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Deforestation and threats to the biodiversity of Amazonia

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Abstract

This is a review of the main factors currently perceived as threats to the biodiversity of Amazonia. Deforestation and the expansion of the agricultural frontier go hand in hand within the context of occupation and land use in the region, followed by a hasty process of industrialization since the 1950s and, more recently, by a nation-wide attempt to adapt Brazil to economic globalization. Intensive agriculture and cattle-raising, lack of territorial planning, the monoculture of certain crops often promoted by official agencies, and the introduction of exotic species by cultivation are some of the factors affecting Amazonian biodiversity. There are still large gaps in knowledge that need to be dealt with for a better understanding of the local ecosystems so as to allow their preservation, but such investigation is subjected to manifold hindrances by misinformation, disinformation and sheer ignorance from the legal authorities and influential media. Data available for select groups of organisms indicate that the magnitude of the loss and waste of natural resources associated with deforestation is staggering, with estimated numbers of lost birds and primates being over ten times that of such animals illegally commercialized around the world in one year. The challenges to be met for an eventual reversal of this situation demand more systematic and concerted studies, the consolidation of new and existing research groups, and a call for a halt to activities depleting the Amazonian rainforest.

Keywords: Amazonia, biodiversity, deforestation.

Desmatamento e ameaças à biodiversidade da Amazônia

Resumo

Este trabalho mostra um panorama dos principais fatores hoje percebidos como ameaças à biodiversidade na Amazônia. O desmatamento e a expansão da fronteira agrícola caminham lado a lado dentro do contexto da ocupação e do uso da terra na região, seguidos de um processo acelerado de industrialização desde a década de 1950 e, mas recentemente, de tentativas em escala nacional para adaptar o Brasil à globalização econômica. Agricultura e pecuária intensiva, a falta de ordenamento territorial, a monocultura de certas espécies e a introdução de espécies exóticas para cultivo são alguns dos fatores que afetam a biodiversidade da Amazônia. Ainda há grandes lacunas de conhecimento que precisam ser resolvidas para o melhor conhecimento dos ecossistemas locais de modo a possibilitar sua preservação, mas essa investigação anda sujeita a inúmeros empecilhos devido à desinformação, contra-informação e pura ignorância das autoridades legais e da mídia influente. Dados disponíveis para alguns grupos de organismos indicam que a magnitude da perda e desperdício de recursos naturais devida ao desmatamento é imensa, com estimativas de números de aves e primatas perdidos da ordem de mais de dez vezes maior que as desses animais comercializados ilegalmente em um ano em todo o mundo. Os desafios necessários a uma eventual reversão desse quadro exigem estudos mais sistemáticos e coordenados, a consolidação de grupos de pesquisa novos e já existentes, e um apelo para a cessação das atividades que exaurem a Floresta Amazônica.

Palavras-chave: Amazônia, biodiversidade, desmatamento.

1. Introduction

The highest annual rates of deforestation ever registered for Amazonia occur in the region known as the Deforestation Arch, which occupies most of its east-west expanse, and is currently under pressure from interest groups from all over the country, which are occupying public lands for the development of agricultural and cattle-raising activities.

In spite of the fact that most of the literature hitherto published indicated that the diversity and the fragility of Amazonian ecosystems demanded careful, wellplanned occupation, colonization of Amazonia since the late 1960s was marked by a violent process of occupation and environmental degradation typical of "frontier economics", in which progress is understood simply as boundless economic growth and prosperity, based on the exploitation of natural resources perceived as equally limitless (Becker, 2001). Disregarding the peculiarities of the diverse Amazonian ecological spaces and the desires and aspirations of local populations, an alien model based on the predatory extraction of forest resources, followed by the replacement of the forest by expanses for grazing and agriculture, proved inappropriate for the region. Occupation took place in overwhelming bursts associated with the momentary valorization of products in domestic and international markets, followed by long periods of stagnation (Becker, 2004). The environmental cost of this process, with some 700,000 km^2 of natural ecosystems undergoing drastic changes by 2005, surpasses by far the limited social benefits generated by such activities.

