Deforestation and Economic Development

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Tropical deforestation is of growing concern to the world community. Global effects associated with this process include loss of biodiversity and changes in the carbon cycle. Although the importance and present severity of these two externalities are subjects of intense controversy, few would deny the catastrophic nature of their potential impacts. Deforestation also poses local and regional problems. Loss of tree cover can destabilize the hydrologic cycle, leading to drier climate, desiccated soils, and increased flood risks in downstream areas. When poor farmers clear forest land for subsistence, they often impose substantial costs on their neighbours in the short run. Should land abandoned by these farmers prove barren and should processes of ecological succession be stymied by edaphic conditions, an intertemporal opportunity cost arises in the long run, since possible forestry revenues and environmental protection values will be lost to future generations.

Despite the importance of the tropical forest biome from an ecological perspective, forest cover competes directly with the primary factor of agricultural production, namely land. Development processes necessarily involve landscape changes as land is put to different and evolving uses in response to demographic phenomena, technological change, and shifts in consumer preferences. Indeed, substantial deforestation has occurred in the so-called developed world, a fact often overlooked in discussions on tropical deforestation. Of the various forest types, the greatest deforestation losses have been realized in temperate closed forest, which has declined by 32 to 35 percent

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since pre-agricultural times. By way of contrast, tropical evergreen forests have declined (as of 1988) by 4 to 6 percent (Repetto 1988: 3).[1]

This paper addresses the spatially conflicting facts that tropical deforestation is necessary to economic development, while at the same time tropical forest is necessary to the maintenance of the global life support system. The central task of the paper is the presentation of deforestation models for developed and developing countries. I argue that forest areas in developed countries are outcomes of economic development, and that the current loss of tropical forest is closely linked to development processes. I address, in turn, whether deforestation in the tropics will imitate the trends of forest recovery experienced by certain developed countries. The paper is organized as follows. Section II draws a distinction between deforestation and environmental degradation, considers landscape dynamics associated with the phases of economic development, and builds a conceptual framework linking these two processes. Some evidence is presented from developed economies suggesting the existence of a point in time of landscape *turnaround*, when the extent of forest in a national system of land use is minimal, and beyond which forest recovers terrain. Section III addresses tropical forest value and current deforestation processes in developing countries. Section IV draws a conclusion about the validity of concern for tropical deforestation and the issue of global equity involved.

The Development Context of Deforestation

Deforestation and Environmental Degradation

The concern over deforestation in developing countries reflects, in part, the idea that this process is a form of resource abuse leading to lowered agricultural productivity. Popular accounts point to soil degradation, erosion, and regional climate change as deforestation outcomes that reduce local resource productivity. While such impacts no doubt occur, their extent and severity from a global perspective remain empirical questions. Many have observed robust natural regeneration from harvested sites, suggesting that the soil degradation problem is not universal (Moran et al. forthcoming; Bushbacher et al. 1988; Uhl and Buschbacher 1985). While much high quality agricultural land is derived from converted grassland, forests do overlie fertile soils, and deforestation that leads to productive and sustainable agriculture cannot be regarded as environmental degradation.

1. Recent data from the FAO (FAO 1992) is possibly less sanguine about the current extent of tropical forest; according to these statistics, 72 percent of the land in forested areas (tropical rainforest) is presently forested. Presumably such data may include pockets of savanna, mountain peaks, and other types of land which are naturally non-forested.

The actual extent of fertile forest soils in tropical areas is not known, although in heavily populated areas, such as Southeast Asia, it may be reasonable to assume that traditional settlement patterns reflect productivity conditions. In areas of low population density such as Africa and parts of South America, little detailed information actually exists on soil conditions in the aggregate for individual countries. Even in undeveloped and forested areas in Southeast Asia, however, fertile soils are likely to be found locally. Calculations of rates of deforestation do not disaggregate by soil quality, so such rates overestimate the amount of wasteful forest conversions properly identified as environmental degradation. To the extent that deforestation is a necessary outcome of economic development, some conversion of forest represents an optimizing reallocation of groundcover.

