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DIAGNOSIS OF THE NATURAL RESOURCES OF AMAZONIA

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DIAGNOSIS OF THE NATURAL RESOURCES OF AMAZONIA

The purpose of this paper is to give a broad outline of the natural resources of the Amazon area. Hopefully, this will be made easier thanks to some of the following presentations during this Symposium, which take particular resources in more detailed consideration. To approach meaningfully such a wide subject in a short lapse of time one has to adopt some kind of integrating principle. In the present case this paper will have a strong ecological bias, emphasizing the importance of environmental quality as a natural resource per se, necessary for the stability of economic production systems.

The Amazon river basin has an approximate area of 7,000,000 square kilometers, including de catchment areas of the rivers Tocantins and Araguaia. The Amazon rain forest is smaller, with about 5,500,000 square kilometers, but overlap to a great extent with the hidrographic basin, extending itself out of it to the north in Venezuela, Guiana, Surinam and French Guiana. 60% of the Amazon forest lies in Brazil, and the remaining area is distributed among Bolivia, Peru, Ecuador, Colombia and the above mentioned countries. The so called "Amazônia Legal" in Brazil is an administrative division of the country established for purposes of regional development through fiscal incentives. Its area is about 5,000,000 square kilometers (60% of the country) and includes vast areas of savannas ("cerrados") and transition forests.

Obviously, if one considers the extension of the Amazon forest, which is about half the size of Europe (10,236,511 square kilometers), one can see what are the potentialities of this region in just territorial terms.
However, the situation is completely different if one compares the human population. While in Europe the population density may lie around 140 inhabitants per square kilometer, in the Amazon this number is less than 3, and about half of the inhabitants live in the few larger cities and towns, and the remaining people are dispersed in villages and isolated huts, mostly along the rivers. Presently, there are about 100,000 indians living in the Brazilian Amazon forest, belonging to approximately 100 different tribal groups. Before the European conquest they may have been 1 or 2 million or even more. About 200 different languages have been identified until the beginning of this century.

With such continental dimensions, the Amazon region conceals, under an apparently homogeneous physiognomy, a

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remarkable variability in geology, soils, rivers and lakes, forests, even climate, but particularly in the geographic distribution of plants and animals. Many surveys and inventories of natural resources have been made to date. The most comprehensive one certainly is the PROJETO RADAM survey, now extended to the whole area of Brazil under the denomination RADAMBRASIL. With the help of the technique of side looking radar imagery, complemented by ground studies, all Brazilian Amazon area has been surveyed for its geology, geomorphology, soils, vegetation, forestry and agronomic potential (DNPM, 1979).

CLIMATE

The climate is typically equatorial, very regular during the year, but with a marked tropical tendency, characterized by the intercalation of a short dry season of 2 to 4 months, particularly along a wide strip joining Roraima to Central Brazil, with the city of Santarém in the middle. The dayly variation of temperatures, of a few degrees, are greater than the variation among the monthly means. The annual mean is 26 oC. The annual rainfall is mostly above 2000 mm.

GEOLOGY AND RELIEF

The Amazon basin is formed by two cristaline shields bordering the northern and southern margins, respectively the Guiana shield and the Brazilian shield, of Precambrian age (more than 600 million years); to the west it is bordered by the Andean mountains, originated at the beginning of the Terciary (70 million years) by the folding and lifting of marine deposits. The depression between those more ancient features was filled during the Terciary with sediments of fluvial and lacustrine character. These thick layers of Terciary sediments were deposited on top of Paleozoic sedimentary formations, 200 to 500 million years old, strips of which emerge between the Precambrian shields and the Terciary sediments north and south of the Amazon river valley east of Manaus.

During the Quaternary, in the last million years, the Amazon river and its tributaries formed deep and wide valleys during the glacial periods, when the ocean level was much lower than now, and during the pluvials, when the ocean level goes up as in the present time, these rivers filled their valleys with new sediments, originated principally from the Andean mountains, forming very extensive alluvial plains (so called "varzeas" in the Brazilian Amazon area).

