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Reflections on the tropical deforestation crisis

William F. Laurance [a,b,*]

[a] *Biological Dynamics of Forest Fragments Project, National Institute for Research in the Amazon (INPA), CP 478, Manaus, AM 69011-970, Brazil*
[b] *Biodiversity Program, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA*

Abstract

Tropical forests do far more than sustain biodiversity; they are homes to indigenous peoples, pharmacopeias of natural products, and provide vital ecosystem services, such as flood amelioration and soil conservation. At regional and global scales, tropical forests also have a major influence on carbon storage and climate. I highlight these benefits, then assess the pattern and pace of tropical forest destruction in the Americas, Asia, and Africa. Asia emerges as the most immediate concern, because it has less surviving forest than the other two regions and higher relative rates of deforestation and logging. At regional and national levels, however, there is enormous variation in rates of forest loss. I discuss some factors that tend to promote forest conversion in developing countries, and propose that four — human population pressure, weak government institutions and poor policies, increasing trade liberalization, and industrial logging — are emerging as key drivers of forest destruction.

Keywords: Biodiversity; Government policy; Habitat fragmentation; Human overpopulation; Logging; Rainforests; Trade liberalization; Tropical deforestation

1. Introduction

In the tropics, as elsewhere, the processes of habitat loss and fragmentation are inextricably linked. It is therefore vital when considering the consequences of forest fragmentation to think also about habitat destruction. What exactly is being destroyed? Where? How fast? What forces drive deforestation? What are its implications?

The following review grapples with these questions. It begins by highlighting some consequences of the tropical deforestation crisis, both for nature and human welfare. It then assesses the scale and pace of forest loss in the major tropical regions, and suggests key factors that help drive forest conversion.

2. What are we losing?

People of our generation will have an unenviable task: to explain to our grandchildren what it was like to watch the world's great rainforests disappear. Let us not underestimate the significance of this event. Like the meteoric blast that exterminated the dinosaurs (Alvarez et al., 1980) and the hunting blitzkrieg that killed off most of the Pleistocene megafauna (Martin, 1984; Flannery, 1994), the reverberations from the destruction of rainforests will surely be felt for many millennia.

To biologists, the most alarming aspect of the tropical deforestation crisis is the unparalleled threat to biodiversity. Tropical forests are the most ancient, the most diverse, and the most ecologically complex of land communities (Myers, 1984). Though occupying only 7% of the earth's land surface, they probably sustain over half of the planet's life forms (Wilson, 1988). In virtually every biological discipline, tropical forests have been grossly understudied (Janzen, 1986).

Tropical forests provide vital habitats for people, too. The rampant pace of forest conversion is causing severe dislocations — even extinctions — of indigenous groups (Alcorn, 1993). In the Amazon, Amerindian tribes are endangered by deforestation, logging, and by invasions of illegal gold miners, who dominate the Indians and inadvertently introduce exotic diseases (Fearnside, 1987; Christie, 1997). In Sarawak, many Dayak groups have been overrun by rampant logging (Chin et al., 1992; Weissman, 1994; pers. observ.), while in New Guinea, native tribes are being squeezed by multinational mining

* Tel.: +55-92-642-1148; fax: +55-92-642-2050.
E-mail address: wfl@inpa.gov.br (W.F. Laurance)

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operations, foreign loggers, and transmigration programs that have brought hundreds of thousands of Javan immigrants to the island (Sekhran and Miller, 1995; Flannery, 1998; Laurance, 1999b).

But the loss of tropical forests will do far more than destroy indigenous cultures and depress nature-lovers. These forests are pharmacopeias of irreplaceable products — from pharmaceuticals to perfumes, rare latexes to disease-resistant germ plasm for humankind's most vital crops (Myers, 1984; Balick, 1990; Smith et al., 1992). Where markets are accessible, the value of tropical forests to local residents — as sources of food, construction materials, remedies, and myriad other natural products — can exceed that produced by logging or felling the forests (Prance et al., 1987; Peters et al., 1989; Balick and Mendelsohn, 1992). Moreover, products gleaned from tropical forests today are merely the tip of the iceberg; only a tiny fraction of all rainforest plants, for example, have been assayed for biologically active compounds that could lead to the development of new drugs (Balick and Mendelsohn, 1992).

