DECISION SUPPORT SYSTEM FOR SUSTAINABLE ECOSYSTEM MANAGEMENT IN ATLANTIC RAIN FOREST RURAL AREAS (ECOMAN)

Tropical Rainforests Bibliographic Review

ANNEX D

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Oeiras, January 2003

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"…In any consideration of human impact on the environment it is probably appropriate to start with vegetation, for humankind has possibly had a greater influence on plant life than on any other components of the environment…"

Andrew Goudie, 2000

1 INTRODUCTION

Preindustrial societies used forests as a source of energy and of construction materials and for recreation, being the hunt preserves (of European aristocracy) one of the first actions taken to, in somehow, safeguard the forests. The expansion of European colonial potencies and the overseas trade led to a valuation of timber, which was crucial in ship-building, and to a widespread clearance of temperate forests. The process of industrialisation converted forests in the source of charcoal to the emergent steam engines. Nowadays, the forests of developed countries, although very reduced when measured against its "original" extension, seem to have started to increase. Although the regrowth of forestlands, which seems to result from more efficient forest management policies, a decrease of biodiversity has been felt (Matthews *et al*., 2000).

At the present time in developing countries, forests are performing an analogous function in the development of these countries. Forests are, in these regions, under great pressures resulting from the fact that they are the support for the activities of very poor rural communities. Forestlands are being converted to agricultural land and cash crops and forest fragmentation is being the result of activities such as: mining, logging, and roads building.

However, post-industrial societies, especially the wealthier ones, are valuing other goods and services provided by forests: hiking, bird-watching, ecotourism, survival training courses, but also the services in protecting watersheds, in regulating the climate and in conserving biodiversity.

Therefore, today's world forests are being pressure by the overlapping human demands of goods and services usually related with preindustrial, industrial and post-industrial needs. In consequence forests and deforestation are key environmental concerns, focusing the work of several international institutions to achieve better ways to manage these ecosystems.

This report aims at presenting a literature review on the issues of tropical rainforests. It is structured in four main points: tropical rainforests characteristics, structure and distribution; tropical rain forests, goods, services and values; deforestation in tropical rainforests; sustainable strategies for management of tropical rainforests.

2 TROPICAL RAINFORESTS ISSUES

The tropical rainforest is one of the most significant biomes of our planet covering around 6% of the continents (Myers & Myers, 1992). It is one of the most complex and, at the same time, one of the most distinctive ecosystems of Earth (Demangeot, 2000).

The multiple functions of tropical rainforests require an interdisciplinary approach to its study, inspiring a dialogue between social sciences and natural sciences to achieve a better comprehension of its problems and to support the definition of better strategies for its sustainable management. In this line of reasoning is expressed one of the biggest challenges of studying the tropical rainforest: although it is an issue that matters to everyone in the planet (especially on account of the global negative impacts of its destruction) it also complies with interdependent, as well as contradictory, local contexts (Smouts, 2001).

These forests, as a study object, inspire significant amounts of scientific research, and important environmental worries that are encouraging programmes on nature conservation, which represent one of the priorities of international policies. At the same time, it corresponds to an issue, politically, scientifically, and emotionally charged, where the different visions and perceptions are sometimes argumentative confronted.

The subject "Tropical Rainforest" is encompassed by the discussion of the relations "North-South" countries[1] that occur at global level about the issues of control of raw materials, in this case the exotic hardwood (Smouts, 2001). Moreover, the tropical rainforest is included in the debate about the economic, social and environmental dimensions of sustainable development, which is in our time inseparable from the discussions about the globalisation of the economy.

For the multiple questions arisen in the context of its study, the tropical rainforest is a very challenging subject to think about the social structures and how their dynamics interact at global and local level. The international dimension is inherent to the forest management in tropical countries. Not only because the discussion about the sustainable management of forests is made at global level, but also because frequently the social actors, directly participating in the exploitation and conservation of this natural resource, are foreigners to the tropical countries, being the presence of international institutions almost constant. Moreover, tropical wood is a raw material that is traded in the international markets and therefore subject to the fluctuations of the global economy. Additionally, it is recognised the importance of the tropical forest degradation (with its consequences on soil erosion and decrease of agricultural productivity) as a reinforcing factor of underdevelopment of those countries.

It is an issue where the economic and environmentalist perceptions of the "North" and "South" countries are being confronted, taking us to realise that the tropical rainforest is basically an human construction that evolved essentially in the last 100 years.

In accordance with Philip Stott (1999) the tropical rainforest as a biogegraphic object doesn't exists, and is subject to myth construction at large scale, among which it should be stressed its

[1] Although reductive, the expressions North and South are still very helpful to identify the more developed countries (basically from Europe and North America, to the north of Brandt's line) and the less developed countries, the "South", mainly situated in tropical regions (Brandt, W., 1980). However these terms have not a precisely geographic sense, since we can find outside the Northern Hemisphere some countries (such as Australia) that from the Development Indicators are clearly associated with the "North".

durability, the high biodiversity as well the fragility of the ecosystem. On the other hand, the population from the "South" countries requires (and it isn't this also a request imported with the models of economic growth from the "North" countries, and reproduced in these regions?) the appliance of the right of sovereignty[2], and therefore the right to manage the lands as they wish, since their actions don't cause any damage to other countries. It is, at the bottom line, their perception that by means of a process of experimentation they could learn how to reach a better management of their lands.

Also M.-C. Smouts (2001) stands up for the idea that the concept of tropical forest is a construction from the Political Ecology. It isn't referred to ecosystems clearly defined by the experts. By the contrary, in this concept are mixed dry forests and humid forests; open forests and closed forests; equatorial, tropical and sub-tropical climates. As a result, in the international statements, tropical forest correspond to anything situated between the Tropic of Cancer and the Tropic of Capricorn, being a wonderful and threatened natural resource, which deserves that something should be done to achieve its protection.

Although, the forests are a reflection of the environmental conditions it is also true that is state expresses "…the trajectories and social dynamics, which would be illusory attempt to guide trough external interventions…" (Smouts, 2001).

2.1 Some mythology associated with tropical rainforests

From the visions of paradise of the 16th century to the lavishly cinematographic descriptions of a dark, mysterious and hostile jungle[3], the tropical rainforest has its share of impressionist myths.

Among the founding myths related with the tropical rainforest we came across with the perceptions of the peoples of Europe on the periods of maritime expansion, exploitation and colonial rule of tropical regions. These perceptions (so well depicted in the *Letter of Pêro Vaz de Caminha to the king of Portugal*, describing the discovery of Brazil, and the descriptions of the unfamiliar landscapes and vegetation in the epic poem of Luís Vaz de Camões), result from the projection of the European culture over a reality that it is totally strange, but that is appraised and classified in conformity with the European values. These perceptions can be seen in the view of the vegetation as an exotic asset; in the analogies with the territories of origin of the explorers; and in the images of amazing fertility, fecundity and diversity.

Frequently regarded as one of the crucial ecosystems to preserve the environmental balances of the planet, the tropical rainforests owe this repute more to the fact that they stock up significant reserves of CO_2 (released during the decay of organic matter and during forest

[2] This right it is very well expressed in the Principle 21 (also known as the "Canadian Principle", because was put forward by Canada) of the Declaration of Stockholm (1972): "States have, in accordance with the charter of the United Nations and the principles of international law the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."

[3] From the Hindi word *jangal*, for a "wild or desolate place" (Smouts, M.-C., 2001).

fires, contributing for the global warming) then to the production of O_2. In fact, the high quantities of O_2 produced throughout the photosynthesis process are compensated by its also high consumption during the process of decay of the organic matter (Caufield, 1986). This fact appears to bring to an end the myth of the tropical rainforest functioning as the lungs of the planet[4].

In the beginning of the 20th century, the successional theory emerges as well as the concept of climax formations, ruling the scientific production of the ecology experts until the sixties (Stott, 1999). The climate was then considered as the key ecological determinant of the vegetation succession to accomplish its final adult phase: the climatic climax[5]. The latter being a phase that all the plant formations tend to attain with great stability and where the vegetation is in equilibrium with climatic environment, which is also very stable.

Therefore, the tropical rainforest would be the climatic climax of the wet tropical regions, having evolved in a stable environment during millions of years, and becoming the oldest ecosystem of the planet. This of course disregarded the significance of landscape disturbances and shifts in forest cover produced by the climatic changes related with the retreats and advances of ice sheets during the Glacial Ages of the Pleistocene[6].

In the years 1960-1970, the vegetation analysis as an organic community give way to an analysis more centred in the individuals, integrated in an autecological interpretation, which gives more significance to the inherent individuality of each species in opposition to the synecological interpretation of A. Schimper[7]. Therefore, the analysis of the vegetation as a specific mix of individuals in a certain place and in a certain moment prevails over the analysis of the biogeographic units.

Moreover, the climatic changes that have always occurred in our planet, disturbing gradually, catastrophically[8] and unpredictably all the regions of Earth, are in the origin of a constant adaptation of the plants to the changing climatic conditions. Thus it is not correct to state that the tropical rainforest constitutes the evidence of the primordial forest ageing millions of years. As Smith & Smith (1998) say, the mature tropical forest is a mosaic of continually changing vegetation, but these continuous random disturbances across the forest ensure the persistence of the species.

It is in this sense that the tropical rainforest can't be recognised as an object, with sharp definition of its boundaries, permanence and components, which could typify it as an organic unit clearly opposed to other units (Stott, 1999). Therefore in this frame, can it still be maintained the perception of the human intervention as a destructive action of the distinctive

[4] It is rather curious that this anthropomorphic expression (spread since the eighties) reveals a function opposite of the organs of the human body: the lungs absorb O2 and release CO2. Besides that, it is known that only the forests in process of growth, and suitably managed improve the quantity of O2 in the atmosphere, and stock a portion of the CO2 under the form of organic matter, the wood (EUROFOR, 1994).