Though most of the Amazon basin lies under 200 metres above sea level, it is in this region that is situated the Pico da Neblina, the highest point of Brazil (3014 metres). The most general geomorphologic units correlate basically with the geologic structure described above: 1) alluvial plains, formed by recent sediments, periodically flooded, and pleistocenic terraces, formed when the water levels of the rivers were a few metres higher than now; 2) Amazonian plateau, with maximum altitudes of 200 metres, formed by the clayey and sandy Terciary sediments; most of these land surfaces are strongly compartimented by the drainage system of small forest streams or larger autochtonous rivers; several terrace levels may be present; 3) cristaline shields to the north and south of the sedimentary basin, strongly pediplained to the same level as these, so that the contact between both is marked only by the fall zone of the tributaries of the Amazon river; altitudes generally above 200 metres.

MINERAL RESOURCES AND FOSSIL FUELS

The variety of geological environments just described for this large region, indicate the great potentiality of the Amazon area for deposits of the more important minerals, and also fossil fuels.

According to SANTOS, B.A., 1981, the climatic conditions prevailing during the last millennia resulted in an expected high proportion of residual deposits, in which the weathering and leaching of the rocks concentrate the economically important metallic elements, like iron, manganese, aluminum, nickel and titanium, in superficial or subsuperficial deposits.

Another type of mineral deposit highly favored under the same conditions are the eluvial and alluvial deposits, in which physically and chemically more resistent minerals are concentrated along river beds and sedimentary land surfaces. The typical examples are gold, cassiterite, columbite-tantalite and diamonds.

This potential has been broadly confirmed, and several of these deposits are already under economic exploitation, like the iron ore in the huge mineral province of Carajás, the bauxite deposits in river Trombetas, the cassiterite in the river Pitinga, north of Manaus, and the many gold washing sites ("garimpos"), the better known and most dramatic example being Serra Pelada.

Concerning the fossil fuels, the Brazilian oil company PETROBRÁS has confirmed the estimated occurrence of 30 billion cubic metres of recoverable dry natural gas (methane) in the river Juruá, 750 kilometers southwest of Manaus.

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In 1986, the same company discovered for the first time petroleum and natural gas with a commercial potential in a Paleozoic sedimentary basin, along the river Urucu, 650 kilometers southwest of Manaus. The basin may attain the area of 100 square kilometers. The potential recoverable volumes are 20 million barrels of oil of excellent quality ("oil in place" being 110 million barrels), 15 million barrels of condensed gas and 20 billion cubic metres of rich gas. The commercial exploitation of the oil has already begun, with an actual production of 4500 barrels/day through 10 wells.

SOILS

Under an equatorial or tropical climate, the high temperature and rainfall cause the complete weathering of the rocks and clay minerals, together with the leaching of the bases, forming deep soil profiles, well drained, reddish or yellow, and of low fertility (SÁNCHEZ, P.A, 1981). Two orders of soil with these general characteristics predominate in the Amazon (COCHRANE, T.T. and SÁNCHEZ, P.A., 1982): 1 - Oxisols, with an excellent physical structure, uniform properties along the whole profile and very low natural fertility; they occur in 45% of the Amazon. 2 - Ultisols, characterized by a horizon B with clay accumulation, agronomically less favorable physical properties and low natural fertility; they occur in 30% of the Amazon.

The remaining area is occupied by different orders of soils, particularly by well drained, fertile soils in non-flooded areas, spodosols (white sands) and alluvial soils of different orders, some very fertile (Table 1).

In Table 2 there is a summary of selected soil fertility parameters of the Amazon basin, indicating that most soils present agronomic restrictions. Contrary to a very common generalization, however, according to which Amazon soils once cleared will irreversibly harden into plinthite or laterite, only about 4% of the whole Amazon present soils with plinthite in the subsoil that can be hardened when exposed after erosion.

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Table 1. Soil distribution of the Amazon region at the order level.

Order	Million hectares	% of Amazon
OXISOLS	219.9	45.4
ULTISOLS	141.7	29.3
ENTISOLS	72.0	14.9
ALFISOLS	19.8	4.1
INCEPTISOLS	16.0	3.3
SPODOSOLS	10.5	2.2
MOLLISOLS	3.5	0.8
VERTISOLS	0.5	0.1
Total orders	484.0	100.0

Source: Adapted from COCHRANE and SÁNCHEZ, 1982

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Table 2. Summary of selected soil fertility parameters of the Amazon.