Perhaps the most important impact of tropical forest destruction, however, is the loss of natural ecosystem services. Recent studies reveal that rainforests play a far more vital role in keeping our planet liveable than was previously realized (Laurance, 1999a). On local and regional scales, forests are crucial for maintaining the stability of rivers and watersheds. The recent, devastating floods in Central America and China that caused thousands of deaths and billions of dollars in damage were greatly exacerbated by deforestation in the headwaters of rivers (Padgett, 1998; Gorman, 1999). Forests stabilize soils, preventing the kind of massive erosion that turned many of Sarawak's rivers blood-red in the 1980s and severely degraded local fisheries (Chin et al., 1992; pers. observ.).

Tropical forests are also vital for regional climates. In the Amazon Basin, as much as half of all rainfall originates from plant evapotranspiration (Salati and Vose, 1984). Reduced evapotranspiration from large-scale forest loss could cut the basin's rainfall by about 20%, leading to lower humidity, higher surface temperatures, and greater dry-season severity (IPCC, 1996). Such changes are likely to cause more frequent and severe wildfires, especially in the eastern and southern areas of the basin, which experience strong dry seasons (Nepstad et al., 1998). Alarming synergisms between droughts, logging, and slash-and-burn farming are already leading to catastrophic wildfires, such as those that consumed millions of hectares of Southeast Asian and Amazonian forests in 1982/83 and 1997/98 (Brown, 1998; Laurance, 1998; Nepstad et al., 1999).

Finally, the effects of deforestation are being manifested globally. The rapid burning, logging, and fragmentation of tropical forests is a major source of greenhouse gases like carbon dioxide and methane, contributing perhaps a quarter of all anthropogenic emissions (Houghton, 1991; Fearnside, 1997a; Laurance et al., 1997). Tropical forests also function as massive heat-engines, absorbing solar radiation and helping to drive global patterns of precipitation (Hastenrath, 1997). The dramatic loss of tropical-forest cover is increasing regional albedo (reflectivity to solar radiation), a phenomenon that could potentially alter rainfall patterns at tropical and even temperate latitudes (Dickinson, 1981; Henderson-Sellers and Goritz, 1984; Myers, 1984).

Recent studies further suggest that, at least in the Neotropics, undisturbed forests are functioning as a globally significant carbon sink (Grace et al., 1995; Malhi et al., 1998; Phillips et al., 1998). The Amazon Basin appears to be absorbing over a billion tons of extra carbon dioxide each year (Laurance, 1999a). The most plausible explanation is rainforest plants are growing faster and accumulating additional biomass, about 50% of which is carbon, in response to increasing atmospheric CO_2-fertilization (increased nitrogen and phosphorus deposition from forest burning could also play a role; Grace et al., 1995). But it is vital to emphasize that only undisturbed forests are acting as a net carbon sink (regenerating forests can be temporary carbon sinks, but only because they initially lost much of their carbon via deforestation). Thus, as the area of cleared and degraded forest increases, the positive effects of rainforests will diminish accordingly. Areas that had formerly been carbon sinks will instead become sources of greenhouse gases.

3. What is happening?

In simplest terms, tropical forests are being cleared, burned, logged, fragmented, and overhunted on scales that lack historical precedent (Laurance and Bierregaard, 1997). But such generalities disguise much that is important in understanding the deforestation crisis. Here I briefly overview key trends in forest conversion in the American, Asian, and African tropics. Far more detailed regional assessments are available elsewhere (e.g. Collins et al., 1991; FAO, 1993; Primack and Lovejoy, 1995; Whitmore, 1997; Laurance, 1998).

How fast are tropical forests disappearing? The most exhaustive estimates of forest cover were compiled in 1980 and 1990 by the United Nations Food and Agricultural Organization (Lanly, 1982; FAO, 1993). By comparing the two values, mean rates of forest loss can be gauged for the decade of the 1980s. These figures suggest that an average of 15.4 million ha of tropical forest was destroyed each year, while another 5.6 million ha was logged. The net rate of forest conversion (21 million ha/year) means that about 1.2% of all remaining tropical forests were cleared or logged annually (Whitmore, 1997).