[5] Plant community that no longer undergoes changes in species composition due to succession.

[6] The time period that spanned from 1,8 million to 11 000 years ago.

[7] Andreas Schimper was one of the founders of scientific ecology and published in 1898 his masterwork *Plant-Geography Upon a Physiological Basis*, translated and published in English in 1903.

[8] This expression refers to the huge magnitude of these disturbances and not to their impacts in terms of damages produced to human society.

and enduring tropical rainforest, which configures the Primeval Paradise, the Wonderful Eden of human myths and fantasies, present in some scientific and non-scientific discourses?

We are witnessing a dispute of arguments of "North" and "South" countries. Rainforests are being felled for timber by logging companies and cleared by people for farming, and it is frequent to assign to these activities, the direct responsibility of the problems resulting from the global warming of the planet's environment. This argument led the "North" countries to establish the conservation and restoration of tropical rainforest as priorities of international policies.

However, the transfer, to the "South" countries, of the responsibilities by the environmental problems that the planet is facing nowadays, comprise some significant questions:

1. The process of industrialisation of the "North" countries is easily forgotten as one of the causes of the problem of the global warming;
2. The process of industrialisation of the "North" countries led to the destruction of the forests of temperate regions, which survive today almost only in small patches, or on mountains. In much of the northern hemisphere, most of the natural broadleaved forests have been cut down to provide farmlands.
3. The markets (hardwood, rubber, cattle, coffee, cocoa, etc.) of the "North" countries are a central driving force of the deforestation of the "South" countries forests;
4. The regulation and strong punishing of the activities responsible for the depredation of the forests of the "North" countries go together with the transfer/exportation, for the "South" countries, of the models of economic growth that led to the destruction of the temperate forests.
5. This twofold intervention of the "North" countries led some international institutions to propose the construction of natural reserves, where the more original tracts of the tropical rainforest could be preserved[9], and where it could be introduced a model of sustainable management of the forest, based mainly in extractive activities.

2.2 Operative concepts of forest

Many definitions of forest are in use throughout the world, reflecting wide differences in biogeophysical conditions, social structures and economies (IPCC, 2000). The Report coordinated by H. Gyde Lund (2000) to the United Nations Framework Convention on Climate Change, compiles about 240 definitions of forest.

There are three broad categories of forest definition: administrative, land use and land cover (IPCC, 2000). The first category defines forest according with legal jurisdiction or

[9] The World Wide Fund for Nature, in cooperation with the World Bank, is setting up reserves in Brazil and in other tropical countries (http://www.panda.org/news/press/news.cfm?id=293).

administrative requirements. These definitions don't show any relationship with the types of vegetation present in the land.

The second category of definitions relates the forest with the land use, defined in terms of timber production, protection of catchments or recreation. Frequently, it is included in the forest area some land without any coverage of large trees, and in opposite, some treed areas without a forestry purpose (for grazing for instance) are excluded, showing how this type of definitions isn't related with land cover, but mainly with the intent of management of the land (Lund, 2000; IPCC, 2000).

The category of definitions of forest related with land cover, classifies the forest in terms of vegetative land cover. They include the density of coverage (open or closed canopy, the limits of which varies from country to country), the height of the trees (which has being diminishing from 7m in the 1980's to 5m at the end of the 1990's[10]), the proportion of tree biomass exceeding a minimum threshold, etc.

Looking for a definition of forest is very important not only to scientifically demarcate the boundaries of the study object (with all the difficulties described before) but also for the monitoring of a biological entity that is (having confidence in the statistical data produced by credible international institutions such as FAO and WRI) in retreat.

However it should be said that the monitoring of changes in the forests frequently constrains the type of definition of forest. The costs of the tools for the monitoring (usually remote sensing techniques) as well as their technical limits, turns the definition of the analysis units in a "...trade-off between practicality (cost) and the ability to identify areas where actual changes have taken place..." (IPCC, 2000).

2.2.1 The FAO definition of forest

Although the diversity of forests and forest ecosystems in the world and the diversity of human approaches to forests, several authors consider the definition of FAO as the basic definition of forest (FAO, 2001; FAO, 2001a)[11]:

> *"Forest includes natural forests and forest plantations. It is used to refer to a land with a tree canopy cover of more than 10% and area of more than 0,5ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5m. Young stands that have not yet, but are expected to, reach a crown density of 10% and tree height of 5m are included under forest, as are temporarily unstocked areas.*
>
> *The term includes forest used for purposes of production, protection, multiple-use or conservation (i.e. forest in national parks, nature reserves and other protected areas), as*

[10] The implications of the variation of the height of the trees and of the cover density are clear: according with the different thresholds accepted, the forest area is smaller or bigger.

[11] The World Resources Institute considers, as a working definition of forest ecosystems the following "*…terrestrial ecosystems dominated by trees, where the tree canopy covers at least 10 percent of the ground area…*" (Matthews *et al*., 2000).

well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts with a width of more than 20m), rubberwood plantations and cork oak stands.

The term specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations. It also excludes trees planted in agroforestry systems."

This definition articulates the land cover and land use criteria, and is an effort of FAO to find a definition, which is at the same time minimalist and encompasses the diversity of forests of the entire world. Moreover, it is presented by FAO as a tentative to improve the former definition of forest[12], which distinguished the forest from developed countries and the forest from developing countries:

Developed countries

"Land with tree crown cover (stand density) of more than about 20 percent of the area. Continuous forest with trees usually growing to more than about 7 m in height and able to produce wood. This includes both closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground, and open forest formations with a continuous grass layer in which tree synusia cover at least 10 percent of the ground."

Developing countries[13]

"Ecosystem with a minimum of 10 percent crown cover of trees and/or bamboos, generally associated with wild flora, fauna and natural soil conditions, and not subject to agricultural practices. The term forest is further subdivided, according to its origin, into two categories:

1. *Natural forests: a subset of forests composed of tree species known to be indigenous to the area; and*
2. *Plantation forests:*
   - *established artificially by afforestation on lands which previously did not carry forest within living memory;*
   - *established artificially by reforestation of land which carried forest before, and involving the replacement of the indigenous species by a new and essentially different species or genetic variety."*

Therefore, the change in the concept of forest it must be seen at the light of a political definition since the forest is at the root of other concepts such as deforestation, forest degradation, etc. Therefore, if nowadays we have a more broad definition of forest we have also areas that weren't considered as forest before and that now are. At the same time that the forest is decreasing, the rates are dissimulated by increasing the concept of forest[14]. So it is possible that the decreasing rates of forest loss are not to be completely trusted.

[12] The different meetings that gathered several experts in forest resources from member countries of the United Nations, international, national and non-governmental organisations and individuals culminated with the "Expert Consultation on Global Forest Resources Assessment 2000" (Kotka III) held in Kotka, Finland in 1996. From these meetings arisen recommendations and concepts that were very significant to help FAO in the planning of the Forest Resources Assessment 2000.

[13] In a certain matter one can see that the definition of forest in developing countries match the definition of tropical forest.

[14] Some institutions, for instance, the World Rainforest Movement, consider that FAO is being manipulating the information by changing the definition of forests, not including logging as deforestation, and continuing to include monoculture tree plantations as forests. Therefore, according to WRM, FAO has missed the opportunity to provide the world with a tool to adopt and implement policies to ensure the conservation of its imperiled forests (WRM, 2002).

In accordance with Smouts (2001) this new *official* definition of forest is one of the examples of the work undertaken by the United Nation organisms. It is an effort to find at global level an agreement that embraces the immensity of different and divergent approaches giving us the illusion of a common vision named consensus. Moreover, the new definition, even if less precise from the technical point of view and with little differences in the essential, would be less accurate but diplomatically correct.

According with the last UN-FAO report on State of the World's Forests (FAO, 2001a) there are about 3870 million ha of forests (natural[15], 95%; plantations[16] 5%) in our planet. Although the data stating the worldwide retreat of the forests, these figures are higher than the forest cover estimates made by the same institution in previous forest assessments (more 400 million ha than the estimates of 1995, specially in Australia and Russian Federation). This difference in figures reflects the change in the definition of forest and the incorporation of new national inventory data (FAO, 2001a).

2.3 Tropical Rainforest characteristics

From the conceptual point of view, the expression tropical rainforest has been changing a lot in time and space, unveiling how much this entity is more a social construction then a biogeophysical unit. Even if insisting in the idea that the concept of tropical rainforest is a social construction, it is helpful to discuss and establish an operational set of concepts related with the tropical rainforest.

The German botanist Andreas Schimper constructed, in 1898, the expression "*Tropische Regenwald*", linking clearly this vegetation unit "evergreen, hygrophilous in character, at least thirty metres high, rich in thick stemmed lianes, and in woody as well as herbaceous epiphytes" with a climatic background, the "ever-wet tropics" (Stott, 1999).

He followed, the knowledge gathered by the German naturalist Alexander von Humboldt[17] and in some way, the ideological principles of the Environmental Determinism introduced by the geographer, and also German, Friedrich Ratzel in his masterwork *Anthropogeographie* (1882-91). Although criticised by some, the basic criteria to define the tropical rainforest are still considered very useful by diverse scientists.

The tropical rainforest (the forest from the ever-wet tropics) was then defined very much in opposition to the plant formations of the tropical regions with dry season, where he set apart three vegetation units: monsoon forest, savanna forest and thorn forest. These different types of tropical forest grade one into another, with no sharp boundaries, and even within the tropical rainforest are many subtypes: mountain forest, cloud forest; gallery forest; swamp forest, mangrove forest (Smith & Smith, 1998).