Parameter and range	Topsoil (0-20 cm) Million ha	%	Subsoil (21-50 cm) Million ha	%
Soil pH:				
< 5.3	392.2	81	398.9	82
5.3-7.3	91.2	19	84.7	18
% Organic matter:				
< 1.5	43.9	9	405.2	84
1.5-4.5	357.8	74	77.8	16
> 4.5	81.9	17	0.4	-
% Al saturation:				
0-10	81.8	17	96.2	20
10-40	37.9	8	49.8	8
40-70	78.4	16	39.4	8
> 70	285.3	59	298.0	61
Exch.Ca (meq/100g):				
< 0.4	222.5	46	349.4	72
0.4-4.0	159.7	33	81.3	7
> 4.0	101.2	21	52.8	11
Exch.Mg (meq/100g):				
< 0.2	185.6	38	356.8	74
0.2-0.8	185.8	38	84.3	18
> 0.8	112.1	23	42.1	9
Exch.K (meq/100g):				
< 0.15	298.8	62	439.1	91
0.15-0.30	113.7	24	37.9	8
> 0.30	71.1	15	6.5	1
ECEC (meq/100g):				
< 4	80.0	17	193.4	40
4-8	238.5	49	210.1	44
> 8	165.2	34	80.1	16
Avail. P (ppm):				
< 3	276.9	57	414.6	86
3-7	159.1	33	54.6	11
> 7	47.7	10	14.4	3
P fixation:				
High	77.3	16	-	-
Low	406.3	84	-	-

Source: Adapted from COCHRANE and SÁNCHEZ, 1982

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BIOTIC RESOURCES

The tropical rain forests of the world may concentrate in about 7% of the surface of the continents, 40% or more of all species of organisms (WILSON, E.O., 1988).

The fact that 2/3 of the about 1,400,000 described biological species occur in extra-tropical region (WOLF, E.C., 1987), mostly in the northern hemisphere, results from the much more intensive research effort in Europe and North America. All surveys of the most different groups of organisms, with very few exceptions, point to the above cited proposition.

The insects are the more numerous (with about 875,000 described species) and less known taxonomic group, the estimates going up to 30 million or even more (ERWIN, T., 1983). Other invertebrates (about 120,000 described species) could also easily reach more than one million species. The higher plants (250,000 described species) could attain the number of 400,000 species. Among the vertebrate animals, the fishes (19,000 described species) are the more numerous and less known group, with about 10% of the species to be discovered by science; one believes that only in the Amazon and Orinoco river basin the number of 2000 described species can be doubled. The other vertebrates, like the reptiles and amphibians, the mammals and particularly the birds are quite well known to date, with prospectively about 5% of the species to be described (WILSON, E.O., 1988; WOLF, E.C., 1987).

The total number of biological species in the biosphere may, therefore, range between 5 million to 30 million, depending on the accuracy of the insect estimate. Half or even more, depending on the insects, of these live in tropical rainforests, of which the Amazon forest represent 1/3.

THE FOREST ECOSYSTEM

All these physical and biotic components interact with each other in different spatial and temporal scales, forming environmental systems, ecosystems or more extensive landscape systems. The ecological questions which concern the Amazon nowadays need to be put in the right perspective, in face of these very different scales; the deforestation process, for instance, may have global or regional climatic effects, but it must also be considered, on a more local basis, from the poit of view of its ecological and economic viability as a method of converting the forest in distinct production systems.

The Amazon forest, through its evapotranspiration and also through its soil protection function, has a very important role in the control of the water cycle of the largest hidrologic basin in the world. This subject, however, will be presented in more detail by Professor E. SALATI later on during this Symposium.

Still on a global scale, the Amazon forest is a reservoir of carbon, and its extensive conversion to agroecosystems of smaller biomass than the forest could contribute to the worsening of the "green house" effect. A calculation made by FEARNSIDE, P.M., 1989 indicates, however, that if the whole area of the Brazilian "Amazônia Legal" were converted to pastures, then 50 billion metric tons of carbon would be liberated to the atmosphere. This is only ten times the size of the annual emission due to the burning of fossil fuels, greatly concentrated in the industrialized nations.