The social and economic failure of this model of colonization over the past thirty years was not enough to restrain the process of indiscriminate occupation of the Amazonian territory. If such activities were once financed by official resources, leased at low interest rates and payable in endless installments, now highly capitalized sectors of Brazilian society are jointly working in order to promote a new era of aggressive occupation of the region, taking advantage of the fragility of the state structure in the region and the support of political sectors little concerned with local aspirations. Consequently, we have witnessed a considerable increase in deforestation in the region. In the past four years alone, some 92,000 km^2 of forest have been destroyed.

In this article, we present a review of recent data on deforestation in Amazonia, supporting the claim that it is responsible for an enormous rate of loss of biodiversity.

2. The Deforestation Arch in Amazonia

The Biome Amazonia extends from the Atlantic Ocean to the eastern slopes of the Andes Cordillera, up to altitudes of about 600 m (Ab'Saber, 1977), and contains parts of nine South American countries. Sixty-nine percent of this area belongs to Brazil, whose Government has defined as "Legal Amazonia" an area of 5,217,423 km^2 that includes the totality of the States of Acre, Amazonas, Roraima, Rondônia, Amapá, Pará, Mato Grosso and Tocantins, and the portion of the State of Maranhão west of the 44° W meridian. This area corresponds to 61% of the Brazilian territory and harbors a human population of about 20 million, 3/5 of which live in urban areas (INPE, 2004). Large-scale human pressure on Amazonian resources has long been a factor of environmental devastation. For instance, in 2006, the cumulative deforested area in Legal Amazonia amounted to about 710,000 km^2, or 17% of the territory. Most of the deforestation was concentrated along the so-called "Deforestation Arch", within the boundaries defined by the southwest of the State of Maranhão, the north of Tocantins, the south of Pará, the north of Mato Grosso, the entire State of Rondônia, the south of Amazonas and the southeast of Acre (INPE, 2005). In the 2003-2004 period, approximately 80% of deforestation in Legal Amazonia occurred in about 50 municipalities in the States of Mato Grosso, Pará and Rondônia. In some of those municipalities, the deforested area reached 80-100% of their total area. In the State of Pará, the most serious case of forest depletion happened in municipalities located in the east and southwest, where, in addition to having most of their area deforested, there was a new advancement of deforestation outside the Arch, towards the West, mainly along the axes of the Trans-Amazonian Highway (BR-230) and Cuiabá-Santarém Highway (BR-163).

Recent estimates (2006) by the National Institute for Space Research (INPE) show that almost 71 million hectares of Amazonian forest – an area larger than that of France, Belgium, the Netherlands and Israel combined – have already been destroyed. It should be noticed that most of this deforestation was done by sidestepping the Forest Code and the Provisional Measure N° 2,166-67 of 24 August 2001, which regulate the use of natural resources and establish restrictions in the use of Legal Reserve Areas and Permanent Preservation Areas within private properties. Most of the deforestation conducted in Amazonia has taken place without any permission by the authorities in charge. For instance, the total area authorized for deforestation in Legal Amazonia by the country's official agency for environmental protection, the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) corresponds only to 14.2% and 8.7% of the area actually deforested in 1999 and 2000, respectively (Casa Civil da Presidência da República, 2004).

3. Causal Factors of Deforestation and Degradation

The appearance of altered or degraded areas in Amazonia is directly related to the process of its human occupation. In fact, human interference in the forest is centuries-old, either for exploiting wood or non-wooden products, or for the practice of traditional slash-and-burn agriculture and intensive cattle-raising. A systematic policy of occupation began in the early 1940s, with the creation of the Superintendency of the Plan for the Economic Valorization of Amazonia (SPVEA). Its main achievement was the construction of the Belém-Brasília highway in the 1960s, which also started the practice of deforesting along the roadsides for the establishment of settlements and towns. Soon, other roadways (such as the Trans-Amazonian highway) were built and tax incentives were created for small-scale agriculture and intensive cattle-raising in those settlements. Ultimately, this decentralized rural-urban model failed and, by the mid-1970s, a program of large-scale projects was implemented instead, with a massive injection of funds mainly towards mining, wood extraction, cattle-raising and energy-production initiatives. Thus, major development projects such as "Polamazônia" and "Grande Carajás" came to be, and, together with the opening of the Belém-Brasília highway, further contributed to the deforestation of the region. This model of development based on large-scale projects is still in operation, in the form of the so-called "axes of regional development" (Projects "Avança Brasil" and "Brasil em Ação"), also grounded on the opening and paving of roadways, with a highly controversial environmental impact-vs.-benefit rate.