[15] A forest composed of indigenous trees and not classified as forest plantation (FAO, 2001).

[16] A forest established by planting or/and seeding in the process of afforestation or reforestation. It consists of introduced species or, in some cases, indigenous species (FAO, 2001).

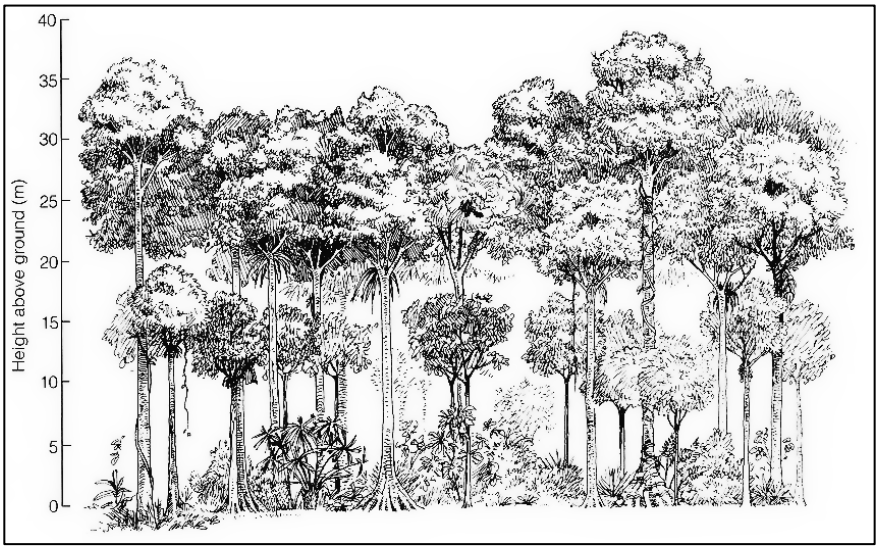
[17] As Orlando Ribeiro (1980) stated, Humboldt, which was one of the pioneers in the geography of the plants, remarked with perspicacity that the vegetation should be considered the main indicator to situate the landscape in the planet.

However, this definition, used by part of the scientific and academic community, has been "…largely ignored, altered, or played about with by many latter ecologists, often leading to total confusion…" (Stott, 1999). In accordance with Philip Stott, this concept of tropical rainforest has been so damaged, in the construction of environmental myths of the "North" countries that became too insufficient and politically dangerous.

2.3.1 Vertical structure of tropical rainforests

Undisturbed tropical rainforests are characterised by high species diversity and complex vertical and horizontal structures, which constitute a mosaic of vegetation in a continuous state of change and that conditions the internal climate of the forest. Four vertical layers characterise these forests (Fig. 1): overstorey, canopy, understorey, and forest floor.

Fig. 1 - Vertical structure of Tropical Rainforests



Source: Adapted from Smith, R. L. & Smith, T. M., 1998

Overstorey stands at 40-80 m above forest floor, comprising scattered emergent trees with umbrella-shaped canopies, exposed to the light and to the winds. The canopy, at 30-40 m, refers to the dense ceiling of leaves and tree branches formed by closely spaced trees, which constitutes an efficient barrier to the sunlight and to the rain, obscuring the layers below, where little air movement and high humidity are almost constant. In this understory layer, which stands at 10-20 m, the reduced sunlight (only 10-15% of the solar radiation that reaches the upper canopy) restricts the growth of trees and shrubs. Since two thirds of rain and 99% of light are intercepted by canopy and understorey layers, the forest floor just have sparse plants and herbs, which grow among roots and the store of dead and decaying plant matter (Smith & Smith, 1998).

2.3.2 The spatial distribution of tropical rainforest

Near the equator, on the low lands, especially in Amazonian Basin (South America), in the Congo River Basin of Africa, and in the Indo-Malayan region, high temperatures and abundant yearly rainfall combine to produce a dense, broadleaf, evergreen forest (Fig. 2). This tropical rainforest grows on the tropical regions with an estimated total area of about 1084 millions of hectares, corresponding to about 28% of the world forests (FAO, 2001a) and 7% of the land surface of the planet. The most important area is Central and South America (59%) followed by Africa (24%), and Indo-Malaysia (17%).

These regions present practically invariable conditions for the development of the vegetation during all the year (Withmore, 1998). Within the tropical wet climate, seasonal temperature variations are small (normally less than 3°C) because the noon sun is always high and the number of daylight hours is relatively constant. However, there is a greater variation in temperature between day (average high about 32°C) and night (average low about 22°C). All months have an average temperature higher than 18^{o}C; wet all seasons and all months have at least 60mm of rainfall. Typical annual rainfall totals are greater than 1500 mm and in some cases the total may exceed 4000mm (Ahrens, C. D., 1999). These areas correspond to the Tropical Rain Forest Climate (*Af*), based on the Waldimir Köppen[18] system of classification, as modified by G. T. Trewartha (1968).

As far as we move away from the equatorial regions, with the decrease of the annual precipitation together with the existence of a dry season, the tropical rainforest gives way to other forest formations less dense, up to the savanna[19] ecosystems in the less wet regions where the dry season strikes more clearly the annual rhythm of rains and landscape.

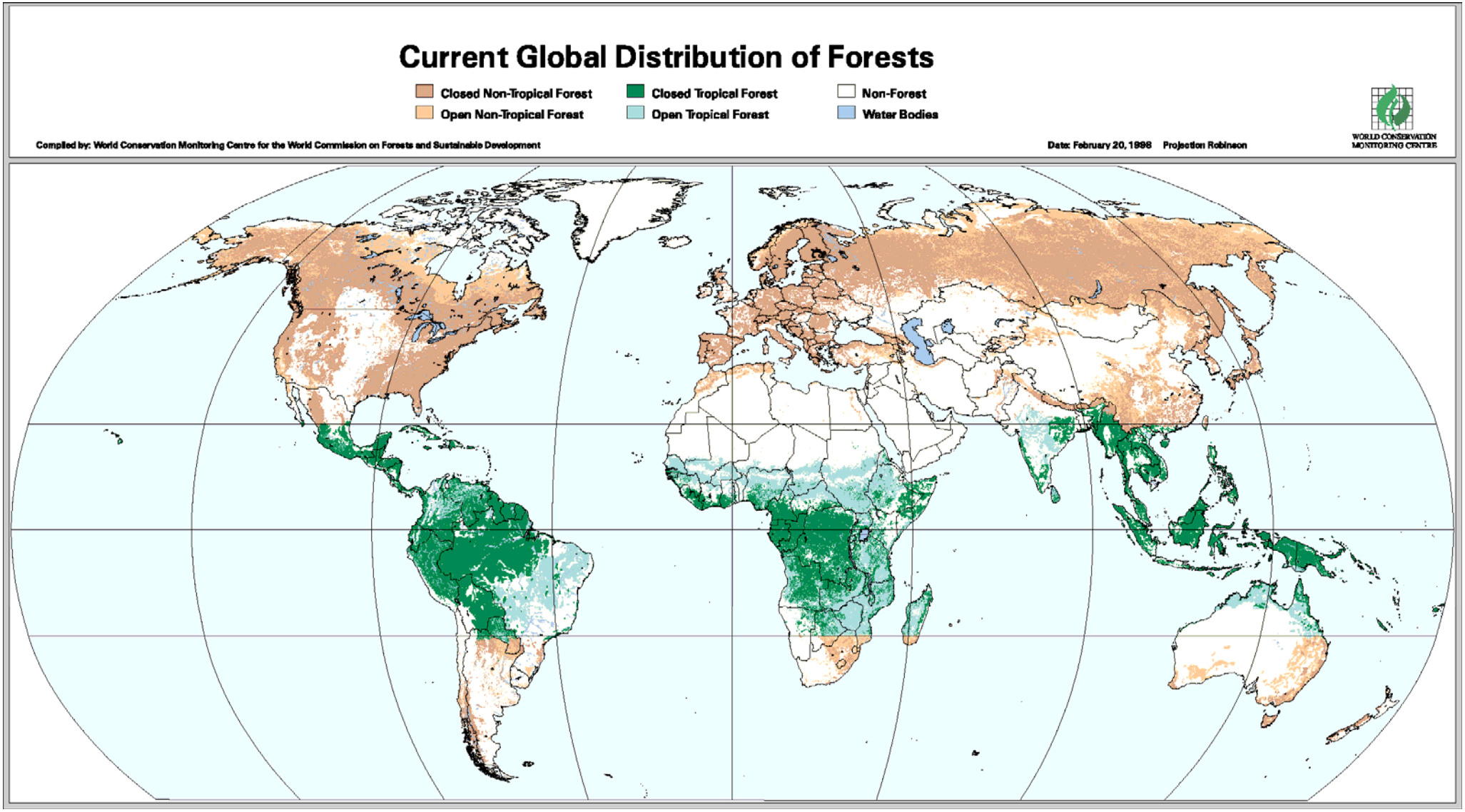
The tropical rainforests grow up in more then fifty countries, from South and Central America, Africa and Southeast Asia, and three countries (Brazil, 33%; Dem. Rep. of Congo, 10%; Indonesia, 10%) concentrates about half of their growing area (FAO, 2001).

In the American continent (Fig.2), the Amazonian forest is outstanding by its extension and by encompassing some relatively undamaged areas, although the tremendous human pressures undergone in the last decades. It is still considered as the world's richest ecosystem in terms of biodiversity (FAO, 2001).

[18] Köppen related the distribution and type of native vegetation to the various climates. In this way, climatic boundaries could be drafted approximated where no climatological data were available.