Erosion and loss of soil productivity stress agricultural systems and impoverish farmers. Nevertheless, they are both amenable to human intervention through investments in landesque capital (for example, terraces), the use of fertilizer inputs, etc. (Blaikie and Brookfield 1987). That investments can effectively combat such impacts suggests environmental degradation is not an irreversible condition, but a socially-conditioned outcome depending, in part, on a country's level of economic development. Indeed, it may be argued in the extreme that all lands are potentially productive, given sufficient levels of investment and technology, and that any green plant photosynthesizes. Under such an assumption, an optimal landscape pattern at the national level might include little forest, and experience little environmental degradation, strictly speaking.

Clearance of forest from fertile land surely yields environmental impacts other than those associated with degradation, which I have restricted here to a local, productivity-based definition. The main impacts that have caused such worldwide concern, namely loss of biodiversity and changes in the carbon cycle, result, theoretically at least, from deforestation, a landscape phenomenon; they need not involve environmental degradation, a resource abuse phenomenon. I make the distinction in order to call attention to the differing spatial orders of value. In particular, developing countries often deliberately plan for a certain degree of deforestation.[2] What they hope to avoid is the more pressing concern of deforestation externalities within their own borders, namely environmental degradation.

2. Resettlement programs can target forest areas, and governments can classify forests for conversion, to make way for agricultural development (Williams 1989).

Deforestation: Regional and in situ

Boserup (1965, 1981) describes long-run processes of land use change whereby forest-fallow systems with long rotations (15-25 years) give way, through time, to increasingly intensive and sedentary modes of agricultural production. As population pressures grow, so does the demand for food, and fallow periods shorten. Ultimately, systems of annual and multi-cropping are adopted, and shifting-cultivation ceases altogether.

Implicit in such agricultural evolution is an ongoing process of ground-cover change, driven by demographic phenomena. Deforestation under Boserup's model might be illustrated by the contrasting patterns of vegetative cover in Java and Borneo. Deforested Java is under intensive rice cultivation and sustains a very high population density. Population densities are low in forested Borneo, where forest-fallow agriculture is still practised, although not by everyone. These landscape differences are explained, presumably, by the long-term accumulation of human population on the island of Java, and historic avoidance of Borneo as a colonization site.

The adoption and imposition of new agricultural systems, with associated landscape impacts, may occur so abruptly as to appear to fall outside the gradualist paradigm of Boserup. The intensity of forest conversion in certain frontier areas of Brazil, for example, seems inconsistent with the evolutionary sweep depicted by Boserup. Moreover, exploitation of forest for timber, an extensive land use with intensive soil impacts, is a highly commercialized activity yielding industrial products, not food for local farmers or regional markets. Evidently, processes other than growth in food demand associated with increasing human population are implicated. Mobility phenomena, in particular, figure prominently in the current era of forest clearance in developing countries. The landscape changes described by Boserup occur in a certain respect under conditions of demographic *autarchy*, whereby changed agricultural technologies, with their reduced fallows, emerge on the basis of increasing food demands stemming from growing resident populations. By way of contrast, flows of labour and capital to forest regions are pronounced in the present day.

Although little quantitative assessment appears in the literature, much discussion and concern has focused on the deforestation impacts of these factor flows. The labour flows consist of so-called migrant peasants, who flee both urban and rural poverty to seek their fortunes in forest zones. The actual deforestation impacts attributable to peasant farmers is a subject of controversy. When peasants engage in unsustainable land uses, they are likely to do so on the basis of economic necessity, and so it is important to interpret the consequences of their agricultural practices within the context of their motivational circumstances. Nevertheless, such individuals bring a lack of skills and inappropriate practices to their forest destinations, in contrast to the sustainable systems of indigenous peoples (for example, Moran 1990; Posey and Balee 1989; Dove 1986; Hames and Vickers 1983). In both Indonesia and Brazil public policy has encouraged this factor mobility through highway construction, provision of infrastructure, job creation, the offering of fiscal incentives, and the provision of land (Repetto and Gillis 1988). Although programs in both countries have fallen short of stated goals with respect to population movements, appreciable numbers have moved to forest areas.

