AMAZONIAN TROPICAL FORESTS: CARBON SOURCE OR SINK?

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The Amazon Basin contains a wide range of ecosystems and a wealth of biological and ethnic diversity. It includes the largest extent of tropical forest on Earth, over 5 x 10^6 km^2, and accounts for an estimated one fourth of the planet's animal and plant species. Currently, only few species are used by man. The region is abundant in water resources. Annual rainfall is 2.3 m on average and the mean outflow of the Amazon River into the Atlantic is approximately 220,000 m^3/s, which corresponds to 18% of the total flow of fresh water into the world's oceans. The region stores over 100 Gton of carbon in vegetation and soils. However, over the past 30 years rapid development has led to the deforestation of over 550,000 km^2 in Brazil alone. Current rates of annual deforestation are in the range of 15,000 km^2 to 20,000 km^2 for Brazil, according to figures of INPE (2001) based on Landsat satellite-derived analyses. The spatial pattern of deforestation in Brazilian Amazonia up to 1997 is illustrated in Figure 1.

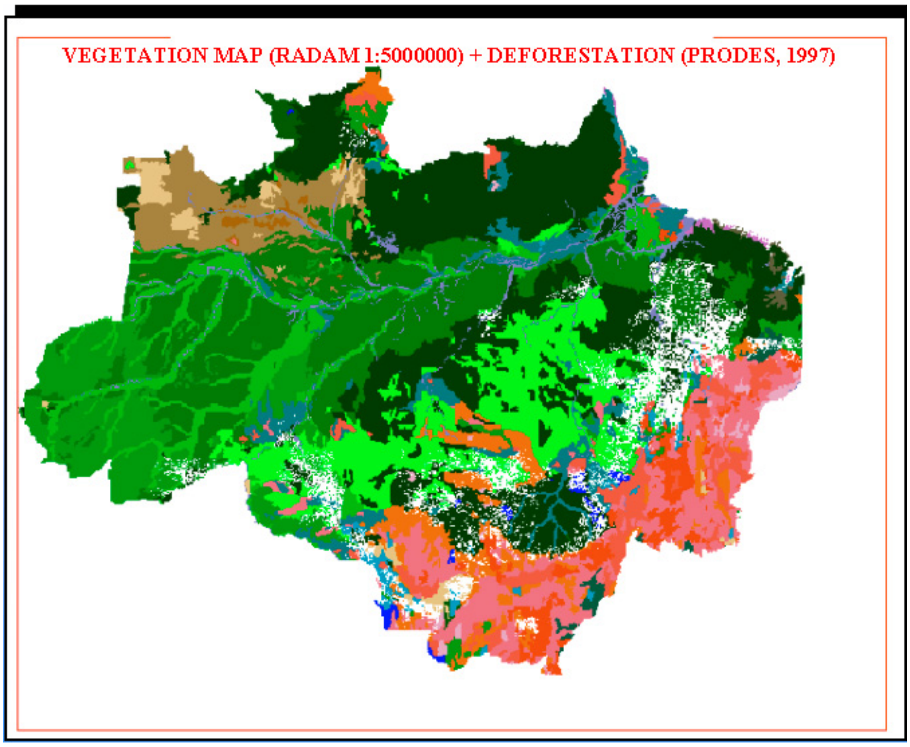

Figure 1. Analysis of spatial deforestation patterns *from 1978* to 1997 (in white) in Brazilian Amazonia superimposed on a vegetation map. Courtesy of R. Alvala and E. Kalil, INPE, Brazil.

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A number of field studies carried out over the last 20 years showed that deforestation and biomass burning caused significant, but still localized changes in the water, energy, carbon and nutrient cycling, and in the atmospheric composition. For instance, the forest is important in recycling water vapor through evapotranspiration throughout the year, thus contributing to augmented rainfall and to its own maintenance.