[19] Grasses and sedges, with open stands of widely spaced trees that are frequently thorny, dominate savannas, which occur widely in Africa and South America. Savannas may result from soil conditions, from periodic fires caused by lightning or set by humans, or from climatic influences (Smith & Smith, 1998).

Fig. 2 - Current Global Distribution of Forests



Source: **World Commission on Forests and Sustainable Development. Available on-line at http://iisd1.iisd.ca/wcfsd/currentforests.htm. Last accessed 11-03-2002**

Moreover, it can be seen one ribbon of forest stretching from the coast of Ecuador, all the way through Central America till the south of Mexico. Likewise in the Atlantic coast of South America, another ribbon stretches from Northeast Brazil to Uruguay (Fig. 2). These two last cases are the clear illustration of how the depredatory exploitation of the forest resources carried out the fragmentation and extreme degradation of the tropical rainforest, in coastal areas.

3 TROPICAL RAINFOREST: ASSETS, GOODS, SERVICES, ENVIRONMENTAL FUNCTIONS AND VALUES

Although its small global extension tropical rainforests play an important role for human well-being in many dimensions. They are multi-functional and provide habitat for human beings, shelter and sanctuary for fauna and flora; they operate regulatory functions of climate and watersheds at local, regional and global levels; and they have significant production functions (Soest, 1998).

3.1 Environment and economy

To attribute a value or put a price on environment is rather difficult and, at the same time, problematic, being this process of valuation frequently reproached for its inherent monetary measure of Nature[20]. But the decision-making process related with the management of natural resources involve decisions of economic kind, and therefore economic value is one possible way to support decisions that involve the justification and the prioritisation of programs, policies, and actions to the environment and environmental services protection or restoration (King & Mazzotta, n.d.). Therefore, valuating the environmental services provided by forests is of prime importance in order to implement strategies for the sustainable management of tropical rainforests, and for allowing the optimisation of benefits and minimisation of negative impacts. In fact, as stated by Camille Bann (1997) "*…Unless the full range of costs and benefits of projects, including their impact on the environment, are fully accounted for, comparisons between options cannot be made fairly. Bad projects may be chosen, and good projects will not get fair consideration…*".

Two kinds of approaches have been used to understand the relationships of economy and environment. On one hand, there is a vision of environment as a free gift, which states that environment "…has no value because it does not represent any materialised labour and therefore, it has no price…" (Marx, 1967)[21]. From this economic theory, it is assumed that Nature, per se, has no value, being only the source of resources to be exploited for production.

In the traditional neoclassical framework predominant in Western countries, the value of a good can be measured only on a market, and normally is the same as the market price. When outside the market, it is assumed, that there is no relevant economic value. The price is related to the costs the producers incur (price of labour and capital and natural resources, when these are traded on a market, and all other intermediate deliveries) in the production process (Straaten, 1996).

[20] Environmentalists frequently refuse to accept this way to measure the significance of Nature. For them Nature is "*…an indivisible national or global heritage about which people hold personal beliefs and convictions, rather than preferences in terms of economic cost or benefit.* (…) [Therefore the values of the environment should be measured through] *biophysical indicators of sustainable development, carrying capacity of particular territories, or flows of materials trough the economy…*" (Bartelmus, 1999b).

[21] In the middle of the 19th century, when Marx wrote the *Capital*, the environment was primarily seen as a medium for human labour. Nature was to be used by humans for their production purposes, and Nature's destiny was to be shaped by human labour.

Therefore, neoclassic economic theory considered that the use of Nature, submitted to the market laws of offer and demand, doesn't create any special problem, since the increasing scarcity of natural resources will promote the growth of their prices, and therefore the search for cheaper substitutes, e.g. human or produced production factors (Bartelmus, 1999a). However, natural resources are provided to consumers frequently at zero price, which doesn't give any reliable indication of a good's relative scarcity. Moreover, since the environmental externalities[22] are not part of the prices paid by producers or consumers, they distort the market by encouraging activities that are costly to society even if the private benefits are substantial. Therefore, this model of Nature exploitation cannot persist since environmental goods and services are not available in infinite quantities.

These two kinds of approach led to a widespread exploitation of natural resources and serious problems of environmental degradation. These environmental problems[23], as well as the energy crisis, of the second half of 20th century led to a new vision of the role of Nature in Economy.

This new approach deals with the concept of Sustainable Development[24], by considering that humanity is an integral part of the Biosphere, which constitutes the only life-support system for our species. The threats to the integrity and functioning of Biosphere affect the quality of human life and, moreover, put in risk the existence of life on Earth. Under this approach, "*…environment provides the economy with raw materials, which are transformed into consumer products by the production process, and energy, which fuels this transformation. Ultimately these raw materials and energy return to the environment as waste products…*" (Tietenberg, 2000).

This implies that there are thresholds at which the levels of stress will lead to the disruption of the exploitation of the natural resources, since no population can live beyond this limits for very long. These thresholds refer to the number of individuals who can be supported in a given area within natural resource limits, and without degrading the natural social, cultural and economic environment for present and future generations. It is the concept of carrying capacity, which is not fixed for any given area. The pressures associated with the growth of

[22] Economic concept of uncompensated environmental effects of production and consumption that affect consumer utility and enterprise cost outside the market mechanism. As a consequence of negative externalities (notably environmental depletion and degradation), private costs of production tend to be lower than its "social" cost. It is the aim of the "polluter/user-pays" principle to prompt households and enterprises to internalise externalities in their plans and budgets by means of economic instruments, including fiscal measures and other (dis)incentives with the purpose of discouraging further damage to the environment, as well as encouraging the search for environmentally sound production and consumption patterns (UNSD, n.d.; Bartelmus, 1999).

[23] Environmental problems result, according to W. Sachs (2000), from two contradictory sets of conditions. On one hand, the success and domination of corporations and consumers of wealthy world "*…dispose of the economic power to mobilise (…) huge amounts of resources, producing pollution, devastation and turbulence in the process. In the second instance, poor people without purchasing power degrade their habitats, after having lost their traditional rights (…) to secure sufficient sources of livelihood…*" (Sachs, 2000).

[24] Among the multiple definitions of Sustainable Development that were composed since the Brundtland Report of 1987, the World Wild Fund defines sustainable development as "…improving the quality of human life while living within the carrying capacity of supporting ecosystems...". Sometimes, associated to this definition is the idea that sustainable economies are only possible if economic growth and population growth are reduced, or even zero (Pearce & Warford, 1993).

population usually reduce the carrying capacity, although the technological changes can increase it[25].

3.2 Valuing environment

Valuing environmental goods and services faces the fact that "*…no market place exists in which their true values can be revealed through the acts of buying and selling…*" (Bann, 1997). Therefore, contemporary environmental economics consider that, far from being a free resource, Nature provides goods and services, which have a positive value and not a zero price, that contributes positively to human well being[26] (Seják, 1994). This economic value is the result of the performance of the following four functions that "*…many people are willing to pay to insure their continued availability…*" (Pearce *et al.* 1989):

1. Supply natural resources to the process of transformation in economic goods;
2. Provide a sink to the wastes of economy;
3. Supply amenities, such as wilderness, landscape, scenic wonders;
4. Support life.

3.2.1 Tropical rainforests environmental functions

In general, the services provided by rainforests can be divided into consumptive (e.g. logging and hunting) and non-consumptive (e.g. bird watching, appreciation of the existence of an ecosystem, flood control, and soil conservation). While consumptive uses can be valued directly based on market prices, it is harder to assign value to non-consumptive uses.

These environmental functions can be defined as "*…the provision of goods and/or services by the natural environment for human use…*" (Braat *et al.*, 1979; de Groot, 1992). Therefore, they represent the benefits to the environment and society, resulting from ecosystem functions[27]. A more detailed classification of these environmental functions was defined by de Groot (1992), which identified a set of thirty-seven functions organised in four categories: regulation, carrier, production and information (Table 1).

[25] However, technology by itself shouldn't be faced as the solution for the problem of going beyond the carrying capacities. According to Bartelmus (1999b) the efficiency provided by technology "*…needs to be reinforced by more or less voluntary restrictions in consumption levels…*".

[26] "…Economic valuations of forest goods and services are based on the notion of willingness to pay which, in turn, is based on the measurement of individuals' preferences, the basis for 'welfare economics'. Willingness to pay is determined by motivations that may vary from pure self-interest to altruism, concern for future generations, environmental stewardship and a concern for other sentient beings…" (Pearce & Pearce, 2001).

[27] Environmental functions are also named environmental services represent the benefits to human population, and should not be confound with ecosystem functions, which concern the habitat, biological or system properties and the physical, chemical, and biological processes that take place between the ecosystems living and non-living components within its defined boundaries, contributing to the self-maintenance of the ecosystem (Costanza *et al*, 1997; Pirot, Meynell, Elder, 2000).