Some of the main causal factors of deforestation in Amazonia are described in the sections that follow.

4. Human Occupation: Agriculture and Cattle-Raising

The development of Amazonia relies on an expanding, voracious economic model based on agriculture and cattle-raising, installed in a consolidated frontier region. In the past five years, the mean rate of annual deforestation in Amazonia has been of about 1.7 million hectares. Some of that area was deforested for the implementation of agricultural and cattle-raising activities that ceased after a couple of years and abandoned by its owners. Schneider et al. (2000) estimated that percentages of abandoned farming areas in Amazonia vary from 8.4% in the drier zones (rainfall below 1,800 mm per year) to 28.5% in the older colonization zones with rainfall above 2,200 mm per year. However, data by Fearnside and Guimarães (1996) show that, until 1990, some 50% of the area altered by agriculture and cattle-raising in Amazonia was abandoned and covered with secondary forest in diverse stages of development.

Cattle-raising is responsible for about 80% of all deforested areas in Legal Amazonia. Tax incentives for cattle-raising have decreased in recent years, but technological and management adaptations for geoecological conditions in areas such as the "consolidated" frontier of Eastern Amazonia made way for an increase in productivity and cost reduction.

The main agents of deforestation for the implementation of pastures are large- and medium-size cattle raisers. However, there is a large number of go-betweens, with low opportunity costs, who anticipate those cattle-raisers and are directly responsible for much of the deforestation. Expansion of cattle-raising in Amazonia has benefited from the availability of inexpensive lands and, in many cases, from the disregard of environmental and labor laws.

This development of the agricultural frontier and deforestation in Amazonia occurs in the context of the regionalization of Brazilian agriculture, following the accelerated industrialization initiated in the 1950s and expanded in the recent attempts by Brazil to adapt itself to economic globalization.

Within this framework, several factors may lead to high rates of deforestation, such as the availability of public and private funding, population dynamics, the organization of production systems and various physical conditions. All those factors show considerable variation from region to region and involve diverse social groups and production networks that need to be recognized regionally, socially and economically, so as to allow for the formulation of appropriate public policies.

5. Lack of Territorial Planning

According to Dirzo (2001) and Wright (2005), the future of tropical regions is directly linked to the process of conversion of the phytophysiognomies of natural forest in cultivation areas. This global pattern is even more accentuated in Brazil. One of the main problems associated to this economy based on agriculture and cattle-raising is territorial planning, since the undefined land situation allows for intense, uncontrolled and unplanned human intervention.

Notwithstanding the significant advances in recent years in implementing conservation areas to preserve information on ecosystems, the formal conservation unit system adopted by IBAMA is out of step vis-à-vis the proportional representation of the 23 ecoregions and/or the diverse phytophysiognomies of Amazonia. Studies conducted by the Research and Development of Methods, Models and Geoinformation for Environmental Management Project (GEOMA) demonstrate that the Protected Areas in the Amazonia Program (ARPA) of the Brazilian Ministry for the Environment still needs some readjustments in order to be efficient in this aspect (see www.geoma.lncc.br).

What are the prospects of optimistically changing this current pattern? Despite some positive signaling by the State Governments of Pará (Ecological-Economic Zoning – ZEE) and Mato Grosso (more thorough inspections) of their willingness to sit at the negotiating table, there have been some setbacks. The Sustainable Amazonia Program (PAS), which would be an innovative planning action, is inactive. Then again, official inductive, reparatory and surveillance actions are generally slower than chainsaws and skidding chains. Unfortunately, the likelihood for reversion is very slight.