Internal migration in developing countries has continued in recent years to be dominated by movement to core urban areas (Vining 1986), but large rural populations persist, on the order of two billion (Jordan 1988). The number of people living in forest zones has been estimated at between 200 and 300 million (Denevan 1982; Gradwohl and Greenberg 1988) for the early 1980s. More recent estimates suggest that subsistence agriculture currently involves about 500 million people throughout the tropics, with impact on 2.4 million km^2 of closed forest (Goldammer 1988).[3] While net migration favours cities in developing countries, substantial population growth has been documented in select regions of tropical forest. For example, during the decade of the 1970s, *rural* population in the Brazilian Amazonian states of Amapa, Para, and Rondonia grew annually at 3.2, 4.5, and 16.7 percent, respectively (Helena and Henriques 1988). Forested zones represent a common destination for migrants from traditional agricultural areas.

Capital movements occur simultaneously with such migrations, but with little production complementarity or job creation potential. Under the model of *invasive forest mobility*, for example, loggers build roads into old-growth or virgin forest, and engage in selective harvesting. Shifting cultivators follow them independently to farm the cutover tracts. Once soil fertility is depleted, the farmers move to other harvested areas, in a continuing cycle of soil degradation, migration, and forest destruction (Walker and Smith 1993; Repetto and Gillis 1988; Walker 1987; Office of Technology Assessment 1984; Ross 1984; Leslie 1980; Myers 1980; Schmithusen 1980).[4]

Forest and forest areas often possess exploitable renewable and nonrenewable resources. Timber concessionaires, cattle ranchers, and miners all undertake operations to extract and utilize these materials, often capturing both resource rents and government subsidies in the process. The provision of such inducements can lead to considerable and presumably excessive allocation of capital to forest areas, and overexploitation of forest resources. By the end of the Indonesian timber boom of the 1970s, fuelled by a revenue system granting loggers a considerable share of resource rents, more land had been

3. The degree of forest impact may not be as great as suggested by the numbers, since secondary forests associated with shifting cultivation fallows are probably included in estimates of forest clearance (Homma et al. 1993).
4. Destructive independence between production factors in the case of the invasive mobility model can be mitigated by forest processing investments on part of loggers, as is sometimes required in concession contracts (von Schlabrendorff 1987).

granted to concessionaires than was classified as production forest, available for exploitation (Repetto 1988). Such awards probably included salvage operations targeting conversion forest (Sedjo 1987), but the magnitude of the overall land allocation is striking given the area planned for production. Subsidy capture has been identified as a major factor in the development of cattle ranching in the Brazilian Amazon (Browder 1988).

The mobility of capital and peasant labour, and consequent impacts on forest zones, are regional in the sense they involve relationships between regions within a country or between countries. By way of contrast, the stylized version of landscape change I have attributed to Boserup may occur *in situ*, with little regional interaction. This contrast is artificial to the extent that it depends on boundary definitions. Nevertheless, the importance of capital and labour flows between bases of economic activity in the present era, and their impacts on the forest resource base, call for a distinction founded on a spatial disaggregation of interacting units, as is implicit in the notion of land extensification at national level (Bilsborrow 1992; Geores and Bilsborrow 1991; Bilsborrow and Geores 1990). The Boserup paradigm can provide an aggregate description of landscape change given regional interactions. I retain the term, *in situ* deforestation, for situations in which such interactions are muted, at least in the short run; *regional* deforestation occurs when capital and labour flows into forest zones are pronounced.