Table 1 - Environmental Functions

Regulation functions	Carrier functions	Production functions	Information functions
Protection against harmful cosmic influences	Human habitation and (indigenous) settlements	Oxygen	Providing aesthetic information
Protection of the local and global energy balance	Cultivation	Water	Providing spiritual and religious information
Regulation of the chemical composition of the atmosphere	Energy conversion	Food and nutritious drinks	Providing historic information
Regulation of the chemical composition of the oceans	Recreation and tourism	Genetic resources	Providing cultural and artistic inspiration
Regulation of the local and global climate	Nature protection	Medicinal resources	Providing scientific and educational information
Regulation of runoff and flood prevention		Raw materials for clothing and household fabrics	
Water catchment and groundwater recharge		Raw materials for building, construction, and industrial use	
Prevention of soil erosion and sediment control		Biochemicals (other than fuel and medicines)	
Formation of topsoil and maintenance of soil fertility		Fuel and energy	
Fixation of solar energy and biomass production		Fodder (animal feed) and fertilizer	
Storage and recycling of organic matter		Ornamental resources	
Storage and recycling of nutrients			
Storage and recycling of human waste			
Regulation of biological control mechanisms			
Maintenance of migration and nursery habitats			
Maintenance of biological (and genetic) diversity			

Source: de Groot, 1992

Although the contribution and benefits of tropical forests to Man and to the Environment shouldn't be emphasised, it is well accepted that tropical forests provide a great multiplicity of good and environmental services. *Regulation functions* express the capacity of the natural and semi-natural ecosystems to provide and maintain a healthy environment with clean air, water and soil and by providing flood control, soil protection, carbon storage and waste absorption. *Carrier functions* concern the capacity of the natural and semi-natural ecosystems to provide space and a substrate to several human activities like habitation, cultivation and recreation. *Production functions* are related with the resources supplied by nature such as raw materials, food, and energetic, genetic and medicinal resources. *Information functions* are associated with the aesthetic values, with the accumulation of practical knowledge about animals and plants that can be used for the development of medicine, agriculture, toxicology, etc., and with cultural values that are a source of inspiration for scientific reflection or fulfil spiritual and religious need of human society.

Tropical rainforests are the habitat for almost half of the 1.7 millions of animal and plant species identified[28] in the planet, which correspond to less than 5% of the actual biodiversity of tropical rainforests. The conservation of this biodiversity not only prevents the loss of genetic resources, which have a market price, but also contributes to increase the resilience of the ecosystem[29].

These forests operate both as sources and sinks of CO_2, being responsible for about 25% of global CO_2 emissions to the atmosphere. Slowing deforestation and promoting forest regeneration and plantation can contribute to decrease these emissions that are in the root of climatic changes. In tropical rainforests is estimate to be stored as much as three times the amount of CO_2 found in atmosphere (WRI, 2000). Rainforests also provide a significant source of energy. In fact some 80% of total energy needs in tropical countries is meet by fuelwood.

These environmental services and the natural capital[30] stocks that produce them have an essential role in the functioning of the Earth's life-support system, contributing directly and indirectly to human welfare, and therefore representing part of the total economic value of the planet (Costanza *et al.*, 1997). However, since many of these goods and services are not traded on commercial markets (not allowing a suitable comparison with economic services), it is not easy to adequately quantify them, turning difficult its fully integration in the process of decision-making. Nevertheless, Costanza *et al*. (1997) estimate an annual average value of 33 trillions of US Dollars[31] for the whole of environmental services (and approximately 3.8 trillions of US Dollars for the environmental services provided by tropical forests) being the global gross national product total around 18 trillions of US Dollars. Therefore if "*…these services were actually paid for, in terms of their value contribution to the global economy, (…) the price of commodities using ecosystem services directly or indirectly would be much greater…*" (Costanza *et al.*, 1997).

However these environmental services can be threatened by the growth of population and the growth of resources consumption, since they put in conflict the short-term needs and long-term societal well-being. Environmental degradation, biodiversity loss, deforestation, and the breakdown of social and economic systems are a few of the signs, which indicate that ecosystems are stressed. According to Costanza *et al*., the increasing stress on natural capital and ecosystem services will turn them increasingly scarce and "*…if significant, irreversible*

[28] Although the total number of species remains unknown, the *Global Biodiversity Assessment* (Heywood, V.H. (ed), 1995) finds that a reasonable estimate is close to 14 million, of which only about 1.75 million species have been scientifically described. (Watson, 1995).

[29] Resilience is the tendency of ecosystems to maintain their integrity when subject to disturbance. C.S. Holling (1973) starting from the basic premise that man is an integral part of the ecosystem, considered that an ecosystem can find itself in different states of equilibrium, each with differing structures and functions. Therefore an ecosystem that has been subject to a disturbance could jump over to a new state of equilibrium with a new structure and new functions. Maintaining the ecosystem's resilience is also preserving it's capability to supply man with the products and services he are dependent upon.

[30] Natural capital is calculated as the sum of the stock value of the following renewable and non-renewable resources: agricultural land, pasture land, timber, non-timber forest benefits, protected areas, oil, coal, natural gas, metals, and minerals (Kunte *et al*, 1998).

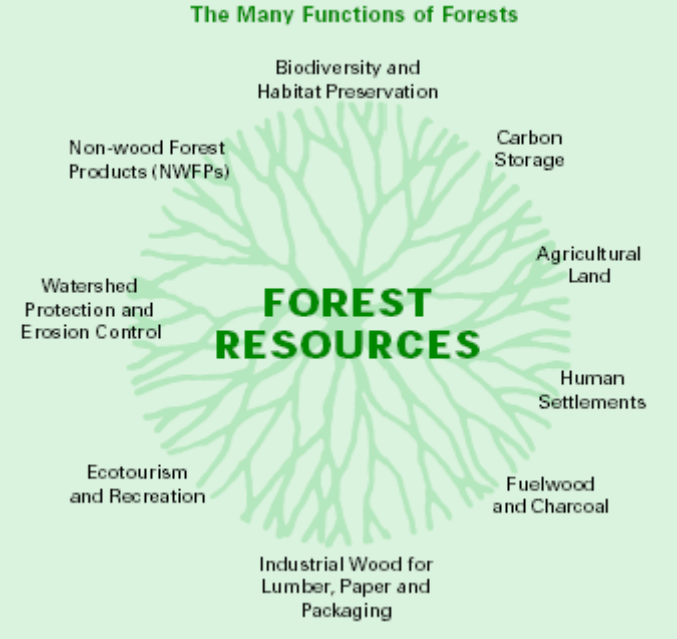
[31] However the authors of this estimate consider that "…despite the many uncertainties included in this estimate, it is almost certainly an underestimate…" (Costanza *et al*., 1997).

thresholds are passed for irreplaceable ecosystem services, their value may quickly jump to infinity…"(Costanza *et al.*, 1997).

3.2.2 Economic values of tropical rainforests

Forests provide a multiplicity of goods and perform a set of environmental services (Fig. 3) that produce benefits and costs (felt at local, national and global levels), which, although the uncertainties, should be valuated. Estimates of forest values [both positive (benefits) and negative (costs)] are useful to the decision-making process.

Fig. 3 - Goods and services provided by forests



Source: Gardner-Outlaw & Engelman, 1999

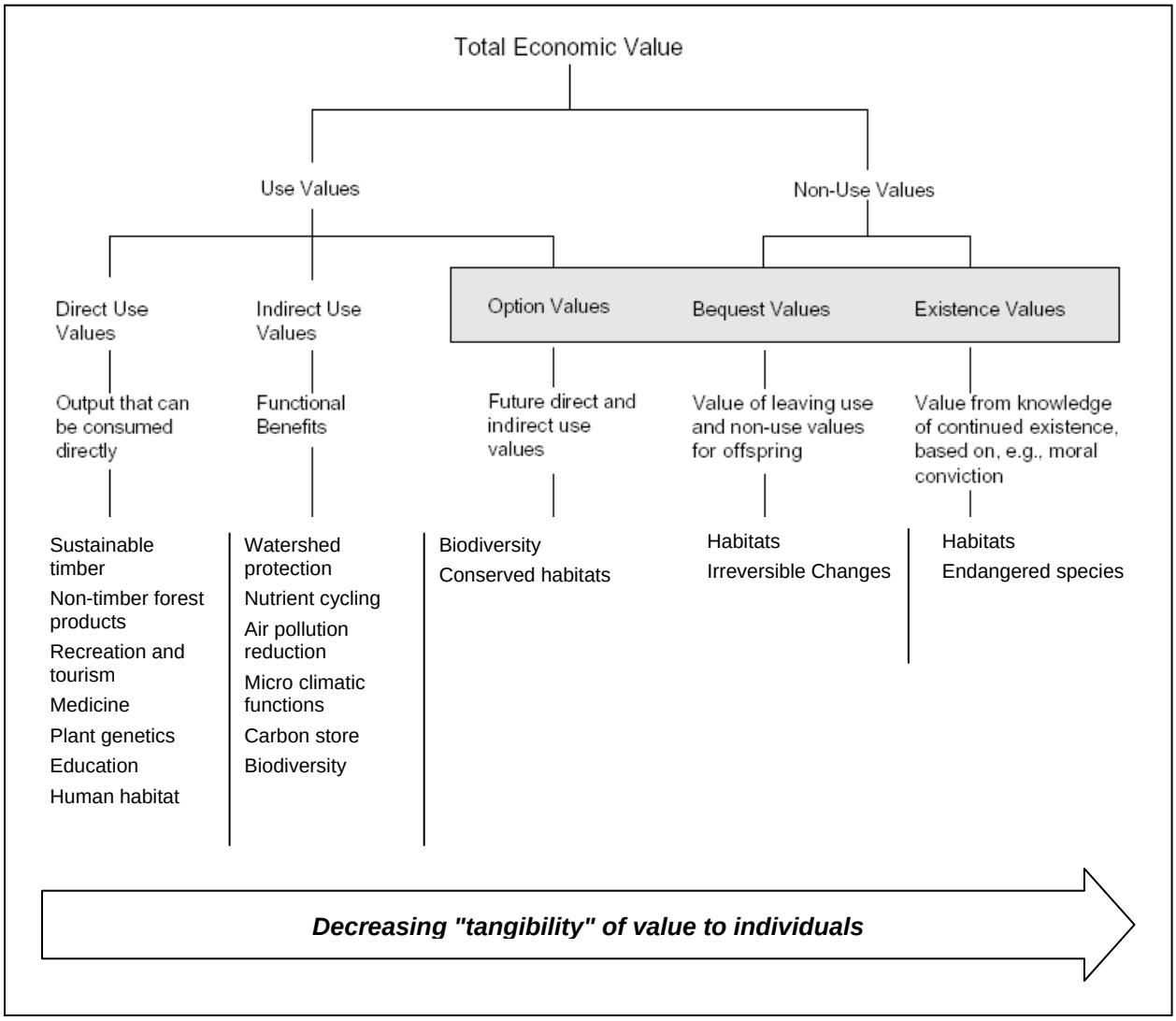
However, in order to guarantee that these values are effective inputs to the decision, mechanisms must ensure that the decision-maker, and those he represents (individuals, companies, local communities or nation), not only capture the benefits, but also will pay the costs that derive from the decision (Gregersen, Lundgren, Kengen & Byron, 1997).