6. Monoculture

In recent years, mechanized agriculture aimed at the international market has been implemented in Amazonia, a process that engages an indirect cycle of deforestation, generally for the benefit of the cultivation of a single, highly profitable crop. The monoculture of soybeans has found a receptive niche in the region, motivated by the low cost of the land and the fragility of environmental law enforcement throughout northern Brazil. The installation of a grain outlet by an American company in Santarém in 2002 caused a tenfold increase in the value of local arable land within the following three years, which led family farmers to quickly sell their properties and move out to the town outskirts and, in many cases, also onto primary forest areas. Today, in spite of a significant decline in soybean prices in the international market and the organized resistance of concerned citizens and groups, nothing prevents the monoculture of that grain in previously opened areas such as pastures – from which an invasion of the primary forest is a serious possibility (Puty et al., 2007).

With the promotion of ethanol fuel as an economically viable alternative to fossil fuels by the current Administration, two prime candidates for monoculture in Amazonia have recently emerged: sugarcane and red palm (dendê, *Elaeis guineensis* Jacquin, 1763), originally from Asia and Africa respectively but acclimatized and cultivated in Brazil for centuries. The same economic factors that made soybean monoculture a lucrative business for some entrepreneurs may well make the single-species cultivation of sugarcane and red palm in Amazonia an attractive prospect in no time. Considering the havoc to biodiversity caused by the monoculture of soybean and other plants in Brazil and in other countries, this is a matter of serious concern indeed.

7. Introduction of Exotic Species

The introduction of exotic species into a habitat is generally regarded, with countless examples to spare, as harmful to local biodiversity, by altering and/or degrading ecosystems and community structure, introducing diseases and eventually even causing biological extinctions (Taylor et al., 1984; Mills et al., 1993).

A number of edible exotic species brought to the region for commercial-scale farming, including African tilapia (*Oreochromis* spp.) and the giant brown freshwater prawn (*Macrobrachium rosenbergii* (De Man, 1879)), have thrived in the Amazonian environment. Even though they are well-known as exotic species, their cultivation is fostered by many Government projects in northern and northeastern Brazil. The environmental impacts of tilapia introduction are well-known, and can be of two major types: the effect of feral populations of this fish on native species, in concert with severe human impacts on local aquatic systems, and nutrient enrichment of local waters from intensive tilapia farming (see Fitzsimmons, 2001 for a review). In Venezuela, tilapia was found to be the fourth more abundant fish species in Río Manzanares, having spread all over that river in the four decades since its introduction in 1959, and contributing to the disappearance of six native species previously reported for the area (Pérez et al., 2003). Information on the impact of tilapia in Amazonia is urgently needed.

The cultivation of the giant brown freshwater prawn in Brazil started in 1977 through an initiative of the Department of Oceanography of the Federal University of Pernambuco (UFPE). Impelled by official agencies and private enterprises, the farming of this species – and soon its occurrence in natural environments – eventually spread out southward to the States of Rio de Janeiro, São Paulo and Santa Catarina and westward to the State of Pará (Gazola-Silva et al., 2007). In this latter Amazonian locality, it was found reproducing normally in estuarine waters (Barros and Silva, 1997). *Macrobrachium rosenbergii* is a prolific, omnivorous and quite voracious prawn of great commercial value and potentially dangerous to native species as a transmitter of the White Spot Syndrome (WSS) virus (Gazola-Silva et al., 2007).

On the other hand, not all exotic species should be associated to hazards to biodiversity. In the case of plants, only those with a strong capacity for seed dispersal and fast reproduction should pose real threats, and, in contrast to those, introduced coconut palms (*Cocos nucifera* Linnaeus, 1753) may be seen as a useful tool for the indirect conservation of the protected indigenous lands of Brazil. Those lands are important to the conservation of biodiversity because their inhabitants maintain the integrity of the ecosystems within their respective area, and coconut palms are highly valuable to them as a source of raw material (Salm et al., 2007).

The bottom line is that the introduction of exotic species is generally risky, and the very existence of successful counterexamples calls for a very careful impact assessment prior to any introduction. There is a need for establishing proper protocols for risk evaluation, coupled with field and controlled experiments to assess the possible effects of species introduction (Lévêque, 1996). At any rate, researchers working within the industry should be always fully aware of the possible threats to local biodiversity posed by escapees from cultivation ponds.