The Deforestation Process

As has been suggested, deforestation is largely regarded as a phenomenon and problem in developing countries, in spite of the fact that much deforestation has already occurred in so-called developed countries. A revealing consideration is that the extent of forest land at the present time is in relative steady state in many developed countries. A question arises, in this regard, about possible relationships between the level of economic development and stability in the overall pattern of a nation's system of land use. If such a relationship exists, then national land use systems evidently tend toward aggregate stability with respect to forest cover, and current deforestation trends in tropical developing countries might be viewed as correlates of economic development. This is not to justify or excuse current rates of deforestation, or to downplay their importance, but simply to point out that patterns of land use are not independent of economic factors, and thus they evolve with structural changes in the national economy.

Table 1 presents time series data for the extent of forest land in the continental U.S., Canada, Puerto Rico, a number of European countries, and Japan. Generally, these data show that forest recovery has occurred during some phase of the various historic records, and that the current extent of forest cover is greater than at an earlier time. In comparing early forest area to current

TABLE 1 Forest Areas for Select Countries and Puerto Rico (in hectares)

Puerto Rico[a]		**United Kingdom**	
1828	587,000 forest cover	1914	1,342,186 woodland
1940s	53,400 forest cover	Current	2,027,000 closed[b]
1980	250,000 forest cover		2,178,000 total
Greece		**Italy**	
1923	1,800,000 forest area[c]	1870-	5,025,910 forest area
Current	2,512,000 closed	1914	4,554,656 forest area
	5,754,000 total	Current	6,363,000 closed
			8,063,000 total
Switzerland		**France**	
1923	939,271 forest	1923	10,327,233 forest area[d]
Current	935,000 closed	Current	13,875,000 closed
	1,124,000 total		15,075,000 total
Norway		**Sweden**	
1923	6,882,591 forest area	1923	27,038,750[e] forest area
Current	7,635,000 closed	Current	24,400,000 closed
	8,701,000 total		27,842,000 total
Spain		**Portugal**	
1923	6,836,437 forest area	1923	1,621,486 forest area
Current	6,906,000 closed	Current	2,627,000 closed
	10,811,000 total		2,976,000 total
Japan		**Canada**	
1923	18,866,396[f]	1923[g]	245,344,129 forest area
Current	23,890,000 total closed	Current	264,100,000 closed
	25,280,000 total		436,400,000 total
United States (excluding Alaska)			
Originally	373,279,352 forest and woodland		
1923	222,672,065 forest and woodland[h]		
Current	226,526,721 forest land[i]		

a. Excludes coffee shade; b. Closed is closed forest; total includes woodland; c. Includes brush forest; d. Includes Alsace-Lorraine; e. Estimate based on ratio of total to productive forest in Norway; see Zon and Sparhawk (1923: 252 and 328); f. Excludes empire holdings; g. Data combines areas for the Dominion of Canada and the Dominion of Newfoundland; h. Includes 32,793,522 hectares of 'degraded' land; i. Excludes 'reserved' and other forest land in parks.

Sources: for Puerto Rico, Birdsey and Weaver (1987); current area for U.S., USDA (1990); other current areas, World Resources Institute (1990); early dates for European countries, U.S., Canada, and Japan: Zon and Sparhawk (1923).

Note: Zon and Sparhawk (1923, xi) identify forest land in their compilation as "land covered by any woody growth of economic importance". They define economic importance broadly to mean commercial values associated with extraction, as well as local values associated with use for "firewood, fence posts, and small material". The gross measures they give include forest cover interrupted by "lakes, swamps, meadows, burns, and mountain tops above timber line". See Allen and Barnes (1985) for discussion on difficulties in forest classification and cross-country comparisons.

closed forest, the United Kingdom, Greece, Italy, France, Norway, Spain, Portugal, Japan, and Canada all show gains. In the U.S., current forest land exceeds the forest and woodland of 1923, and forest cover in Puerto Rico in 1980 is greater than in 1940. Switzerland and Sweden register declines, although relatively minor ones, when comparing current closed forest to early forest area. Comparison involving current *total* forest shows an increase in both countries. There is no guarantee that the early year in the 1900s represents the point of minimal forest expanse for the various countries. Thus, the areal increments indicated by the data are lower bounds to the actual extent of reforestation. Puerto Rico, in particular, has experienced a remarkable restoration of forest cover, on the order of 370 percent, or 9 percent per year from 1940 to 1980.