There is considerable variation among regions in rates of forest conversion. Asia emerges as the greatest concern, both because its tropical forests are more limited (ca. 316 million ha) than in the Americas (ca. 916 million ha) and Africa (ca. 527 million ha), and because it has the highest relative rates of deforestation and logging (Fig. 1). Relative rates of conversion in the Americas (including the Caribbean) and Africa (including Madagascar) are quite similar (Fig. 1). In absolute terms, however, the American tropics has the highest pace of conversion (10 million ha/year), followed by Asia (6 million ha/year) and Africa (5 million ha/year) (FAO, 1993; Whitmore, 1997).

Variation is even greater at regional and national levels. In the Neotropics, forest loss is occurring rapidly in Central America, the Caribbean, and the southeastern arc of the Amazon, but in relative terms these losses are buffered by the vastness of the Amazon Basin (Whitmore, 1997; Laurance, 1998). In the African tropics, Madagascar has been devastated (Smith, 1997) and many West African countries are being rapidly deforested (Horta, 1991; Chatelain et al., 1996; Dixon et al., 1996), while much of the Congo Basin is still intact (Myers, 1994). In tropical Asia, the Philippine archipelago, Indochina, Malay Peninsula, India, Java, and Lesser Sundas have been heavily (>75%) deforested, while Borneo, Sumatra, Sulawesi, and New Guinea retain over half of their forest cover but are experiencing rapid conversion (Dinerstein and Wikramanayake, 1993; Primack and Lovejoy, 1995; Brooks et al., 1997).

Because deforestation is a highly nonrandom process, not all forest types are equally endangered. Most vulnerable are accessible areas with relatively productive, well-drained soils and moderate topography, which are suitable for farming or ranching. Seasonal forests (also termed tropical dry forests or monsoonal forests) have been devastated in many regions, such as in Central America and Madagascar, where 98 and 97% of these forests have been destroyed, respectively (Kramer, 1997; Smith, 1997). Lowland forests are also being rapidly felled in most tropical regions (e.g. Janzen, 1986; Dirzo and Garcia, 1992; Lynam, 1997). In the vast Amazon, physical access is particularly important: deforestation is concentrated along highways, roads, and rivers, especially white- and clear-water rivers which contain sediments that are most productive for agriculture (Fearnside, 1987; Laurance, 1998).

4. Why are the forests disappearing?

There is no simple consensus among biologists, economists, and policymakers about the ultimate and proximate factors that promote tropical deforestation. The factors are complex, varying in importance among nations and regions [for example, see Kaimowitz and Angelsen (1998) who reviewed over 150 economic models of tropical deforestation]. The following is an attempt to identify several factors that in my view are of general (or at least increasing) importance. My perspective is that of an ecologist who has spent the last 15 years studying the impacts of forest fragmentation and logging on tropical ecosystems.

4.1. Population pressure

There seems little doubt that human population pressure is the most crucial *underlying* cause of deforestation.