8. Misinformation and Disinformation

Throughout many decades of historically-oriented biogeographical studies focusing on organism distribution patterns explained by means of barriers long gone, it has been taken for granted that Amazonian ecology should be generally uniform. It was only in the past fifteen years or so that ecological heterogeneity in the region was acknowledged, and further, more detailed and thorough studies on the ecology of present-day Amazonia are necessary (Tuomisto and Ruokolainen, 1997).

Scientific collections are repositories of specimens found in a region, and, ideally, they should be representative of that region's diversity and richness. However, this ideal situation is still far on the horizon. For instance, the great majority of botanical collections of Amazonian material currently available for study hold a low density of specimens in a clumped, biased distribution: some few areas in Amazonia are relatively well sampled, while at least four main regions (in, respectively, lowland Colombia, western, northern and southeastern portions of Brazilian Legal Amazonia) being particularly poorly known and hypothesized to contain large numbers of uncollected species (Hopkins, 2007). At any rate, the plant biodiversity of the region may be considerably underestimated, and the implementation of sound collecting programmes is of paramount importance to fill in those sizeable gaps of knowledge.

Obviously, the fuller the knowledge we have of the Amazonian environment, the better prepared we shall be to protect and maintain its biodiversity. Therefore, ignorance is a threat of enormous consequences. It is thus deeply troubling that, in recent years, the official Brazilian agency in charge of safeguarding the country's ecosystems – IBAMA – has taken highly counterproductive measures targeted at scientists who collect specimens for taxonomic and ecological studies. That branch of the Ministry of the Environment has determined all life forms in Brazilian territory as sharing what was called the "national genetic patrimony", an abstract entity defined legally but lacking any biological reality, which could be a conceivable target of biopiracy. Incensed with a misguided perception of scientists (especially, but not only, foreign nationals) as potential biopirates bent on exploiting this "national genetic patrimony", IBAMA officers have often threatened systematists and ecologists with heavy fines and even imprisonment for having collected one more specimen of a frog or an insect without due license, for having provisionally examined collected material in an institution other than the one for which it was earmarked for permanent holding, or for not reporting beforehand the collection of a new species that was just being described. Lacking basic notions of natural history, life cycles or population dynamics, they act as environmental zealots bordering on the irrational, banning researchers from collecting any reasonable number of specimens so as "not to endanger the species". The problem of our collective ignorance of many patterns and processes involving the diversity and distribution of Amazonian organisms is compounded by the plain ignorance of some misinformed officials who are ironically in charge of that all-powerful environmental agency. To remedy this, there have been high-level talks between leading scientific institutions and IBAMA, but progress has been dismayingly slow due to bureaucracy, miscommunication and a certain lack of goodwill on the part of authorities who should have known better.

9. Deforestation and Loss of Biodiversity

Annual estimates of forest loss in Amazonia are calculated by means of satellite imagery and measurements in square kilometers. Thus, for the 2003-2004 period, deforestation in the region is estimated at about 26,130 km^2. What is not generally known is the number of living organisms (which may be considered natural resources) lost per square kilometer of cut-down forest.

Plants attain an extraordinary biodiversity in Amazonia. It is estimated that the region harbors some 40,000 vascular plant species, of which 30,000 are endemic (Mittermeier et al., 2003). Studies on the density of plants in Amazonia have been mainly focused on a restricted group of plants – trees with trunks with a diameter at breast height of over 10 cm. In one hectare of Amazonian forest, some 400 to 750 such trees can be found. A recent study estimated that, in the region of the Deforestation Arch, the number of such trees in an area of 1 km^2 of forest may vary from 45,000 to 55,000 (Ter Steege et al., 2003). By multiplying these values by the above-mentioned total deforested area, we can estimate some 1,175,850,000 to 1,437,150,000 trees were cut down in the Arch between 2003 and 2004.