The data suggest the existence of a point of *landscape turnaround*, beyond which factors causing deforestation dissipate, and forest actually recovers lost terrain. Although the sample is limited, it covers a substantial part of continental North America, several of the larger Western European countries, and Japan. The long run stability of the current forest area steady state remains to be seen, as do the turning points in forest landscapes for other developed countries. Moreover, while reforestation may come to dominate landscape processes in the long run, forest characteristics change radically. In many cases, floral diversity is lost, and forests in general become younger.[5]

Population growth in an agrarian economy, given historic conditions and in the absence of easy migration outlets, leads to the *intensification* described by Boserup (1965, 1981), a variant of *induced innovation* processes described by Hayami and Ruttan (1987) under conditions of growing land scarcity. Without sudden technological change that economizes radically on the use of land, diminishing fallow periods will be manifested in the landscape, over the long term, as *in situ* deforestation. In such a setting, the pace of deforestation will be associated with the rate of natural increase of the population, and its demand for food. In the developed countries, the onset of urbanization, the growth of manufacturing, and the development of labour-saving agricultural technologies sparked rural outmigration to cities. An implication is that the demand for agricultural land weakened over the long run, a process further facilitated, presumably, by the development of land-saving technologies, by increased knowledge about positive forest externalities, and by the evolution in

5. The finding on landscape turnaround should be interpreted in a suggestive light, as forest area definitions can be highly dependent on data sources. Nevertheless, identifying a consistent data series for long time periods could prove difficult. My selective presentation chose countries for which some consistency in the records over time seems likely, at least relatively speaking. I assessed forest trends for several developing countries using data from the World Resources Institute (1991) and Zon and Sparhawk (1923). This assessment revealed wide variation across countries, with both deforestation and reforestation. The current FAO report (1992) clearly shows ongoing deforestation throughout the tropical world, however.

consumer preferences for the amenity value of natural areas.

These observations suggest a two-stage model of landscape change, in which deforestation gives way to reforestation and ultimate forest area steady state beyond a point of landscape turnaround. For the developed countries, I hypothesize that *in situ* deforestation has been the dominant mode of forest loss, and that labour and land saving agricultural technologies, together with strong rural to urban migration, have been primarily responsible for the resurgence of forest.

A consideration that is central to the paper is the relevance of this two stage model to tropical deforestation in developing countries. The Puerto Rican data is revealing in this regard, since the forest setting has been that of a developing, tropical country, albeit one with unique characteristics given Puerto Rico's relationship with the United States. Table 1 shows an abrupt and rapid reforestation; current forest expanse is nearly half of what existed in the early 19th century. The 1978 per capita Gross Product for Puerto Rico was approximately $2796 (Junta de Planificacion 1978), which is higher than 1987 per capita gross domestic product for middle income countries such as Brazil ($2021), Costa Rica ($1608), and Malaysia ($1820) (World Resources Institute 1990). In the recent past, however, the Puerto Rican economy produced at levels comparable to Caribbean and South American neighbours.

Nevertheless, much of the developing world shows rapid and continued rates of deforestation. In 16 tropical countries, net forest loss was estimated to have exceeded two percent annually for the years 1980-1985; while the percentage rate of loss tended to be relatively low for countries with large forests, the absolute amounts of deforestation suffered by Brazil and Indonesia, for example, were very high (Repetto 1988). Between 1981 and 1990, the annual rate of loss worldwide is estimated at 16.9 million hectares, which is 0.9 percent a year (FAO 1992). This reflects an annual loss over that period of 8.3 million hectares in Latin America (0.9 percent annual rate of loss), 3.6 million hectares in Asia (1.2 percent), and 5.0 million hectares in Africa (0.8 percent).

