ENVIRONMENTAL SERVICES AS A BASIS FOR THE SUSTAINABLE USE OF TROPICAL FORESTS IN BRAZILIAN AMAZONIA

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ABSTRACT

Deforestation is rapidly converting Brazil's Amazon forest to unsustainable land uses such as cattle pasture. Deforestation greatly diminishes the forest's environmental services such as maintenance of biodiversity, water cycling and carbon storage. These services are worth much more to human society than are the land uses that replace the forest, but mechanisms are currently lacking to convert these values to monetary flows. The biodiversity and carbon storage services are global, while water cycling supplies precipitation to all of Brazil, including population centers such as São Paulo. The forest is seriously threatened by deforestation, fire and by projected precipitation and temperature changes from unmitigated global warming. Atmospheric concentrations of greenhouse gases must therefore be kept at relatively low levels (well below 550 ppmv). Negotiations on defining the maximum permitted level of atmospheric CO_2 are about to begin. It is in Brazil's interest to use its diplomatic weight to obtain agreement on a level that assures maintenance of Amazonian forest. It is also in Brazil's interest for mitigation measures to include carbon credit for maintaining tropical forest, and to take rapid measures to contain deforestation.

1. DEFORESTATION, SUSTAINABLE USE AND ENVIRONMENTAL SERVICES

Deforestation is advancing rapidly into the Amazon forest. Most clearing activity is concentrated in the "Arc of Deforestation" along the southern and eastern edges of the forest. However, highways opening previously inaccessible portions of the region to the entry of population and investment have tremendous potential for unleashing the deforestation process in new areas (*e.g.*, Laurance *et al*., 2001). Much of the deforestation process is outside of government control. The BR-163 Highway (Cuiabá-Santarém) offers a current example (Fearnside, 2005a).

Deforestation is driven both by "old" motives such as land speculation and the role of deforestation in maintaining land-tenure claims, and by "new" drivers such as soybeans and beef production for export. The "new" drivers are added on to the "old" ones – the "old" ones are not replaced, although actors may be physically displaced to new locations in the region (Fearnside, 2005b).

Use of tropical forests in Amazonia has been characterized by a long history of failures in terms of sustainability. Sustainability is different from financial profitability and is also not necessarily synonymous with minimal environmental impact. Cattle pasture is by far the most widespread land use in deforested areas in Brazilian Amazonia. The poor record of sustaining pasture productivity has not impeded the spread of ranching, which is driven by various alternative motives in addition to beef sales (notwithstanding the recent arrival of the "hamburger connection" that has given beef sharply increased importance). Small-scale commercial farming (as envisioned for settlement areas on the Transamazon Highway and in Rondônia) has also proved ephemeral, as have monocultures of cacao, rubber and oil palm. Questions persist regarding large-scale high-input agriculture (such as soybeans), timber management and silvicultural plantations. Extractive reserves for non-timber forest products are potentially sustainable, but require linking to the environmental benefits of the forest if they are to resist conversion to logging and agriculture.

This author has proposed a development strategy in the region based on tapping the environmental services of Amazonian forest (Fearnside, 1997). Amazonian forest provides a series of environmental services to the Amazon region, to the rest of Brazil and to the world as a whole. These services include the maintenance of Biodiversity, water cycling and carbon stocks (Fearnside, 1999, 2000, 2004). This could provide a sustainable alternative to the current destructive land-use patterns, in addition to other benefits. Progress towards obtaining monetary flows has so far been greatest for the forest's role in mitigating global warming.

2. WATER CYCLING

The vast area of Amazon forest in a continuous block gives the forest a role in water cycling that is greater than in other tropical forest areas in the world. Due to the rotation of the Earth, the trade winds enter the region from its northeastern edge, bringing water vapor from the Atlantic Ocean. This water falls as precipitation. A portion of this rainfall is recycled through the trees as evapotranspiration, after which the water either falls again as precipitation in the Amazon region or is exported to other regions. When forest is converted to pasture, the percentage of water that runs off over the surface increases by as much as a factor of ten (Fearnside, 1989). The runoff water enters the streams and descends to the Atlantic Ocean via the Amazon River—it is not recycled.