Two groups of animals for which some statistics are available are birds and primates. It is thought that Amazonia harbors over 1,000 avian species: some 250 species of birds can be found in a single square kilometer of Amazonian forest. Studies in French Guiana (Thiollay, 1994) and Peru (Terborgh et al., 1990) indicate the number of individuals living in a square kilometer: 1,658 in French Guiana and 1,910 in Peru, respectively. The same calculations done previously for plants yield an estimate of 43 to 50 million individual birds affected by deforestation in that period. As for primates, which comprise fourteen genera in Amazonia, of which five are endemic, studies conducted in various subregions show that their density vary considerably (Peres and Dolman, 2000). If one applies the aforementioned calculations to the simian populations in Rondônia, Mato Grosso and Pará, the States most subjected to deforestation, where a square kilometer of forest could harbor between 35 and 81 individuals, one estimates between 914,550 and 2,116,530 individuals would have been wiped out.

Those numbers, albeit in a somewhat oversimplified way, may give us a notion of the magnitude of the loss and waste of natural resources associated to deforestation in Amazonia. For a mental picture of such numbers, if we placed all felled trees side by side and assumed each one has a trunk with a maximum diameter of 10 cm (a considerable underestimation in Amazonian terms), we could state very conservatively that they would extend for 117,585 to 143,715 km – that is, some three to three-and-a-half times the circumference of the Earth at the Equator. Estimated numbers for animals are also huge, many times higher than those known, for instance, for the illegal animal trade: it is estimated that some 2-5 million birds and 25,000-40,000 primates are annually commercialized in the world (RENCTAS, 2001). Such numbers are mere fractions of what would have been lost with deforestation in Amazonia last year.

Loss of biodiversity is the main consequence of deforestation in Amazonia, and is also totally irreversible. It is always possible to prevent soil erosion and recover water bodies and nutrient cycling by means of simplified ecological systems, but it is impossible to bring back extinct species. In addition, Amazonian species are not widely distributed, but have instead a restricted distribution (Cracraft, 1985). Also, most of the species are rare, with small populations and very sensitive to any change in their respective habitats (Terborgh et al., 1990; Thiollay 1994). Large-scale deforestation threatens thousands of species, many of which are already listed as endangered by the Brazilian Government, such as some birds (*Dendrexetastes rufigula rufigula* Lorenz, 1895*, Dendrocincla merula badia* Zimmer, 1934*, Dendrocincla fuliginosa trumai* Sick, 1970*, Pyrrhura lepida coerulescens* Neumann, 1927*, Pyrrhura lepida lepida* (Wagler, 1927)*, Clytoctantes atrogularis* Lanyon, Stotoz and Wilard, 1990 and *Phlegopsis nigromaculata paraensis* Hellmayr, 1904) and primates (*Cebus kaapori* Queiroz, 1982*, Allouatta belzelbul ululata* Elliot, 1912 and *Chiropotes satanas* Hoffmannsegg, 1807).

10. Some Hope for the Future: the Positive Role of Secondary Vegetation

Agriculture in Amazonia creates unique landscapes composed of a shifting patchwork of crop fields, fallows of various ages, secondary forest derived from fallows, and remnants of the original vegetation. Fallows or secondary vegetation are primarily components of an agricultural land-use system, and their ecological or forestry status as secondary vegetation or phases in the "reconstitution" of forest in this context is, indeed, secondary. Fallows are components of an integrated farming system, in which multiple objectives for the livelihoods of the farmers have to be met. They exist for a number of ecological and socio-economic reasons, among which are the restoration of soil fertility, the reduction of erosion, the control of weeds, or the generation of opportunities to gather products for sustaining the livelihoods of the household. As far as forest "reconstitution" is concerned, in many tropical landscapes, fallows may never develop into a community resembling the original one of the site, even if they are not subject to further disturbance. The vegetation component of the community will normally be made up of plants which regenerate naturally when the land is left fallow, useful plants which are conserved by the farmer, whether planted or naturally regenerated, and remnants of agricultural crops and weeds.

The growing consensus is that the conservation of tropical biodiversity can no longer be centred solely on protected areas, but will require action in all land use types across landscapes and regions (Aide 2000).