The ongoing process of forest conversion in the developing world contrasts sharply with the Puerto Rican experience, and invites a comparative assessment. At least two possible explanations may be offered. It may be that Puerto Rico has travelled further along the "path of development" than its neighbours, in which case we can expect similarly dramatic turnarounds in deforestation processes in these other countries. Alternatively, Puerto Rico's unique relationship with the U.S. may have liberated the island from what could be a fundamentally different landscape dynamic than that experienced by developed countries historically, and currently unfolding in the developing world. The U.S. has promoted rapid industrialization in Puerto Rico, provided wage subsidies through transfer payments favouring urban locations, and permitted unrestricted immigration of Puerto Ricans, who are U.S. citizens. In concert, these actions can be expected to have considerably reduced the demand for land.

In the next section, I discuss the likely applicability of the two-stage landscape model (based on developed country experience) to the present day situation in the tropics. Before doing so, I consider aspects of tropical forest value and its articulation in space, which will facilitate the explication of modern day land use conversions.

Spatial Aspects of Tropical Forest Value and Deforestation

Forest Values

Peasants often depend on forests for goods, such as fuelwood, fruits, structural materials, game, and medicinal herbs, not mediated by markets. They are likely to recognize, if not always act on, the watershed protection values of forests serving the purposes of flood control, erosion mitigation, and water quality maintenance. Tourists from the home country and abroad recognize the amenity value of forest, and sometimes travel great distances to experience pristine natural conditions for recreational purposes. Loggers, of course, derive immediate market value from the logs they cut and from any industrial outputs they produce from the harvest. This use of the forest is directed at markets, and motivated by commercial interests. Artisanal use of forest products for small scale market oriented production can also be locally pronounced.

Both loggers and peasants may determine the forest values they derive and their maintenance over the long-run to be inconsistent with other objectives, despite explicit government policy to prevent environmental degradation through forest conservation (see von Schlabrondorff 1987; Barber 1988). Much forest land in developing countries is publicly owned, and forest administration over vast, sparsely settled areas is often difficult to enforce (Palin 1980; Brookfield and Byron 1990). As a consequence, the public goods aspects of forested land, generally appreciated by the population, may be inadequately managed and protected.

The non-market values associated with recreation and watershed protection are largely local in nature in that mostly resident populations benefit from them, notwithstanding the growing importance of ecotourism. The market values also are local in any given country to the extent that the market in wood (and wood products) is dominated by domestic interests, both productively and consumptively. When wood is sold on international markets, consumer surplus is realized in the importing country (given some inelasticity in demand conditions). Producer surplus may also be exported if transnationals engage in forest exploitation. In both these latter case, value transfer occurs between regions and across national boundaries.

To this point, the values discussed have been local and regional in character, involving resident populations or exchanges between producers and consumers across national boundaries. Much of the concern about tropical deforestation relates to possible impacts on what is generally perceived as global value associated with biodiversity and the role forests play in the carbon cycle. Such values are allegedly shared by the world community, since the very survival of our global system depends on them. Little empirical evidence exists, however, on the environmental preferences of deforesting migrants and on the intensity with which they discount the future.

Other values, possibly global in nature, relate to existence of tropical forests and options to visit them. If forest and other natural subjects possess a right to exist independently of human interference or manipulation, this right is founded, presumably, on intrinsic value unmediated by human perception or preferences. Such values, in turn, can themselves constitute a source of human value as individuals come to recognize the rights of nature. Option values stem from human perceptions and a desire for the experience of utility; they may be passed, of course, as bequests to future generations of the world community. Transcendent values such as those based on existence and option are unrelated to the consumption of commodities or immediate use of ecological services (or amenities); nevertheless, they are shared by populations in developed and developing countries alike, in spiritual form or as secular arguments in so-called preference functions.