Economic values derive from the availability of the resource, and from the human perceptions of the relative desirability of one set of goods and services against another (i.e. forestry against agriculture, urban settlement or cocoa and coffee plantations). Therefore they are related with the actual or potential uses made of forests (Gregersen, Lundgren, Kengen & Byron, 1997). Furthermore, the economic value of tropical rainforest can be regarded as the extent to which people would be prepared to sacrifice something else in order to obtain or safeguard a quantity of it[32] (Pearce & Özdemiroglu, 2002).

[32] Willingness to pay corresponds to the amount (measured in goods, services, or currency) that a person is willing to give up to get a particular good or service (King & Mazzotta, n.d.).

Although, these values are not absolute, since they change rapidly over time as individual situations and perceptions change[33], some efforts have been made to identify and quantify the non-market values of the goods and services provided by tropical rainforests, by using the concept of total economic value (Fig. 4).

Fig. 4 - Total Economic Value of Tropical Rainforests



Source: Adapted from Barbier, 1991; Hearne, 1996; IUCN, 1998; Bishop (ed.), 1999

Economic value is an anthropocentric concept, being based on human preferences and including notions of intrinsic, cultural, social and spiritual value. Moreover this concept is related with to the goal of maximising human well-being. (Pearce & Pearce, 2001). Total economic value consists on use values and non-use values (Fig. 4), which comprehends (Pearce, 2001):

[33] The premise that these goods and services can be incorporated in the monetary value system trough the surveys of the individuals "*willingness to pay*" (Bartelmus, 1999), requires a sound knowledge of individual preferences (Crocker *et al*., 1998).

- ***Direct use values****: are self-explanatory values, arising from consumptive and non-consumptive uses of the forest, e.g. timber and fuel, extraction of genetic material, tourism.*
- ***Indirect use values****: values arising from various forest services such as protection of watersheds and the storage of carbon.*
- ***Option values****: are individual values of the option of future individual direct and indirect use of a resource. They reflect a willingness to pay to conserve the option of making use of the forest even though no current use is made of it*
- ***Non-use values*** *are the personal value attached to the bequest to future generations of both use and non-use values (bequest values). They can be also existence values, which are the personal values for goods to individuals who have no expectation of receiving any tangible benefits from the goods.*

The values of tropical rainforests are associated with the benefits felt at local, national and global levels, which are not mutually exclusive but depend on who captures those benefits. (Gregersen, Lundgren, Kengen & Byron, 1997):

- **Local** benefits generally refer to goods and services that are benefiting directly the user of the forest, such as the fuelwood used or sold by a family; fruits, nuts, and other non-timber products collected by a community for sale or own consumption; timber harvested and sold by a logger; the recreation experience of an individual.
- **National, state or provincial** benefits refer to watershed protection benefits, wildlife habitat benefits, some biodiversity protection benefits. They are manly captured beyond the local forest user, and can be accrued internationally.
- **Global** benefits refer mainly to those received by individuals living outside the sovereign nation producing them, but in any case potentially by anyone: carbon sequestration.

4 RAINFOREST LOSSES

The loss of forest cover encompasses the concepts of deforestation and forest degradation that must be presented. Of course, as stated above, these concepts are depending on the concepts of forest, and therefore any change in the later definition implies changes in the concept of deforestation and forest degradation.

According to FAO (2001a) deforestation consists on "*…The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold…*". This unified definition expresses a different concept from the one adapted before by this United Nations organisation, which was distinct to developed and to developing countries (FAO, 1997). On the other side, forest degradation corresponds to the "*…changes within the forest that negatively affect the structure or function of the stand or site, and thereby lower its capacity*[34] *to supply products and/or services…"* (FAO, 2001a).

According to FAO, deforestation implies the long-term or permanent loss of forest cover by its transformation into another land use, and it is caused either by natural disturbances or human activities. Unless the clearing of the remaining logged-over forest follows logging, these areas are not considered as deforested, because, in accordance with FAO, there are conditions to the natural development of the secondary forest since the clearings are not maintained through continued disturbance[35].

Natural causes of deforestation include hurricanes, floods, drought pests and fires, among others. Until the middle of the 20th century the luxurious tropical rainforests covered the greater part of equatorial regions of the planet, reaching about 10% of the forests of the world (Blij, H. J. & Muller, P. O., 1998). However, the development model[36] followed by the countries in these regions, encouraged by international institutions that released the investments needed, generated a intense process of deforestation, aiming at the construction of new urban/industrial settlements, road networks, intensive exploitation of forest resources, establishment of new areas for agriculture and cattle breeding, which give way to an intense destruction of thousands of millions of trees.

Tropical rainforest has provided, from centuries ago, humans with shelter, food, drink, medicines, building materials, clean water, scents, colorants, etc. Human actions are causing the shrinking of tropical rainforest over the last millennia "*…forest clearance for agriculture has been going on since at 3000 BP*[37] *in Africa, 7000 BP in South and Central America and possibly since 9000 BP or earlier in India and New Guinea…*" (Goudie, 2000).

About half of the forest that was present under modern (i.e. post-Pleistocene) climatic conditions, and before the spread of human influence, has disappeared, largely through the

[34] It should be remarked that, as the definition states, the productive capacity of the forests isn't related solely with the capacity to produce timber, but also to the environmental services provided by forests.

[35] Therefore, these areas are defined as temporarily unstocked areas.

[36] This development model is defined (using the north countries standards) by high levels of consumption and access to consumer goods, which require increasing resource consumption and transformation., which are promoted by the economic, political, social, and cultural structures that shape our world (Stedman-Edwards, 1997).

[37] The B.P. following the date means "before present". By long standing convention, "present" is defined as A.D. 1950 on radiocarbon dates.

impact of man's activities[38]. The spread of agriculture and animal husbandry, the harvesting of forests for timber and fuel, and the expansion of populated areas have all taken their toll on forests. Nowadays, only less then half of actual forest cover remains in its original state (Mathews *et al.*, 2000). However, the causes and timing of forest loss differ between regions and forest types, as do the current trends in change in forest cover (UNEP-WCMC, 2000).

4.1 Distressing trends of deforestation

Scientists can't still indicate accurate rates of the retreat of tropical rainforest induced by human intervention, mainly because is rather difficult to precisely determine the original extent of the forest prior to human impact[39]. It is only possible to estimate, through climatic conditions, the areas where forest could potentially exist if it were not human actions (WRI, 2000).

Some of the figures showing the rates of loss of trees in the tropical rainforest are so distressing[40] that clearly forecast an environmental catastrophe, with local and global magnitude. In accordance with N. Myers (1989) every second in the world registers the loss of one hectare of tropical rainforest, corresponding to about 31 millions of hectares per year. In consequence of these tremendous rates of destruction, the natural forest cover continues to decrease in all countries of South and Central America. A total sum of about 4.4 millions of hectares per year was lost during 1990-2000, resulting in a 5% total loss for the period (FAO, 2001). However, it is important to integrate these catastrophic figures of forest loss in a context of some uncertainty. In fact, there isn't an universally accepted definition of deforestation and, as Andrew Goudie (2000) states, "*…there are very considerable difficulties in estimating rates of deforestation, in part because different groups of workers use different definition of what constitutes a forest and what distinguishes rainforest from other types of forest…*" (Goudie, 2000).

However some studies Estimate "*…that preagricultural closed forests once covered about 46.3 million km^2, and that this total had decreased to 39.3 million km^2 by about 1970, a decline of 15 percent…*" (Matthews, 1983). Global rates of forest-loss increased from about 12 million hectares per year in the 1970s to over 15 million hectares (0.8 percent of total natural forest cover) per year in the 1980s, which seems to be the period with higher rates of deforestation. In the first half of the 1990s deforestation continued at about 13 million hectares per year (Watson *et al*., 1998).

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[38] According with Matthews *et al*. (2000) "*…given the difficulty of estimating preagricultural forest cover, and continuing uncertainty about current forest cover, it can be said that approximately one fifth to one half of the world's forest cover has been converted to other uses since preagricultural times…*".

[39] At least 26 attempts were made between 1923 and 1985 to estimate the world's forest cover. These estimates range from 24 million km^2 to 65 million km^2 (Matthews *et al*., 2000), being the different quality of the national inventory data and the different criteria to define forestland, the main responsible for the great span of the results.

[40] Although, in the beginning of the 1970's some warnings were made (Denevan, 1973), it was in the 1980's that the most alarming rates started to be presented to the global community and, in certain manner, used to constrain the international institutions to make the issues of the forests and deforestation a global priority. This process had to wait by the 1990's to be explicitly discussed in the international forums (Smouts, 2001).

The recent estimates of FAO concerning forest loss (FAO, 2001a) are a tentative for increasing the accuracy to assess the forest area change[41]. Between 1990-2000, the natural forest in tropical areas has reduced at an average net annual rate of 12.3 millions of hectares[42], showing that in the nineties the forests continued to be converted to other land uses at a very high rate. According to FAO the estimated net loss of forest was lower in the nineties than in the eighties (when it was 15.4 million of hectares per year), owing this mainly to a higher rate of expansion of forest area.