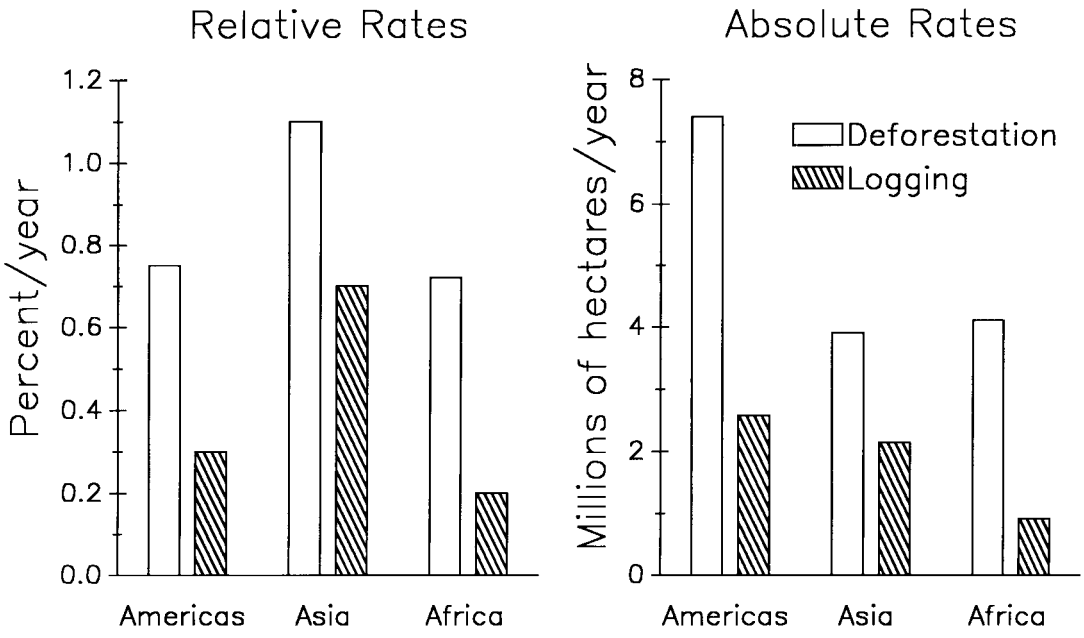

Fig. 1. Relative and absolute rates of forest conversion in the major tropical regions throughout the decade of the 1980s.

Tropical nations have among the world's highest population growth rates. The population of Latin America, for example, nearly tripled between 1950 and 1990, rising from 166 to 448 million residents. Although fertility rates of Latin American women have generally declined in recent decades, the momentum of population growth will continue for some time. This is because a large proportion of the population is young or still in their child-bearing years (Maher and Schneider, 1994).

The relationship between population size and forest conversion can be examined in various ways (cf. Brown and Pearce, 1994; Kaimowitz and Angelstam, 1998, and references therein). When tropical nations are compared, there tends to be a strong, positive relationship between population size and annual rates of deforestation (Fig. 2). Among Amazonian countries, population size of residents in the basin explains about two-thirds of the variation in mean rates of rainforest destruction (Laurance, 1998). Many (but not all) empirical studies have concluded that various measures of population density or growth are important predictors of deforestation at national or regional scales (e.g. Myers, 1984; Palo, 1994; Panayotou and Sungsuwan, 1994; Rudel, 1994; Southgate, 1994).

Some authors (e.g. Westoby, 1978, 1989) have argued that population pressure is a poor predictor of deforestation rates, and that socioeconomic factors, such as poverty and unequal land-tenure, are more important. Such arguments fail to consider, however, that rapid population growth tends to exacerbate a range of socioeconomic problems — and thus is a fundamental, if sometimes indirect, driver of deforestation. Likewise, arguments that foreign debt is a key driver of tropical deforestation rates could potentially be overstated:

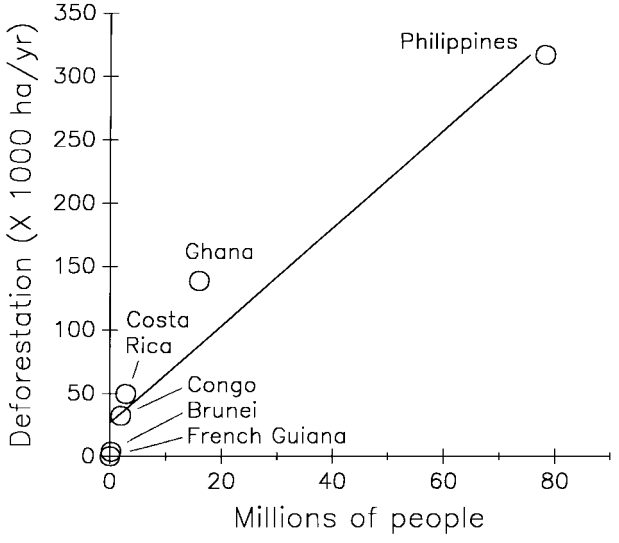

Fig. 2. Relationship between population size and the mean annual rate of forest destruction during the 1980s in six tropical countries ($r^2 = 94\%$; data adapted from Whitmore, 1997).

correlations between debt and deforestation can arise spuriously because both are strongly correlated with population size (Gullison and Losos, 1993).