Tropical Deforestation

I have argued that, in many tropical areas, migrant peasants, cattle ranchers, and loggers penetrate forest zones from distant regions, together with capital. This radical juxtaposition of places, resources, and production factors, with its attendant impact of forest, I have referred to as *regional* deforestation, by way of contrast *in situ* deforestation, emerging from long term residents of the landscape, and their growing demand for food.

Regional interactions no doubt figured in the development processes and landscape dynamics of developed countries. The United States, for example, served as a source of raw materials for the British Empire, and to this day remains a preferred immigrant destination. It has been suggested, however, that farmers, not loggers, were the primary agents of deforestation (in New England) during the early colonial period. Moreover, colonial farmers cleared land with fire, an application they learned from native Americans, who had long engaged in land clearance as an agricultural practice (Cronon 1983). How much land native Americans cleared prior to settlement is unknown, although much forest at the time of colonization was managed for game production, using fire. Presumably, land clearance by the farmers can be attributed to migrants and their succeeding generations, over the course of decades if not centuries.

Over long periods of time, capital and labour have been mobile within and between developed countries during early development stages. The current deforestation epoch is concurrent with the proliferation of capitalist production and its restless search for investment opportunity on a global scale. The regional quality of deforestation in the present day results both from economic integration in a capitalist production order and from dualistic properties of developing economies. The demand for tropical forest products (for example, hardwoods) and the output of cleared forest lands (for example, beef) stems from burgeoning urban populations in the forest countries and also from international trade. The factors that flow in response, in particular the capital resources, originate both domestically and internationally.

While the demand side of these regional phenomena is an articulation of economic integration, an important component of the supply side arises from dualistic labour market structures. The absorptive capacity of industrialization in urban areas of many developing countries has not been sufficient to achieve full employment of potential labour supplies. This labour originates by natural increase and by redundancy and natural increase in rural areas, where agricultural modernization often eliminates jobs and small-holdings. One consequence of employment shortfall is the labour mobility to forest areas already indicated. Intensifying the regional factor flows, particularly the investment of capital, is indebtedness arising from the structure of world capital markets, also a regional phenomena. Rents from forest resources are a ready source of foreign exchange earnings; their liquidation represents a fast, if destructive, avenue to solvency.

At the end of the preceding section, I posed a question regarding deforestation with respect to Puerto Rico; namely whether the process of landscape change at the present time in tropical countries is fundamentally different than what occurred historically in the developed countries. I answer this question in the affirmative. In particular, the regional nature of the interactions between tropical forest places and elsewhere is a distinguishing characteristic of current groundcover phenomena.[6] Value transfer between regions, both within and between countries, has precipitated factor movements into forest regions. Displaced labour flows from traditional farming areas and cities also contribute to deforestation. An implication is that the connection between landscape change and on-site natural increase in the deforestation process has been weakened.[7]

The opportunity costs associated with forest cover maintenance have been

6. Regional interactions have contributed to deforestation in so-called developed countries, since frontier expansion, whenever it occurs, requires factor mobility. On the other hand, *in situ* deforestation has taken place in developing countries, and continues to do so. I draw the distinction in order to isolate the primary modes of landscape change in either case.

7. Tenuous linkage between population growth and tropical deforestation has been noted in country specific studies (for example, Jarosz 1993), despite Malthusian findings in cross-sectional studies at the national scale (for example, Allen and Branes 1985).

dramatically increased in the current era by 1. demands external to forest zones, 2. the development of efficient infrastructure and forest exploitation technologies, and 3. institutional factors relating to land tenure and contract ambiguity, to domestic labour markets, and to international capital markets. One consequence is that the rate of forest clearance and its relative extent will probably surpass the historic experience of developed countries, in the absence of interventions.

Moreover, whether tropical countries are destined to experience landscape turnaround remains to be seen. So felicitous an outcome depends on changes in the opportunity cost of forest cover maintenance. Economic theory suggests that potential scarcity of forest and wood products sets a lower bound to the extent of forest cover; however, this does not guarantee the restoration of forest, even if deforestation processes run their course. For turnaround to occur, the demand for agricultural land must diminish. Population redistribution away from forest zones, weakening demand for domestic agricultural products, and the development and implementation of land intensive farming techniques can all contribute to the restoration of tropical forest. Of course, restoration possibilities may be severely limited by edaphic conditions.