Globally the annual rate of forest loss in 1990-2000 is 0.23%, about 9 million hectares per year (Table 2). These estimates should be carefully analysed since it seems impossible to completely compare the different assessments because there were changes in definitions, changes in methodology and updated inventory information (FAO, 2001a). This is a reason to the great criticism of several ONG to these figures. In a briefing note from the WRI, (Matthews, 2001) are discussed the ways to "*understand the Forest Resources Assessment 2000*". According to this author, if plantations are excluded the absolute global forest loss may possibly reach 16 million hectares per year and tropical forest loss may actually have increased in the 1990s compared to the 1980s.

Table 2 - Rates of forest loss

Region	1990 Forest area (x 1000 ha)	2000 Forest area (x 1000 ha)	Absolute annual change 1990-2000 (x 1000 ha)	Annual change1990-2000 (%)
Africa	702 503	649 866	- 5 264	- 0.78
Asia	545 827	542 116	- 371	- 0.07
Oceania	201 992	201 163	- 83	- 0.04
Europe	1 030 804	1 039 513	+ 871	+ 0.08
North and Central America	555 003	549 306	- 570	- 0.10
South America	910 478	874 194	- 3 628	- 0.41
World	**3 946 608**	**3 856 159**	**- 9 045**	**- 0.23**

Source: FAO, 2001; Pearce, 2001

However, FAO considers that there is reasonable evidence that the net rate of forest loss has decreased, at the same time that natural forest loss in the tropics appears to be accelerated. Being the less intense net decrease related with the growth of forest plantation areas, mainly in south-east Asia, where there is still an enormous rate of forest loss (Smouts, 2001; FAO, 2001). Whatever the correct interpretation, it is clear that tropical forest loss, due to its negative environmental impacts, remains a matter of concern.

[41] The Forest Resources Assessment 2000 (FAO, 2001) used two independent means to assess forest area change in the nineties: data calculated from the information supplied by countries, and of the pan-tropical remote sensing survey (FAO, 2001a).

[42] In non-tropical areas the average net annual rate of change indicates an increase of 2,9 millions of hectares.

4.2 Forest / Men interactions

Is commonly accepted by governments and international agencies that tropical deforestation is the result of poverty, under-development, and over-population. Usually slash-and-burn farmers are considered the most important agents of deforestation, together with loggers, miners, fuelwood collectors[43] and rural communities. Although these small farmers, as well as their families, exploit forests in unsustainable ways in search of means of subsistence, they are also victims of the deforestation process: "*…prisoners of illiteracy and endemic poverty, and driven by the lack of access to arable lands and the lack of alternative employment opportunities, subsistence farming families must survive by clearing the forests to plant their crops.*…" (Roper & Roberts, 1999).

Poor farmers are the principal and direct agents of deforestation as they move into the forest for survival, however which are the causes that drive them into the forest areas? Why these poor farmers have been deprived of land or other means of subsistence? Why government policies and international agencies promote and even subsidise new settlements in tropical forests? One of the answers to these questions is probably related with the lack of land or the right to secure the land of these farmers, and therefore with an inequitable distribution of agricultural land.

For centuries, the rate of loss of forests on temperate regions (first, for intensive small-scale agriculture and, more recently, for commercial farming) exceeded the rate of natural regeneration of vegetation, inducing an extreme deforestation of these regions. In the Middle Age, the negative effects of deforestation in France were so evident that an embryo of forestry code was then written, establishing some regulations for the management of the forests (Smouts, 2001). According to this author, nowadays, the "South" countries would be living a similar moment. The tropical forests would accomplish a role in their economies equivalent to the role played by the European forests in the Middle Age. However, if the trees of these forests are being cut-down, that is the result from the demands of the world markets and the needs of foreign currency to accomplish the development of these countries.

By different methods and for different reasons, we can see in our time that men in tropical regions are cutting down, burning, or otherwise damaging the forests. The causes of these actions are complex and result from the combination of immediate and underlying; local and global; internal and external driving forces. A. Goudie (2000) summarises the causes of tropical rainforest destruction (Table 3).

In the last millennia men has been associated with the rainforest. First as hunters-gatherers, hunting the animals and gathering the fruits, roots, tubers, leaves, bark and wood. Their impacts were reduced, allowing the natural regrowth and restoration of the forest (Smith & Smith, 1998).

[43] Fuelwood gathered from the forested lands is the most important source of domestic energy in the rural areas of many developing countries, according to Hall *et al*. (1993) corresponds nearly to 40% of energy consumption in these countries. Fuelwood collection and consumption not only causes resource degradation but also leads to fuelwood scarcity.

Table 3 - Causes of tropical rainforest decrease

A. Immediate causes - land use

1. Shifting agriculture
(a) Traditional long-rotation shifting cultivation
(b) Short-rotation shifting cultivation
(c) Encroaching cultivation
(d) Pastoralism

2. Permanent agriculture
(a) Permanent staple crop cultivation
(b) Fish farming
(e) Government sponsored resettlement schemes
(d) Cattle ranching
(e) Tree crop and other cash crop plantations

3. Mining

4. Hydroelectric schemes

5. Cultivation of illegal narcotics

B. Underlying causes

1. Socio-economic mechanisms
(a) Population growth
(b) Economic development

2. Physical factors
(a) Distribution of forests
(b) Proximity of rivers
(c) Proximity of roads
(d) Distance from urban centres
(e) Topography
(f) Soil fertility

3. Government policies
(a) Agriculture policies
(b) Forestry policies
(c) Other policies

Source: Goudie, 2000, based on Grainger, 1992

The impacts of the shifting-cultivators[44], which have a system of agricultural production based on the slash-and-burn technique, were absorbed as long as the population were not large. As C. Geertz remarked already in 1963, this type of activity was "*…integrated into, and when genuinely adaptive, maintains the general structure of the pre-existing natural ecosystem…*" (quoted by Goudie, 2000). Unfortunately this system often disrupts (by the lack of the adequate long fallow period), especially when the growth of population increases the pressures on the land, which start to degrade, leading also to significant disturbances in the local social groups.

However, the great offensive to the forest resources begun with the European colonial rule and the intensive exploitation of hardwood timber, the clearance of the forest for grazing land and agricultural land, and its conversion to sugar cane, coffee, cocoa, rubber and palm plantations. The demands of the "North" markets for hardwood have significantly reduced some species, and have driven others to the edge of extinction. Nevertheless, according to Smith & Smith (1998), logging is not the biggest problem, since the secondary forest[45] can grow back. The key issue is that the damages on the residual vegetation, resulting from the road building and heavy machinery, causes soil erosion. Moreover, the new roads open up, for new settlers, areas until then inaccessible.

The increase of the accessibility and a perception of great productivity of tropical rainforest soils, attracted millions of peasant farmers, which could purchase the land at low price (Blij & Muller, 1998), driving to the clear of the remaining trees for cultivation, but rapidly transforming these new fields in unproductive, and almost irreversibly shrub land and grasslands (Smith & Smith, 1998). The tropical soils are very poor, the arable layer is thin and the organic nutrients are lacking. Without the protection of the vegetation, the soils rapidly are

[44] Norman Meyers (1992) shaped the expression "shifted cultivator" to describe the peasant farmer who has left his traditional farm lands in search of new opportunities on forest lands.

[45] When humans abandon an area of rainforest that has been cleared for cultivation or timber exploitation, the forest begins to regenerate; but for an extended period of years this secondary forest is very different in character form the forest it replaces (Goudie, 2000).

exhausted, loosing the nutrients, and the heavy rains, which are brief but very frequent, trigger intense processes of erosion that can culminate (specially in the regions where the dry season is more significant) in the formation of superficial hard cuirasses of iron.

Intensive, or modern, agriculture occurs on a much larger scale, sometimes deforesting several square kilometres at a time. Large cattle pastures often replace rain forest to raise beef for the world market. More recently, mining, hydroelectric schemes and cultivation of illegal narcotics have being responsible for the cutting of trees on tropical rainforest.