The quantities of water are enormous. An estimated 10×10^{12} m^3 of water enters the region annually in the trade winds, while the annual flow of the Amazon River at its mouth totals only 6.6×10^{12} m^3 (Salati, 2001). The difference, or 3.4×10^{12} m^3, must be exported to some other region. This volume of water is almost equal to that seen at the "meeting of the waters" where the Upper Amazon (Solimões) River and the Rio Negro join near Manaus (3.8×10^{12} m^3/year). The water-recycling function of the forest is important in the transport of water across the region: annual rainfall totals 15.1×10^{12} m^3 (or 50% more than the total that enters the region from the Atlantic Ocean. This high rainfall is the result of evapotranspiration, which totals 8.4×10^{12} m^3/year (Salati, 2001). The percentage of rainfall derived from recycled water increases from east to west across the region, and by the time it reaches the foot of the Andes 88% of the water has fallen twice as precipitation (Lettau *et al*., 1979). The water vapor exported from the region, which occurs at its western edge, therefore depends heavily on recycled water.

Water vapor from Amazonia falls as rainfall in all of Brazil, as well as in neighboring countries such as Argentina (Eagleson, 1986). Transport occurs by means of the South American Low-Level Jet (SALLJ), a wind that blows intermittently at a certain altitude (1-2 km). After the east-west air flow hits the Andes Mountains, the SALLJ turns south and east, moving into the La Plata River basin (Proyecto SALLJEX, 2003). This wind blows at intervals, and, depending on the season of the year, carries water vapor from only the southern portion of the region (June, July and August) or from the entire region (December, January and February) (Nicolini *et al*., 2002).

Rainfall in São Paulo depends heavily on this water vapor source. December, January and February is the rainy season in São Paulo, and is precisely the period when the role of Amazonia is at a maximum (see Fearnside, 2004). This is the period when hydroelectric reservoirs fill during a critical few weeks at the peak of the summer rains—if these rains fail, the reservoirs would not fill. It should be remembered that in 2001 the entire non-Amazonian portion of Brazil suffered blackouts and electricity rationing (the "Apagão") due to lack of water in these reservoirs. In 2003 both Rio de Janeiro and São Paulo were within 15 days of lacking drinking water—if the beginning of the rainy season had been delayed by two weeks, serious social consequences would have resulted. In other words, water supply in São Paulo and other areas of south-central Brazil is already at its limit.

If the Amazon forest is converted to a vast cattle pasture, much of this water would be lost as surface runoff that flows to the Atlantic Ocean via the Amazon River, rather than being recycled and transported to central-south Brazil.

3. CARBON STORAGE

The Amazon forest stores a large amount of carbon, the element that makes up 50% of the dry weight of the trees. Carbon is also stored in the soils under the forest. When deforestation occurs, much of this carbon is released to the atmosphere as carbon dioxide (CO_2) and as methane (CH_4), contributing to global warming. While globally most (approximately 70%) of anthropogenic greenhouse gas emissions come from fossil-fuel combustion and cement manufacture, the remainder (approximately 30%) is released by land-use change, especially deforestation. In terms of Brazil's emissions, deforestation releases the great majority (roughly 80%). Emissions from Amazonian deforestation are a concern both because of the current annual releases that result from the high deforestation rates in Brazil, and because of the substantial potential future emissions represented by the carbon stocks in forest that is still standing.

The amounts of greenhouse gases emitted by Amazonian deforestation have been a longstanding source of controversy. A series of official estimates has suggested emissions substantially lower than those calculated by this author (see Fearnside, 2000b). The claim that Brazil's Amazon deforestation emits only 1.4% of the world's CO_2 emissions, made shortly before the "Earth Summit" (ECO-92 or UNCED) held in Rio de Janeiro in 1992 (Borges, 1992) is about one-third the level of emissions at that time as calculated by this author. The low estimate was the result of only counting biomass that burns immediately upon deforestation, omitting emissions from decay of unburned wood and from burnings subsequent to the initial one.

Shortly before the Kyoto Conference in 1997 (which produced the Kyoto Protocol), the Brazilian government announced that the country had zero emissions from Amazon deforestation because the "carbon is reabsorbed" (IstoÉ, 1997). This was the combined result of counting only the initial burn and of assuming a wildly exaggerated absorption of carbon by "plantations" in the deforested areas. Unfortunately, the degraded cattle pastures that occupy most deforested areas in Brazilian Amazonia are succeeded by secondary forests that grow quite slowly (Fearnside, 1996; Fearnside and Guimarães, 1996).

Brazil's National Inventory of greenhouse-gas emissions, released in Buenos Aires in December 2004 at the 10th Conference of the Parties of the United Nations Framework Convention on Climate Change (UN-FCCC) claims that Brazil's Amazonian deforestation released an average of only 117 million tons of carbon per year over the 1988-1994 period (Brazil, MCT, 2004, p. 147). This author's comparable estimate for the same period is 252 t C/year, a discrepancy of 115% (updated from Fearnside, 2000a). Much of the difference stems from omitting the carbon in such forest components as roots and dead biomass, as well as unrealistically high estimates of carbon absorption by the replacement landscape (see Fearnside and Laurance, 2004).