Population pressures can be manifested in a number of ways. Obvious examples include the hundreds of forest-colonization projects in Brazil, and the transmigration programs of Indonesia, both of which were implemented to reduce population pressures in overcrowded urban centers (although, at least in Brazil, national policies to secure its Amazonian frontier have also played a role; Fearnside, 1997b). In the Amazon, illegal logging and forest-clearing are rampant, with advocacy groups like the *Sem Terras* (landless agricultural workers) promoting unlawful colonization (Esterci, 1999). Rural, poverty-stricken poor, which number about 800 million worldwide, cause a disproportionate amount of the world's deforestation (Myers, 1999). Aside from its direct effects, population growth can promote deforestation by exacerbating various microeconomic and macroeconomic factors, such as making market failures more severe, reducing per-capita income, altering labor markets, and increasing current consumption needs (Kahn and McDonald, 1997; Kaimowitz and Angelsen, 1998). The bottom line: more people usually means less forest, and unless population-reduction initiatives are pursued aggressively in developing countries, many contemporary efforts to conserve forests could ultimately be doomed to failure.

4.2. Weak institutions and poor policies

This is a catch-all for a wide range of ills at the governmental and policy levels. Consider, for example, the case of Brazil. Despite a number of recent government initiatives designed to slow deforestation (Laurance, 1998), rates of forest loss in the Brazilian Amazon have actually increased throughout the 1990s (Fig. 3).

One chronic problem is weak enforcement of legislation designed to protect forests, especially in the remote Amazonian frontier (Laurance, 1998). Brazil's national environmental agency, IBAMA, has only 80 environmental inspectors to police its Amazonian forests (Anon., 1997), an area the size of western Europe. Offenders have largely ignored Brazilian environmental laws in the past, and only 6% of the fines levied by IBAMA have actually been paid (Schomberg, 1998). Stronger environmental legislation was recently enacted in Brazil (Anon., 1998a), but its implementation has been thwarted by executive decrees and congressional vacillation that have rendered it impotent (Anon., 1998b; Gonçalves, 1998).

A further problem is that policies designed to protect forests have not been consistently applied across government departments. Brazilian agencies such as INCRA, SUDAM, and SUFRAMA, charged with

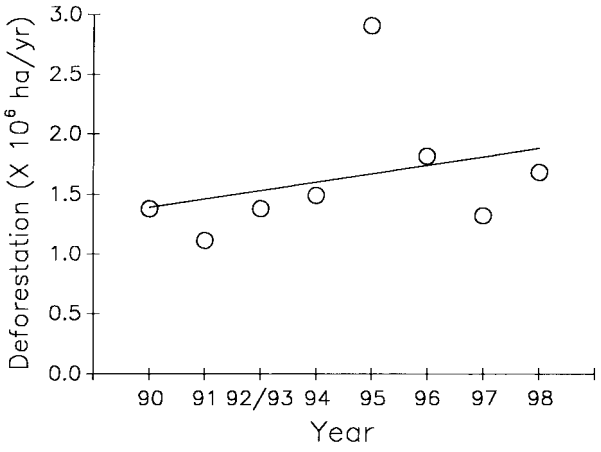

Fig. 3. Annual rates of deforestation in Brazilian Amazonia during the 1990s. Values do not include small (< 6.25 ha) clearings or extensive areas of forest that were logged or affected by ground fires (after Laurance, 1999c).

promoting and planning Amazonian development, have at times seemed barely aware of recent legislation and initiatives to protect forests (Laurance, 1999b). These agencies have also insisted on implementing development projects that are doomed to failure (R. Mesquita, pers. comm.). According to Garo Batmanian, executive director of the World Wide Fund for Nature (WWF), "There's no point in the environment minister flying about in a helicopter to crack down on deforestation if the land reform minister is settling people right in the middle of the jungle" (Schomberg, 1999).