The soils of the Amazon were shown above to be predominantly of low fertility, that means, low reserves of mineral nutrients. These are to a large part stored in the biomass of the forest ecosystem, being constantly recycled with a remarkable efficiency. This can be ascertained through the many results of hidrochemical analyses of Amazonian autochthonous streams and rivers, including the large Rio Negro, which have acid waters with very low cationic content, sometimes equivalent to the composition of rain water.

This efficiency in cycling nutrients has been correlated by several authors with the intriguing biodiversity of the forest ecosystem (SCHUBART, H.O.R. et al., 1984). In one hectare of forest there may be 100 to 250 species of trees, depending on the lower diameter of the trunk chosen as the sampling limit. Compare this number with the 50 species of trees in whole France ! Complementary to this plant matrix there is another one extremely diversified of herbivore insects, pollinators, as well as their predators and parasites (GILBERT, L.E., 1980). The same could be stated in relation to the birds and other vertebrates which explore differentially in space and time the nutritional resources produced by the forest (EISENBERG, J.F., 1980). The biotic community of the soil is also extremely complex and has a key role in the process of breakdown, humification and mineralization of the leaf litter (LUIZÃO, F.J. & SCHUBART, H.O.R., 1987). Nitrogen fixation by bacteria and other microorganisms; the more efficient absortion of phosphorous by mycorhizae, that is, the symbiotic association of certain fungi with the roots of higher plants; all these coevolved ecological interactions contribute, together, to the efficiency of nutrient cycling by the forest ecosystem. Figure 1 summarize some possible feedback loops which could explain the origin and maintenance of the high biodiversity in very humid tropical forests.

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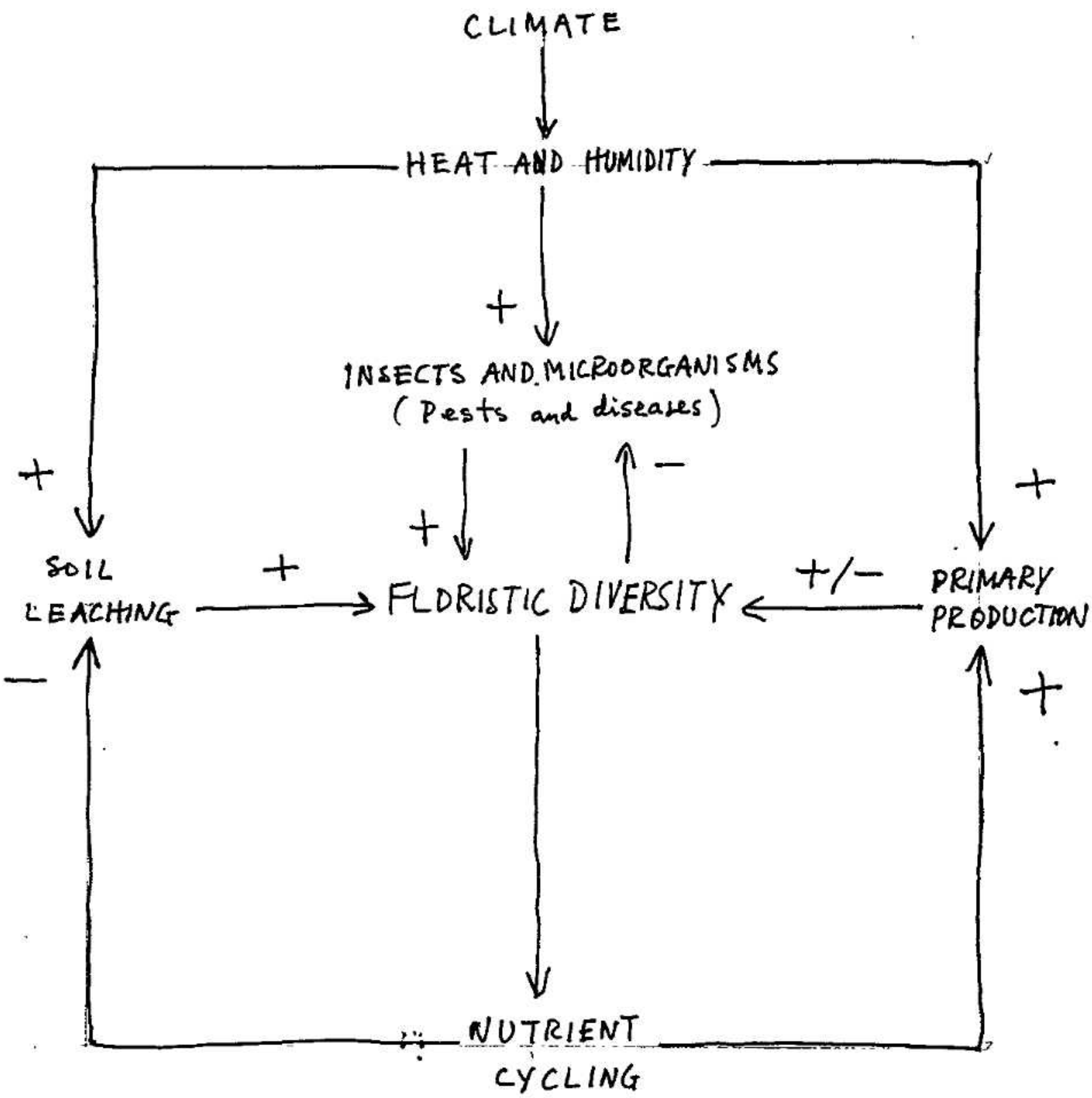