The question of whether and how the global warming mitigation benefits of avoided deforestation should be credited under the Kyoto Protocol has been the source of a lengthy controversy (see Fearnside, 2001). A short-lived program of deforestation control in the state of Mato Grosso demonstrated the capacity of government actions to affect large-scale trends and emissions, which is a key factor in making commitments to avoided deforestation potentially feasible (Fearnside, 2003; Fearnside and Barbosa, 2003). Current proposals for including avoided deforestation in the 2013-2017 second commitment period of the Kyoto Protocol include the compensated reduction initiative (Santilli *et al*., 2005). Much progress has been made in developing means of assessing baselines and in quantifying carbon benefits from avoided deforestation (Schlamadinger *et al*., 2005, nd).

4. THREATS FROM CLIMATE CHANGE

Climate change represents a serious threat to the survival of Amazonian forest in the current century. The Hadley Center model of the United Kingdom Meteorological Office indicates that unmitigated global warming would result in a catastrophic die off of Amazonian forest by the year 2080 (Cox *et al*., 2000, 2004; Huntingford *et al*., 2004). This would be the result of the climate system locking into a permanent El Niño, resulting in reduced rainfall over Amazonia at the same time that substantially increased temperatures would increase the water demands of each tree. In fact, even the Hadley Center scenario is overly optimistic, as it includes only the direct effects of precipitation and temperature—not those of continued rampant deforestation and of increased damage from forest fires (which would themselves be further exacerbated by climate change). During the first five years after this catastrophic result was obtained in 2000 some comfort could be derived from the fact that the various other global climate models did not indicate this disaster (see Nobre, 2001). However, most of the other models have now been extended to include the coupling of the biosphere to the atmosphere and ocean sectors—the Hadley Center's model had previously been the only one with an interactive biosphere, in addition to the atmosphere and ocean sectors that were previously included in global circulation models (GCMs). As of late 2005, five out of seven models show the permanent El Niño pattern, with variation among models as to the timing of its onset. The Hadley Center model, which has the most catastrophic outcome, is the one that best reproduces the current climate of South America east of the Andes (José Marengo, public statement, 2005).

A particularly worrisome result is produced by Japan's "Earth Simulator," a supercomputer that represents the world at a level of resolution (10-km) greatly exceeding that of other computers. When programmed with a coupled biosphere-atmosphere-ocean model with physics similar to those of the Hadley Center model, the Earth Simulator indicates a permanent El Niño forming by the middle of the current century and peak temperatures in Amazonia as high as 50^{o}C. This has implications not only for forest survival and carbon stocks but also for human mortality in the region.

It is essential to understand that the catastrophic predictions for Amazonia under unmitigated global warming need not be the future of the region, as the unmitigated emissions scenario depends on human decisions. While the Hadley Center model indicates that unmitigated emissions result in Amazonian forest die off by 2080, the same model indicates that stabilizing the atmospheric concentration of CO_2 at 750 ppmv would delay this catastrophe for another 100 years, while stabilization at 550 ppmv would delay it for at least 200 years (Arnell *et al*., 2002). The UN-FCCC's Article 2 establishes the Convention's objective as stabilization of greenhouse-gas concentrations at levels that avoid "dangerous anthropogenic interference with the global climate system" (UN-FCCC, 1992). The definition of what CO_2 concentration is "dangerous" is yet to be negotiated, and the initial negotiations are to begin at the Convention's 11th Conference of the Parties in Montreal, Canada in December 2005. It is very much in Brazil's interest that the concentration defined as "dangerous" be well below 550 ppmv. The current concentration of 380 ppmv is rising at approximately 4 ppmv per year.

In conclusion, Amazonian deforestation is rapidly destroying the forest and foreclosing opportunities for sustainable use of the forest. Most important is loss of the opportunity to capture the value of the environmental services provided by the forest as a new basis for the economy in the region's interior. These services, including maintenance of biodiversity, water cycling and carbon stocks, have a value that greatly exceeds that of land uses (such as cattle pasture) in deforested areas. The role of the forest maintenance as a measure for mitigating global warming is the environmental service that is closest to generating an appreciable monetary flow. Such flows must be both large and rapid if they are to change the direction of development in the region. The extraordinarily high predicted impacts of global warming in Brazil, including die off of Amazonian forest, should provide ample reason for Brazil to take on a leading role in international negotiations to set a maximum acceptable (*i.e.*, "dangerous") level of atmospheric concentration at a low value. It also provides a strong reason to create mechanisms by which the carbon value of avoided deforestation can be credited. Above all, immediate actions are needed to greatly slow deforestation in Amazonia.

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