Despite recent improvements, there is still an urgent need for further policy reform in Brazil. Cattle ranching, for example, is the single most important cause of deforestation in the Brazilian Amazon (Fearnside, 1993; Cavalcanti and Mansur, 1999). Large-scale ranchers (those with properties of over 100 ha in area) are thought to be responsible for 70–75% of all deforestation (Fearnside, 1993; Nepstad et al., 1999). Government incentives to promote Amazonian ranching were finally reduced in the early 1990s, but these cuts applied only to *new* incentives — not those that had been previously awarded. In the words of Amazon development expert Philip Fearnside, "Rapid deforestation by ranchers is very much a thing of the present" (Fearnside, 1998a, p. 285).

At the highest levels of government, the importance of environmental policies has seemingly waxed and waned. A recurring pattern is that a dramatic new conservation initiative will be announced with great fanfare, then quietly revoked through executive decrees or suspended by court orders at a later date (Fearnside, 1987, 1997c; Anon., 1998b; Gonçalves, 1998). Initiatives to manage Amazonian development have also been battered by recent economic events and stifled by bureaucratic inefficiency. A plan by Brazilian President Fernando Cardoso and WWF to protect 10% of the Brazilian Amazon was put on hold after $300,000 in World Bank funds was delayed by Brazilian government paperwork (Schomberg, 1999). In late 1998, the Brazilian government announced that it was slashing 90% of its Amazon conservation programs in response to the impending economic crisis in Brazil, cuts that it needed in order to qualify for emergency loans from the International Monetary Fund (Anon., 1998c).

4.3. Trade liberalization

We live in an era of unprecedented economic globalization. Increasing trade liberalization and international free-trade agreements such as NAFTA (The North American Free Trade Agreement) are promoting greater foreign investment in tropical resource-extraction industries (Bowles et al., 1998b). In New Guinea, for example, Australian- and US-owned companies are heavily involved in mineral exploration and development (Sekhran and Miller, 1995; Flannery, 1998). In Brazilian Amazonia, Asian companies invested more than $500 million in timber concessions in 1996 alone (Muggiata and Gondim, 1996), and are expected to pump billions of dollars more into South America's economies in coming years (Epstein and Moore, 1997). North American and European corporations have interests in petroleum, mineral, timber, and infrastructure projects throughout the tropical world (e.g. Wilkie et al., 1992; Soltani and Osborne, 1994; Bowles et al., 1998b).

But because many developing countries lack adequate environmental safeguards and other modifying influences (like strong public sentiment supporting forest conservation), they can easily become feeding grounds for aggressive foreign corporations. The current environmental crisis in China, for example, was greatly exacerbated by its decision in the early 1990s to open its internal markets to foreign investors, which has promoted rampant development (Hajari, 1999; Ng and Turner, 1999). In Ecuador, multinational corporations poured hundreds of millions of dollars into oil and natural gas developments, causing severe pollution problems and a dramatic rise in forest destruction and land speculation (Soltani and Osborne, 1994). Such "boom and bust" scenarios are appallingly common in the developing world (e.g. Horta, 1991; Fearnside, 1997d; Simonetti, 1999), and all too often the sudden influx of wealth ends up concentrated in the hands of a few (e.g. Fearnside, 1986; Anon., 1999). Thus, because trade liberalization tends to accelerate resource-exploitation and environmental degradation, its risks must be evaluated just as carefully as its potential benefits.

4.4. Tropical logging

What are we to think about rainforest logging? Those who advocate selective logging argue that it provides a

vital source of revenues and jobs for cash-strapped governments — and that logged forests have considerable potential for wildlife conservation, carbon storage, and other ecosystem services when compared to cattle ranching or conventional agriculture (e.g. Johns, 1997; Gascon et al., 1998). In developing countries, forest tracts designated for logging are at least 8–10 times larger than those limited areas set aside as nature reserves (Johns, 1997). International banks and development agencies have often funded logging projects in an effort to sustainably exploit tropical forests (Wilke et al., 1992; Bowles et al., 1998a). Under the aegis of "natural forest management", the combination of logging, silvicultural treatments (e.g. vine control, culling non-commercial species), and measures to reduce the negative ecological impacts of logging, is being widely promoted as a viable way to harvest and conserve tropical forests.

