DEFORESTATION AND FOREST LAND USE: THEORY, EVIDENCE, AND POLICY IMPLICATIONS

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The topic of deforestation is seldom examined from the perspective of prices and responses to resource scarcity. This omission creates important errors in policy. Resource scarcity induces investments in both commercial and subsistence uses of the forest once prices overcome the costs of establishing property rights, forest management, and the returns from alternative agricultural uses of the land. Therefore deforestation will induce price increases and investments in forestry well before deforestation attains its physical limit. These prices and costs will alter the boundaries among several important classes of forest land: sustainable private forestry, the forested commons, unsustainable open-access forests, and unused residual forest. The greatest impact on the world's forests will come from refocusing the policy dialogue on the cost factors that determine these boundaries, including agricultural support policies, local concentrations of nonmarket environmental resources, and policy failures that distort incentives to invest in forestry. In locations where reforestation induces large price changes, policymakers must remain attuned to the likelihood that deforestation-induced changes in the prices of forest products and forest policies may cause significant shifts in the activities of the poorest people.

Conserving scarce forest resources is a challenge for both high- and low-income countries. Contemporary forest policy and forest management both reflect this challenge. Forest policy reflects international concern with the pressures of deforestation, including trade in tropical timber, the conversion of forests to agricultural uses, and the effects of deforestation on climate change, biodiversity, and local communities dependent on forest resources. Forest management features the transition to managed forests as deforestation causes

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a decline in the natural environment and includes questions of investments in research on natural habitats and silvicultural practices.

Either deforestation or its relative, forest land use, is at the core of most contemporary forestry problems. An analysis of these problems may begin by reviewing the economic classifications of forest land use, paying particular attention to the thresholds that separate the classes of forest land and that define changes in the levels of deforestation and reforestation. Von Thunen's (1875) classic work on the economic geography of forests underlies this analysis. Von Thunen's insights suggest that the increasing scarcity implied by deforestation will cause the values of forest-based resources (timber, fuelwood, fruits and nuts, forage, and fodder) and environmental benefits (such as climate change, biodiversity, and erosion control) to rise until forests eventually compete well with some agricultural uses of the land. As a result, the world will never reach the physical limits of deforestation.

Observations from a wide variety of economies, social settings, and ecosystems support the basic contention that land managers respond to the increasing scarcity of forest products by planting trees and making other private investments in forestry. For example, lumber prices in the United States have risen at an annual rate of 1.8 percent for 120, and perhaps 170, years (Barnett and Morse 1963; Ruttan and Callahan 1962). This price increase has induced the technical change that allows loggers to use ever-lower quality timber growing ever farther into the interior, and it has also induced private investments in 5 million hectares of forest plantations in the South and the coastal Pacific Northwest in the last thirty years. In Malawi, in a very different example, the rate of deforestation exceeds 3.5 percent annually, and fuelwood prices have risen by more than 5 percent a year for the last decade. Fuelwood may now consume 20 percent of the cash income of subsistence households in rural areas. Malawi's deforestation has occurred largely on open-access forest (land where property rights are nonexistent or unenforced), where there is no conservation incentive. Small landowners are responding by planting trees on their own lands at a rate that may offset all deforestation within ten years (Hyde and Seve 1993).

Similarly, investors have responded to higher prices by planting industrial forests in Chile (Vincent and Binkley 1992), Costa Rica (Rice 1993), Kenya (Scherr 1995; World Bank 1992), and Vietnam (Byron 1993). And farmers have planted trees to meet subsistance needs in Cape Verde (Krutilla and Hyde 1995), China (Yin 1994), Madagascar (Larson 1992), Nepal (Bluffstone 1995; Gautam and others forthcoming; Amacher and others 1993b), and the Philippines (Templeton 1992; Bensel and Remedio 1993).

This evidence suggests that new guidelines be adopted for formulating forest policy. Today's focus on the divergence of private and social values, the absence of secure property rights, and the imposition of fees for forest use is critical in specialized cases. But the policy dialogue could focus more usefully on the relative differences in the costs of forest land; on local rather than general concentrations of nonmarket forest-based environmental benefits, on public policy fail-

ures that distort market incentives to invest in forestry, and on the broader implications of the eventual use of forest land for subsistence-oriented populations.

The Simple Model

Growing populations, increasing food consumption, and government policies that encourage agriculture all generate increasing demands for commercial agricultural land. They also push populations of shifting cultivators farther into the forested interior, where soils are often thinner and the shifting cultivators must either move and clear the forest more frequently or manage an increasingly degraded environment. Except for the difficulty of clearing trees, little deters agricultural expansion because the adjacent forest is unclaimed public domain, the legally unrecognized possession of the indigenous population, or the relatively unmanaged and unsecured responsibility of a government ministry.