1. CARBON EMISSION AND ABSORPTION

An important impact of land use and land cover change in Amazonia with global consequences, are the emissions of carbon dioxide due to deforestation and biomass burning. The total annual emissions of CO_2 in Amazonia due to land use and land cover change range between 150 and 250 Mton C (Houghton et al., 2000). In comparison, the total annual emissions of CO_2 arising from fossil fuel combustion is only about 75 Mton C for Brazil as a whole. On the other hand, carbon cycle studies of the Large Scale Biosphere-Atmosphere Experiment (LBA) and forest inventory studies (Phillips et al., 1998) indicate that the undisturbed forest may represent a sink of carbon at rates ranging from 0.8 up to a high value of 7 ton C ha^{-1} yr^{-1} (Malhi et al., 1998; Malhi et al., 1999; Araujo et al., 2002; Nobre et al., 2000). All of the observational evidence put together is shown in Figure 2, which is a preliminary ‘synthesis’ of our rather incomplete knowledge of the carbon cycle in Amazonia. The `sink strength` is not less than 0.8 to 1.5 ton C ha^{-1} yr^{-1}. For the forested areas of the basin, that might represent a net uptake of carbon of 0.3 to 0.6 Gton C yr^{-1}. Subtracting averaged emissions of 0.2 to 0.3 Gton C yr^{-1}, the net basin uptake would range from 0 to 0.4 Gton C yr^{-1}.

However, it is still uncertain whether at a regional scale, the forest functions as a sink or source of carbon to the atmosphere (Keller et al., 1997). Recent data suggest that emissions of CO_2 from rivers, streams and wetlands may be much higher than previously thought, contributing to about 1 ton C ha^{-1} yr^{-1} (Richey, 2002).

Overall, if the result of the undisturbed forest behaving as a carbon sink is confirmed with further research, it would shed some new light on the role of the tropical forests in the global carbon balance. The carbon sink function could then be considered as an additional environmental service provided by the forest.