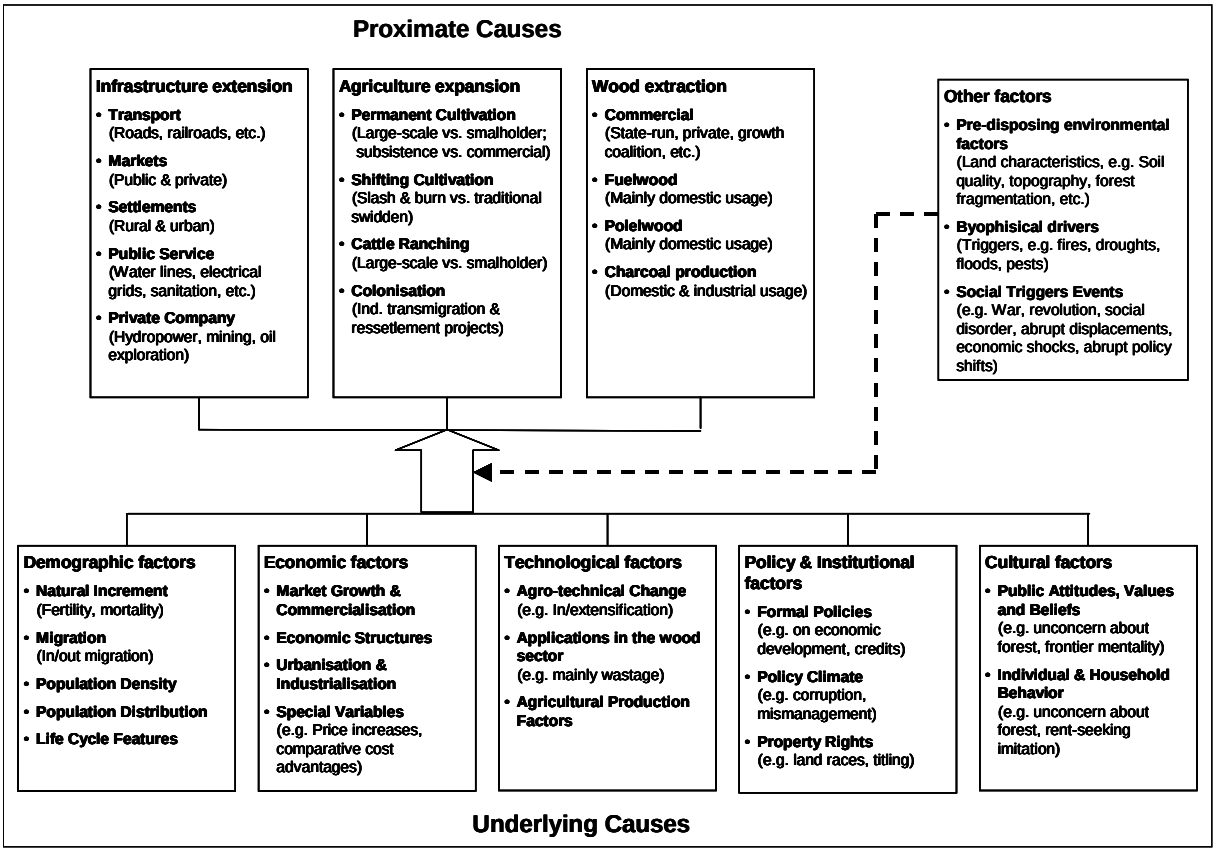
4.3 Underlying and proximate causes of deforestation

Tropical forests are being depleted as the result of different causes, having significant impacts on environmental global change. However, although the progresses made in the last decades, there isn't definite knowledge about the factors (their intensity and regional variability) that drive deforestation. Causes of tropical deforestation cannot be reduced to a single variable, or to a few variables even. The different factors are always closely interlinked and the relationships among them are complex. A recent study on tropical deforestation causes reached the conclusion that "*…tropical forest decline is determined by different combinations of various proximate causes and underlying driving forces in varying geographical and historical contexts. Some of these combinations are robust geographically (such as the development of market economies and the expansion of permanently cropped land for food), whereas most of them are region specific…*" (Geist & Lambin, 2001). Establishing the underlying and proximate causes of tropical deforestation, as well as their diverse linkages (among each other and with the geographic context), constitutes a very significant issue in the analysis of forest issues. Geist & Lambin (2001) present a set of five broad types of underlying causes of tropical deforestation, which are related with socio-economic processes that drive the immediate human actions, which have direct impacts on forest (Fig. 5).

From the exhaustive analysis of 152 case studies in all the realms of tropical forest, Geist & Lambin (2001) conclude that changes related with the extension of overland transport infrastructure, commercial wood extraction, permanent cultivation, and cattle ranching, are the proximate causes most associated (96%) with cases of deforestation. Contrary to widely held views, shifting cultivators, per se, are not the key agents of deforestation. They are often associated with timber logging and road construction. The interconnected economic, institutional, cultural, technological and demographic factors seems to be the most significant underlying cause that drives the human activities responsible for tropical deforestation.

Although one can see some beneficial effects deriving from a conversion of a forestry land use to a more productive one, the great problem is related with the fact that most of the forest land was converted into other type of land use that it isn't in balance with its carrying capacity, contributing to rapidly degrade the soil (Roper & Roberts, 1999). Moreover much of the human-induced deforestation is, in varying degrees, economically wasteful and environmentally negative, as well as socially undesirable, and very often, just a few individuals benefit (Contreras-Hermosilla, 2000).

Fig. 5 – Underlying and proximate causes of tropical deforestation



Source: Adapted from Geist & Lambin, 2001

5 STRATEGIES OF SUSTAINABLE MANAGEMENT OF TROPICAL RAINFOREST

The continued existence of poverty, at global scale, indicates the failure of current economic growth models, and reducing poverty is one of the main goals of contemporary societies. However, the ways to achieve this goal still lack a consensus. At the same time, environmental problems are frequently explained by the combined effects of "*…poverty, population growth, indebtedness, the international trading structure, misguised multilateral aid policies, and environmentally insensitive private foreign investment…*" (Pearce & Warford, 1993).

Nowadays, the concept of Sustainable Development has inscribed in itself the linkages of economy and environment because the societies base their growth in the extraction, transformation and consumption of natural resources. In fact, "*…environment provides the economy with raw materials, which are transformed into consumer products by the production process, and energy, which fuels this transformation. Ultimately these raw materials and energy return to the environment as waste products…*" (Tietenberg, 2000).

According to the Brundtland Report (World Commission on Environment and Development, *1987) "…Sustainable development seeks to meet the needs*[46] *and aspirations of the present without compromising the ability to meet those of the future…*". This model of development should be based on patterns of production and consumption that can be pursued into the future without degrading the human or natural environment. The benefits of economic activities should be equitably shared by all members of society in such a way that improve human well-being and reduce poverty.

To achieve the goals of sustainable development it is comprehensible that "*…economic growth must remain a legitimate objective of national governments and the world community…*" (Pearce & Warford, 1993)[47]. Nevertheless, it is clear now that the former models to pursuit economic growth, which don't give the adequate consideration to the environment, are unlikely to be sustainable. In fact it is important, at the same time man develops technology, which can enlarge the limits of the carrying capacity of ecosystems, to reduce, by means of effective policies, the patterns of consumption and to adapt practices of conservation of natural resources (Bartelmus, 1999b).

Moreover, in a context of economic globalisation it is clear that the linkages of economy and environment, as well as the environmental impacts, are not limited by the boundaries of nation states. Therefore, it is assumed that to correct and to solve the environmental problems it is necessary, not only, to correct the economic distortions associated to the inequity of the distribution of benefices resulting from the uses of natural resources, but also to achieve better/innovative processes to engage individuals and institutions, at global and/or local level, in governing themselves.

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[46] According to Pearce & Warford (1993) the term "needs" can be replaced by well-being or welfare, implying that nutrition, education and health should be top priorities in any development plan.

[47] According to the Brundtland Report "…far from requiring the cessation of economic growth (sustainable development) recognises that the problems of poverty and underdevelopment cannot be solved unless we have a new era of growth…" (WCED, 1987).

In our days the systems that society has developed for governing itself, which are generally based in the nation state, become increasingly complex, and it seems necessary to discuss the basic structures of governance[48], in order to manage the conflicting and changing economic, social and environmental requirements of modern governance systems. Moreover, individuals, households and communities are seeking greater control over their own destinies, while the boundaries between the public and private spheres are continually shifting. According with Pearce & Warford (1993), the accession to this sort of control involves the clear definition of property rights in the environment, the incentive for natural resources conservation, the realignment of prices by turning them closer to the social costs of production, which implies the need to assign an economic value[49] to the environmental goods and services.

Therefore, governance arises as a key issue to the implementation of sustainable development. It is an approach / process to understand and describe the systems, networks, practices and dynamics of governing. However, the creation of appropriate institutions to promote socio-economic equity and environmental sustainability is one of the great challenges that society faces today. These new institutions should be able, by the participation of all legitimate stakeholders, to allocate rights and enforce responsibilities for environmental management at the appropriate level: local, national, regional or global.

Governance refers also to the indispensable promotion of constructive interactions among the different levels of governing. It includes "*…the state, but transcends it by taking in the private sector and civil society (…). The state creates a conducive political and legal environment. The private sector generates jobs and income. And civil society facilitates political and social interaction…*" (UNDP, 1997). Also the increasing transboundary impacts of environmental degradation imply the recognition of the need for cross-national cooperation.

Thus, global governance doesn't mean global government. This could only reinforce the roles and powers of states and central governments. In opposite, is focusing on people participation, as individual and collective social actors, in the processes of decision-making related to the accomplishment of the basic values of sustainable development.

The challenge of preventing further losses of tropical forests lies in finding a balance between the multiple ecological, economic, social and cultural services provided by trees, forests and forest lands that meets the needs of current and future generations.

People in forests are increasingly seen as part of the solution to forest management, instead of being seen as part of the problem, efforts to manage forests without local support usually fail.

[48] In the definition of UNDP (1997), governance is "…the exercise of political, economic and administrative authority in the management of a country's affairs at all levels. Governance is a neutral concept comprising the complex mechanisms, processes, relationships and institutions through which citizens and groups articulate their interests, exercise their rights and obligations and mediate their differences...".

[49] Economic values derive from the availability of the resource, and from the human perceptions of the relative desirability of one set of goods and services against another. The premise that these goods and services can be incorporated in the monetary value system trough the surveys of the individuals "willingness to pay" (Bartelmus, 1999), requires a sound knowledge of individual preferences (Crocker et al., 1998). Therefore, these values go beyond the traditional market values of goods and services.

Ideas of participation, co-management and insider-driven initiatives have gained important support.

The issue of sustainability assumes crucial proportions when confronted by the challenges of environmental degradation and rural impoverishment. Forest management should contribute to poverty alleviation, and that natural resources should be used to improve the quality of human life while living within the carrying capacity of supporting ecosystems. Without poverty alleviation, the environment in developing countries will continue to degrade, and without sustainable forest management strategies, poverty alleviation will be undermined (Gow, 1992).

Forestry is uniquely positioned to make a major contribution to addressing the problems of environmental degradation and rural poverty, given the multiple roles that trees can play in the provision of food, the generation of income and the maintenance of the natural resource base.

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