos*(epsilon) means the human behaviour that is repeated many times as an acquisition of the culture and not as a necessity of the *physis*. Thus, *ethos* (epsilon) makes available the possibility of a permanent 'habit' for doing *goodness.* The mediation of these two moments of the *ethos* is given by the praxis. Vaz (1988:16) states that " the ethical action comes from the *ethos* as from its principles and returns to it as to his accomplished end in the form of a virtuous existence." This circular movement between both types of ethos completes itself in an individual and social educating process. Because the movement of the *ethos* from the universality of habit to the singularity of the ethically *good* action is free, it brings always the possibility of conflict.

The emergence of the democratic *polis* explicitly imposes the ethos as *nomos* (law) and the first constructive efforts of the new science of the *ethos* – **ethics,** focus on the reflection about the law. Justice (*dike*) turns to be the legitimate source of all *nomos*. Thus, concludes Vaz (1988:49): "...the action of being *just* is what qualifies the true citizen". In opposition to this are the intrinsic marks of the *unjust*: the lack of measure (*hybris*) of power ambition (*pleonexia*), the excess of possessing (*philargyria*) and the excess of displaying (*hyperephania*). The just brings within himself the *metron* (measure), fundament of *The Rational Ethics*. Plato built this science as the science of action according to virtue (*arete*) and as a radical criticism against the notion of destiny, uniting intelligence and freedom in a virtuous link with the act for doing good.

The modern scientific revolution links the theoretical *logos* (manifestation of the reason) with the technical *logos* in a way it was inconceivable to Classic Greek Antiquity, the modern human *logos* demanding for itself the *Demiurgic place* that Plato had reserved for God.

What is going on now is the human construction of a new Nature that takes the place of the ancient *physis* and the question regarding the ethical universality meets new challenges with the globalisation of the technical-scientific culture. While platonic science recognises itself as the ontology of the goodness, modern science makes a methodological difference between fact and value, behaving itself as ethically neutral and disconnected from the responsibility of its consequences to Mankind and the world.

Hans Jonas (1979) emphasises that modern science and its new praxis demand the foundation of a new ethics, as ethic nihilism grows along with the increase of the science-technology potential. Contemporary techno-science is building a new space. The dilemma is whether it will be an *ethos* opened to the dimensions of this space or whether ethical nihilism will open new possibilities for survival outside the home of the *ethos*, leading man towards a boundless space.

Ethics and responsibility

The praxis of the sustainability principle demands that a *purpose* for *reaching a certain end* be a key-concept, without which norms and objective values would be meaningless. This principle does not let us forget that our economy is grounded on the fact that we live at the expense of metabolic processes and are creatures with necessities and that the act of supplying our necessities is an act of self-affirmation of life. But so is the reconnaissance of the responsibility towards our descendants and hence the linkage between self-interest and responsibility for the other in the economic activity.

Our main concern is not the construction of an ethics to be reached at a given time in the future but to be able to build **now** an ethics that is concerned with the consequences of our acts for future generations. As a dangerous threshold in our capacity to built destructive technology is being reached, our awareness of a sense of urgency and the call for immediate action becomes clearer and clearer. To perform the acts demanded by this new responsibility, however, we need knowledge that is related to physical events but also to the ends of human purpose. This new responsibility demands, therefore, knowledge of a futuristic perspective, such as supported by futurology - a scientific–technological projection that is informed by scenarios to which present actions may lead. In this context Jonas (1992) faces us with the following warning: the futurology of the desired scenarios is known to us as utopia but we still have to learn the futurology of warning to alert us not to cross the threshold, beyond which life is bound to be jeopardised.

According to Jonas (1992:130), "man is the only being that can have responsibility. As he can have it, he has it. The capacity of the responsibility states its imperative: the power itself also carries its duties". The capacity of responsibility is an ethical ability that lays on the ontological aptitude of man to choose among different alternatives with knowledge and will. Responsibility is, therefore, complimentary to freedom (Jonas,1992: 131). Man can be held responsible for the consequences of his acts only as long as they affect another being, which becomes an object of his responsibility, but this has only an ethical value if the simple existence of this being is a value by itself. And this presupposes vulnerability of the other being and the possibility that he can be affected by the power of man. Thus, it is necessary (a) that we maximise the knowledge of the consequences of our acts in order to find how they can determine and threaten the future of man and b) that we elaborate a knowledge of the goodness that must not be sacrificed by technological development, i.e., what must and must not be, what is allowed and what is forbidden, what man may have and what man must be (Jonas, 1992: 134-135).

These philosophical anthropology arguments gain also support as we attempt to unite the knowledge of man moving through the disciplines of science. From history we can learn what are we at our best (e.g. Inca agriculture, Alexandria library, pasteurisation, art, altruism, philosophy) and, also at our worst (e.g. Hiroshima, ethnical cleansing, forest burning, pollution). Metaphysics provide us a veto towards our self-destruction and teach us the fundaments of what must we be. From psychology and psychoanalysis links we can learn about man's dreams and nightmares and the collapse of his relationships with his own conscience, his society and his whole environment. We can also learn how should we behave to keep acceptable sane relations within our surroundings and ourselves (e.g. Jung, 1964; Roszhak, 1979; Gardner & Stern, 1996).