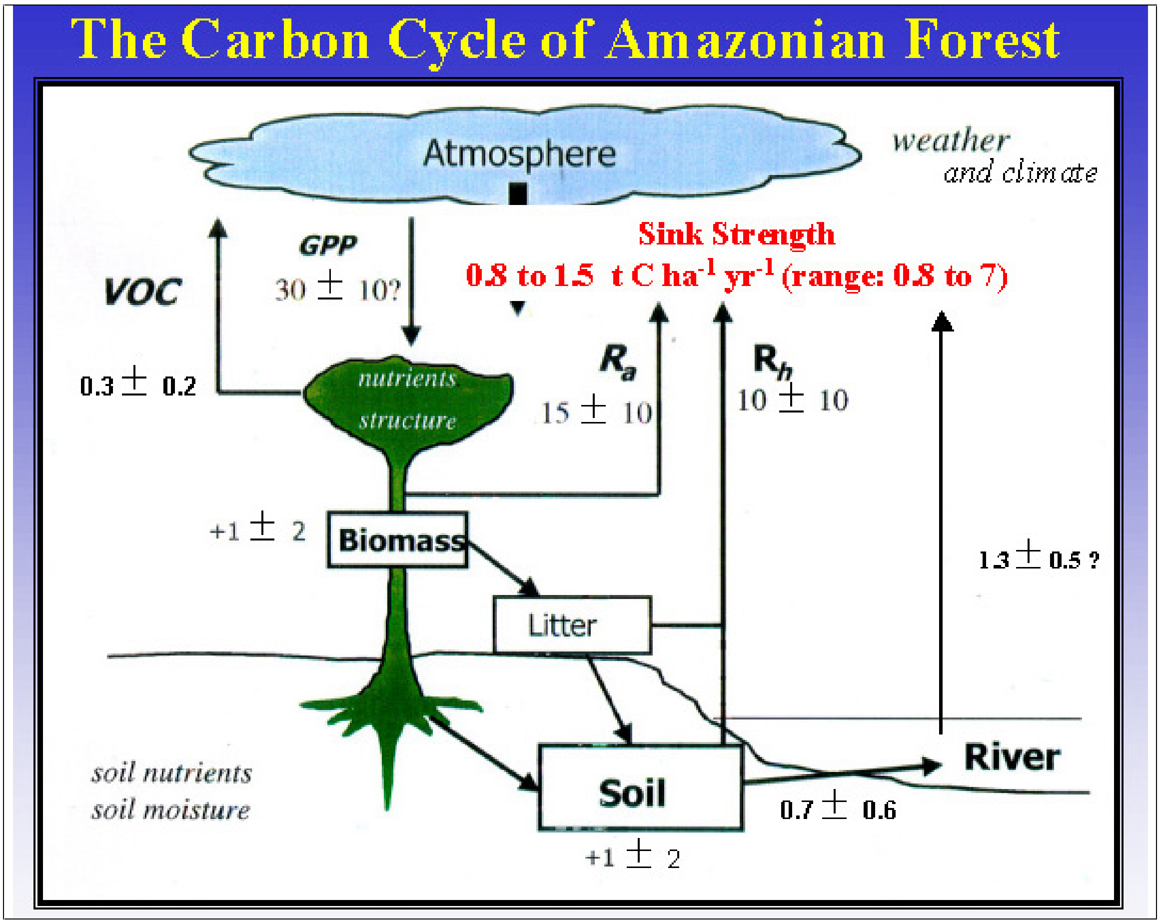

Figure 2 Preliminary synthesis of the carbon cycle for Amazonian forests as derived from LBA studies. Units: t C ha^{-1} yr^{-1}. *GPP*= gross primary productivity; R_a= autotrophic respiration; R_h=heterotrophic respiration; *VOC*= volatile organic carbon compounds.
Source: Alterra, INPA, IH, Edinburgh University, INPE, CENA-USP, Univ. Washington, Univ. California-Santa Barbara, Max Planck Institute for Biogeochemistry.

2. REFORESTATION PROJECTS VERSUS FOREST PROTECTION

Forestry projects in the Amazon Basin can be used in different ways for purposes of carbon sequestration and emission reductions. There is a huge potential for reforestation projects in Brazilian Amazonia: over 200,000 km^2 of land is currently abandoned and/or in degraded state. An ongoing project in Juruena, northern Mato Grosso State may illustrate the costs involved and benefits derived from reforestation activities. In this case, 5,000 ha are reforested using a mix of 20 native species, with a total cost of US$ 12 million over 40 years and a total of 600,000-750,000 ton carbon stored. At 120 to 150 ton C, the costs per ton of carbon sequestered are US$ 16 – 20.

At present, forest protection activities are not included under the Clean Development Mechanism. The following hypothetical example may however show that avoided deforestation has a clear potential as a carbon emission reduction measure. A reduction of 15% to 20% of the annual deforestation rate in Brazilian Amazonia would represent about 3,000 km^2 of forest protected and a total emission reduction of 30 - 40 Mton carbon per year. An estimated reforested area of 40,000 to 50,000 km^2 would be necessary to assimilate this amount of carbon (at growth rates of 6 to 9 ton C ha^{-1} yr^{-1}); it would take decades to implement reforestation projects of this magnitude. In fact, this is why avoiding deforestation could become in the future as important or even more important than reforestation and afforestation as a measure to mitigate carbon dioxide emissions.

It can be questioned of course, whether it is feasible to reduce deforestation rates in Brazilian Amazonia by 15% to 20%. In this respect, an interesting case is provided by the State of Mato Grosso, which shows a trend of decreasing deforestation rates over the last four years. From 1998 to 2001, the reduction in annual rates was about 30%. The combination of rigorous law enforcement, the use of modern technology of remote sensing and GIS to make law enforcement more effective, and educational programs may explain this trend.

3. SCENARIOS OF ECOSYSTEM CHANGE

An important scientific question is whether this possible biotic CO_2 sink will saturate sometime this century due to the global warming, that is, the undisturbed forest could become a source of carbon due to rapid decomposition of soil carbon under increasing temperature. Scenarios of climate change due to global warming indicate a climate 4 to 6 °C warmer for Amazonia towards the end of the century (Carter & Hulme, 2000). This pronounced warming can have severe impacts in terms of ecosystem change. There are suggestions that climate change may lead to drastic changes in the vegetation of Amazonia, primarily a tendency for its “savannization” (Cox et al., 2000). Massive deforestation may result in a similar tendency (Nobre et al., 1991). It is also becoming increasingly evident that forest fragmentation due to selective logging and other land use changes are making the forest more susceptible to fires (Nepstad et al., 2000). This susceptibility would increase further under a warmer climate. The result may be an increase in forest loss due to uncontrolled forest fires, such as the largest forest fire in Brazilian history, which from January through March 1998 burned 14,000 km^2 of forest in Roraima.

4. CONCLUSIONS

On the balance of observational evidence, tropical forests in Amazonia may play a significant role as a carbon sink of excess atmospheric carbon dioxide. Avoided deforestation must be regarded as an important contribution to reducing global emissions.

5. ACKNOWLEDGMENTS

I want to express my gratitude to all of the scientific community of the LBA Experiment. Their diligent work is enhancing significantly the knowledge basis of Amazonia and ultimately this will prove essential to the sustainable development of Amazonia. This paper is partly based on a presentation at the IGBP Open Science Conference, Amsterdam, July, 2001.

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