In this process of alteration of Amazonian ecosystems, it is important to emphasize the role of secondary vegetation areas ("capoeiras") that continue to grow, and eventually could become the predominant ecosystem in the Amazonian landscape, if the current pattern of land use is kept unchecked. The Bragantina Microregion, originally a tropical forest area located in the north of the state of Pará, has undergone 120 years of agricultural colonization and now has less than 15% of the original vegetative cover, while secondary vegetation occupies about 53% of it (Alencar et al., 1996; Vieira, 1996). By the same token, in the Municipality of Paragominas, northeastern Pará, 616,000 ha of forest were cut down in about two decades for the implementation of agriculture and cattle-raising: until 1988, 43% of that area was abandoned and taken over by secondary forest (Watrin, 1991). In the Municipality of Altamira, southwestern Pará, some 47% of primary forest areas in a settlement of family farmers along the Trans-Amazonian Highway were deforested to give way to pastures and annual and permanent crops between 1971 and 1991 (Moran et al., 1994).

Secondary vegetation areas can be regarded as partially degraded ones. However, that does not mean they are ecologically worthless or unsuitable for agricultural or forestry activities. Instead, those areas should be considered as forests in recovery, as they re-establish the organic functions of the soil, and constitute a reserve of regional native seeds and fruits that allows for the maintenance of the floristic diversity and supports the local wild fauna (Vieira et al., 1996; Nepstad et al., 1996; Adams, 1997).

In the slash-and-burn system of agricultural production in Amazonia, secondary forests represent the phase of vegetation fallow. This kind of production system is the basis for the production of food for a significant part of the 600,000 families of small-scale producers living in Amazonia (Homma et al., 1998). In slash-and-burn agriculture, the main role of the secondary vegetation is to accumulate biomass and nutrients, and to "fertilize" the land after cutting and burning its plant biomass. Its ashes contribute to adjust soil acidity and serve as a natural fertilizer for crops. Besides, the fallow period also works as pest and crop disease control, in addition to preventing weed infestation.

From the environmental standpoint, growth of secondary forests contributes to the immobilization of carbon in the atmosphere, the re-establishment of hydrological functions, the recovery of biodiversity, the reduction of potential nutrient losses by erosion and lixiviation, and the decrease in inflammability of the landscape. Beyond the overriding importance of fallows, it's important to note that secondary forests or old fallows also play a significant and often overlooked role in swidden agriculture systems.

11. What There is to Be Done

It should be noted that the information behind the somewhat encouraging previous section, in contrast to the doom-and-gloom scenario of the remainder of this article, was obtained only by means of continuous, systematic scientific research. In fact, any solutions for the future of biodiversity in Amazonia will depend on more and better knowledge of the functioning of this ecosystem and its components.

Some firm steps are fortunately being taken in this direction. In the past decade, knowledge of the various aspects of biological diversity in Brazilian Amazonia has grown exponentially. By means of a strategy of partnerships, public and private institutions have been engaged in institutional articulation to an unprecedented degree. Such actions are motivated by the common goal of the need for a rapid advancement of scientific knowledge on the composition and ecology of Amazonian species, and may be seen as a strategy for advancing through research by evaluating the current pattern of high rates of deforestation and destruction of natural landscapes, as the processes involved in changing the landscape are always faster than the scientific process of describing new species or discovering new natural compounds for medicinal or industrial application.

Existing local research institutions should be consolidated and integrated to similar, extra-Amazonian establishments within the framework of a national program, as well as with other institutions to be created in the region outside the Belém-Manaus axis. Investments will be needed in the organization, in the construction of institutional interrelationships, in the definition and expansion of projects and a firm commitment to the preservation of Amazonian biodiversity. Deforestation Zero is at the very least a cautionary desideratum, if not an emergency measure for recovery programs. Sampling of biodiversity throughout the various phytophysiognomies of the region is sorely needed, and the barriers posed by official ignorance and misguided notions of environmental zealotry should be eliminated through education, clarification and dialogue. New graduate courses focused on the knowledge of biodiversity should be strengthened or implemented, and long-term study programs with consolidated research groups must be enforced as a priority. This is the challenge that we should face with our abilities of innovation and scientific intelligence.

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