FIGURE 1

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RIVERS AND LAKES

The Amazon basin participates ~~contributes~~ with nearly 20% of all freshwater of the Earth. In Brazil, which depends to 90% on hidraulic power to produce its electricity, the inventoried hidroelectric potential of the Amazon basin represents 45% of the potential of the whole country. There is also a high potential for fisheries and fluvial transportation. The hydric resource of the Amazon, therefore, is of paramount importance for the countries which have a share in the basin.

The Amazon river has its headwaters in the Andean mountains and, as a result of the erosion process, it brings sedimentable clay minerals to the valley, rich in nutrients and with agronomically very favorable chemical properties. The quite large areas of alluvial soil formed by the sedimentation of this material are very fertile. The waters in the lakes formed along the floodplains of the Amazon river have a neutral pH and high electric conductivity. This large wetland ecosystem has, therefore, a very high biological primary and secondary productivity, and most important of all, if correctly managed can be ecologically very stable due to the fact that the system is receiving nutrients from an external source.

The autochthonous rivers, like the Rio Negro, on the contrary, have as already noted above, very acid waters and low conductivity, which results in low primary and secondary productivity. Nearly the same can be said of the rivers originating in the Precambrian shields in Central Brazil, like the Tapajós, Tocantins, Xingu etc., all of which have clear waters. The outstanding difference is in the load of fulvic and humic substances which gives the characteristic black color to the autochthonous rivers.

CONCLUSION

The potential of renewable and nonrenewable resources in the Amazon area is very large indeed. However, the exploitation of these resources are coupled with potentially very serious ecological hazards, so that a very carefull planning of the process, and a much higher level of governmental and private investments in environmental protection and research should be made.

For instance, the hydric resources, including ~~of~~ hydroelectricity, could be ruined by erosion and modification of the hydrologic cycle as a result of bad forest and soil management. A very serious problem is already being faced in certain areas due to siltation of rivers and mercury contamination resulting from the precarious gold washing methods being used.

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The Amazon forest is not only a source of raw materials like hardwoods, and food, but is also a very rich source of technologically relevant information, particularly in the areas of pharmacology, chemistry, biotechnology, ecology, genetics etc.

It is recognizably very expensive to read this information and to put it in the service of society. This job can be very much facilitated through the cooperation with the indigenous people, who have imbeded in their culture a remarkable knowledge of forest resources and their utilization. In this sense, it is a real tragedy that our society is not only burning the library, but also obliterating the culture of the people who have the litteracy to read it.

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