Those who oppose logging, however, see a different reality: rather than helping to conserve forests, logging facilitates forest destruction (Winterbottom, 1990: Rice et al., 1997; Bowles et al., 1998a). Loggers create labyrinths of roads, allowing hunters and slash-and-burn farmers to penetrate deep into forests (Wilke et al., 1992; Fearnside, 1997d; Johns, 1997; Bennett, 1999). Indeed, in frontier areas in New Guinea, Borneo, and the Amazon, I have watched as slash-and-burn farmers follow almost on the heels of loggers. The resulting mosaics of clearings and scrubby regrowth bear little resemblance to the original forest. Even when protected from large-scale colonization, logged forests are prone to wildfires, especially during droughts (Laurance, 1998; Nepstad et al., 1998). According to this opposing view, the notion that rainforest logging is "sustainable" is a chimera — predatory logging often depletes valuable timbers (Gullison et al., 1996; Fearnside, 1997d), and because many rainforest trees are ancient (Chambers et al., 1998), unrealistically long intervals are needed for timber stands to recover from harvests.

In my view, both perspectives have some validity. For example, if reasonably well managed, the effects of selective logging can mimic natural disturbance processes (Hartshorn, 1989; Chazdon, 1998), and if hunting pressure is not too severe, most wildlife species can persist in logged forests or recolonize harvest areas from nearby unlogged patches [see Johns (1997) for a detailed review]. Even in heavily logged forests, tree diversity is maintained (Cannon et al., 1998), although high-value species like mahogany (*Swietenia* spp.) may be locally extirpated (Fearnside, 1997d).

The most important determinant of whether logging becomes a recuperable disturbance or an unmitigated disaster is the amount of pressure for converting the forest to agricultural land (Frumhoff and Losos, 1998). Conversion pressure is a function of several factors — population density, economic conditions, and government policies, among others. The enormous challenge facing tropical logging today is that conversion pressure is increasing throughout the developing world as human populations continue to expand. An additional, fundamental problem is that many developing countries suffer protracted bouts of high inflation, leading to elevated discount rates that promote short-term exploitation and destroy incentives for long-term resource management (Costanza and Daly, 1992; Fearnside, 1997d). For loggers, it is usually better to mine ancient trees today than to manage for some uncertain future.

Thus, logging has the *potential* to help conserve tropical forests, but in practice it has often fallen far short of this goal. Logging will continue to be an enormously important issue in tropical forest conservation. Worldwide, about 80% of tropical logging occurs in virgin forest (Whitmore, 1997), and logging operations are now expanding rapidly in the Amazon, West Africa, Indochina, New Guinea, and the South Pacific, led by aggressive Malaysian and other Asian timber corporations (Ito and Loftus, 1997; Pleydell and Johnson, 1997; Johnson and Castaño, 1998; Laurance, 1998). In some of these areas logging will facilitate forest destruction, while in others it will help provide an economic basis for retaining managed forests. There is no blanket prescription. What is clear is that international aid and lending institutions will have to demand the strictest controls on the logging projects they support, and that the proponents of "natural forest management" must accept that, in many instances, logging is likely to do more harm than good.

5. Conclusion

This review describes the pattern and pace of tropical deforestation, and suggests some general factors that appear to promote forest destruction. While it goes beyond the scope of this article to propose "solutions" to these problems, there are many actions that could help ease the tropical deforestation crisis. These include addressing issues of population growth and demographic movement patterns; promoting education and capacity-building in developing countries; devising proactive land-use strategies; discouraging funding of environmentally damaging projects by international banks and development agencies; limiting the expansion of unregulated commercial logging; promoting carbon-offsets, debt-for-nature swaps, and other international mechanisms for funding conservation initiatives; and reducing perverse incentives for forest destruction, among others. The problems are complex, and while there are few simple solutions, one point is clear: without greater commitment from wealthy and developing nations alike, most of the world's tropical forests will disappear within our lifetime.

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