Conclusion

I have suggested that landscape dynamics in tropical countries today are different from those experienced historically by temperate countries. This is due to economic integration and dualistic economic structures in tropical countries, which together have intensified interactions between economic factors and forested places.[8] Developed countries seem to have experienced landscape turnarounds, and recovered substantial forest domains in the course of economic development. Tropical countries are still in deforestation phases.

It is tempting to attribute deforestation to economic development processes and to conclude, on the basis of history, that the driving forces of forest clearance will soon dissipate in tropical regions, allowing recovery to take place according the two-stage landscape model outlined in this paper. It is also tempting to point a finger North and suggest that environmentalists in developed countries have little moral authority, given the extent of temperate deforestation. There are several reasons why these temptations should be resisted.

In particular, relatively more forest could be lost in developing countries, and more quickly, than occurred in the temperate world, even should a robust turnaround take place. Presently, national and international markets affect the

8. Further amplifying the effect of economic dualism is the growing skewness in the income distribution, which can increase the discount rates among the rich and poor simultaneously. (Walker 1991). Increased discount rates intensify the inferior asset problem (Clark 1976).

process of forest conversion to agricultural land, in *addition* to the local demands of rural populations. Moreover, rural populations are growing *faster* than they have historically due to lower mortality and economic dualism, while land-saving technologies remain relatively expensive.[9]

Globalization of land use, and economic dysfunction at national level, can be expected to promote considerable forest clearance; the minimal expanse of global forest that results -- assuming a (positive) lower bound to forest cover in a national land use system -- could be less than what is necessary for maintenance of biodiversity and the carbon cycle. In other words, human institutional processes, although oriented toward positive social goals on one level (for example, Pareto optimality), may nevertheless lead to environmental ruin, as ecologists have long warned (Odum 1971).

Tropical forests yield values at different orders of spatial scale and with different institutional bases. Market based values, both domestic and international, promote deforestation, which could destroy the non-market global values of forest associated with biodiversity and carbon cycle maintenance. Human recognition and acceptance of these values has been regionalized, to a certain degree, in developed countries, since many who are directly responsible for deforestation must struggle for survival on a daily basis. Such a regionalization could provide a basis for forest-conserving exchanges, such as debt-for-nature swaps and the linking of foreign aid and debt forgiveness to environmental management expectations.

The insistence that developing countries put an end to deforestation, issuing largely from developed, temperate countries, is an attempt to get something for nothing. Agents of deforestation may place little global value on the forest; should they be obliged to quit deforesting, they bear a heavy, possibly fatal, opportunity cost of forest maintenance, and receive nothing in return, given their subsistence-oriented preferences. Moreover, temperate forest is to a certain degree substitutable for tropical forest with respect to maintenance of the carbon cycle. Reforestation in temperate countries might contribute -- just as reduced tropical deforestation -- to assuring a proper balance of greenhouse gases in the atmosphere.

It is important that tropical forest not decline to a point at which global biodiversity is threatened. Avoiding this outcome could prove difficult given that an international system of value transfer contributes to deforestation, and that economic development in many tropical countries, with consequent reductions in the demand for agricultural land, is proceeding slowly or stagnating. Complicating attempts at global intervention in this regard is the weakness of the information base relating biodiversity to tropical forest area. Moreover,

9. In a number of tropical African countries, scope remains for further declines in mortality rates; in some of them, population growth rates exceeded three percent per year between 1985 and 1990 (Bilsborrow and Geores 1992).

much remains unknown about biodiversity *per se* and its role in evolution. Despite these difficulties and impediments, all those who have abused the global commons in the name of economic development, past and present, must share in its restoration, maintenance, and longevity.

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