Economics, sociology and biology show us that our evolution involves not only competition for the survival of the fittest but a high degree of collaboration (symbiosis) for the survival of the whole living system (see Barlow, 1991). Geology and palaeontology, on the other hand, remind us that all Earth processes are intimately interlinked with one another and that species evolve or become extinct in each major tectonic and climatological change. As man becomes a global geological actor, producing large-scale changes (Mungall & McLaren, 1991; Ephron, 1988; Salati, this volume) beyond the buffering capacity of the geosphere, he may be triggering natural feedback processes that he is powerless to stop (e.g. changes in the circulation patterns of sea and air currents and ice polar cap melting that may quickly lead to rising sea level). Rather than catastrophes, geologist and theologian Teilhard de Chardin (1955) recognises these phenomena as opportunities for an evolutionary step towards the expansion in the consciousness of the system man-biosphere-Earth, approaching man to Divinity. The earlier, man chooses to be conscious of the bio-geosphere he belongs and cares for the system with responsibility, the less will be the suffering of the next generations and the further will we depart from the anti-utopia scenarios like the one pictured in Aldous Huxley's *Brave New World*.

The science and technology paradox of being simultaneously the cause of the evil and the way of avoiding it, evoke Hölderlin's verses:

there, where danger hides is where salvation rises.

It is not Nature that scare us but our power to interfere with Her. Since the eighteenth century, the technological power is becoming more and more connected with the power structure of the state and with the so-called *free* market forces, to the point that, nowadays, the market chooses (Ferreira, this volume) from available alternatives, the most profitable technology. In this process, Nature is but a 'storehouse of matters' (Francis Bacon) and what really matters are values related to efficiency and productivity. Within such technical modernity, ethical concerns about Her preservation are but romantic wishful-thinking. Before *The Enligthenment*, ethics was part of religious education and since then man's position in relation to life became a personal task. We owe to the great German naturalist, Von Humboldt, the fundaments of an ethical modernity and the project of an universal education through the teaching of a science that knows itself as philosophy and where ethic autonomy is achieved with acquisition of scientific and artistic culture (Schelsky, 1963). As Max Weber (1987) has pointed out, no science is free of pre-conditions. Is its product worth to be known? To whose service is the scientific practice developed? There is no scientific answer whether contemporary science is following a good or a bad command. To many scientists, we need science for the Earth (Wakeford & Walters, 1995). To counterbalance the evils of a scientific-technological *laissez-faire* we need that science itself be responsible. In the core of the ethical modernity that has brought the sustainability principle are vulnerability limits. After surpassing tolerated limits of Nature and Society, development is suffering anti-productive degeneration as Homo industrialis is being reduced, according to Heisenberg, (1979:22) to "the situation of a captain whose ship is so well built with iron and steel that its compass no longer points to the North".

Technologies for Sustainability

Building population consciousness about the strategic importance of sustainability is a major concern of the **Agenda 21.** According to it, it is necessary to redirect the educational system towards sustainable development by training citizens in sustainability technologies. Education in sustainability must incorporate an ethical dimension linked to knowledge, techniques and behaviour. The technologies for sustainability deals with processes and products and, therefore, cannot be viewed as isolated units, but local systems that include scientific-technologic knowledge, know-how, goods, service, equipment and organisation procedures which must be compatible with socio-economical, cultural and environmental national priorities. Access and transfer of such technologies among nations must be more collaborative so that they will not increase the economic and technological dominance of a given nation at the expense of another. This, demands from developing nations considerable national training and innovative research efforts. The development of new such technologies must respect local and national social, cultural and environmental constraints. Its adoption cannot be imposed by market conditions alone and can only take place after there is no risk of irreversible damages. The establishment of international, national and regional co-operative education and research networks has, thus, strategic importance.

Sustainable development technologies demand assessments with long-term perspectives where uncertainties are the rule. This requires not only heavy prospective research on the behaviour of natural systems but a prudent interaction between the scientific endeavour and the decision-making process. Assessments, within the sustainability principles, are ethical decisions with the goal to promote the continuity of life and they must also incorporate local knowledge and wisdom. To become effective in the decision-making process, these principles, ethical codes and guidelines must not only be endorsed by the scientific-technologic community but also recognised by the whole community.

We live a critical transition which is associated to paradigm changes and to radical transformations in the technology base of our modern globalised civilisation (Hobsbawm, 1994). While there are many serious *cul-de sac* predictions like the *End of History* (Fukuyama, 1992), *of Work* (Rifkin, 1995), *of Science* (Horgan, 1996) and *The End* (Ephron, 1988) there are an enormous variety of global synthesis, scenarios, evaluations and agendas that may become building stones for the construction of a new utopia. *The* ***Agenda 21*** (UNCED, 1992) and the *Humane Agenda* (Galbraith, 1998) are already landmarks that can guide science and technology towards a sustainable development.

It is time to act, having in mind that a) technological projects have a long maturing time, b) that new changes must come gradually as to maintain institutional credibility and cultural sustainability, c) that the "sustainability principle" as the keystone of **ethical modernity** must support the *logic of being* to overcome the *logic of having,* d) that plurality and diversity are important qualities in Nature and in Society and e) that an universal education merging science and ethics is the starting point.

To summarise, science is a very important tool to drive Mankind towards the sustainable development utopia. The ethic imperative is that it should neither be self-commanded nor oriented by market forces alone. Rather, it should be at the service of the whole society with the purpose of serving Life!

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