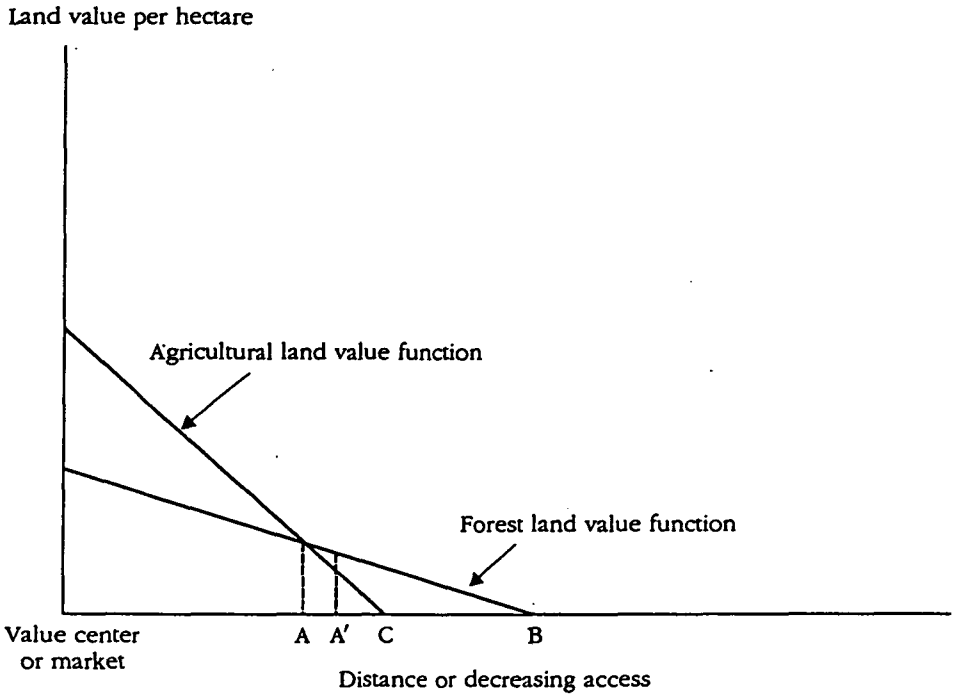
Meanwhile, commercial timber interests and those pursuing other forest resources follow a similar pattern of incentives, first harvesting at the margin between farmland and forest, and then moving ever deeper into the interior until they reach a point where harvest and access costs consume the full value of the standing resource. They repeat- or pulse-harvest this land in subsequent years whenever sufficient new natural growth justifies it. An unused residual of natural forest generally lies beyond the boundary of economically viable forest; access and harvest costs for this residual exceed the value of the land for either market or subsistence production.

Figure 1 provides a graphic description of this problem for a simple landscape consisting of agricultural areas and forests. The vertical axis represents the value of the land, and the horizontal axis represents the distance from the market. The most accessible land is adjacent to the local market (for commercial goods) or to the subsistence household (for nonmarket consumption goods). Highly valued agricultural land with secure property rights gradually gives way to harvested forest land and eventually to unclaimed and unharvested open-access natural forest.

The functions in figure 1 reflect in situ resource values. The agricultural value function reflects the accumulated net discounted value of land for agricultural production, and the natural forest function reflects the net discounted value for the standing forest resource (either timber or other wood or nonwood products). Agriculture occupies all the land between the origin and point A, or until agricultural value declines to a level below the forest value. Thereafter, forestry becomes the preferred economic activity. Forestry remains economically viable until its in situ value declines to zero at point B, and the entire market or subsistence forest value is dissipated in harvest and access costs.

Some land beyond the extensive agricultural margin at point A may have a positive value for long-run production of forest resources. Private individuals

Figure 1. *The Relationship between Land Value and Market Access*



Note: Point A is the point at which agricultural land value equals forest land value; point B is the point at which short-run forest land value equals zero; point C is the point where agricultural land value declines to zero; the area beyond B represents residual natural forest of no private value.

and communities will establish clear rights to this part of the forest if the long-run value exceeds the costs of establishing and protecting the property rights. Somewhere between points A and B, the costs of establishing and protecting permanent rights to the land exceed the in situ value of any products harvested from the forest, and it becomes an open-access resource. Thereafter, the forest value function in figure 1 reflects only short-run or extractive resource values. Generally, the costs of establishing and protecting permanent rights to the land are greater than the value of the land for long-run forest production for all land beyond point A (agricultural uses reclaim the land up to point C, and all of the forest between points C and B is an open-access resource).

This is an important point. It suggests why observed rates of harvest, deforestation, and land conversion are not as socially excessive as they sometimes seem, and also why establishing property rights is not an easy solution. Figure 1 shows that the values of standing forest resources are low relative to other land uses. Forest resources may also be dispersed. For example, fruit and nut-bearing trees

tend to be scattered, and some high-value tropical timber species occur only on an occasional hectare. The costs associated with establishing and maintaining property rights for these resources can easily exceed their in situ values. Fences, forest guards, and roadblocks may help protect these rights, but trespass and theft are common even in the forests of industrial countries. Inevitably, at some point between A and B in figure 1, the value of the forest will be positive but less than the cost of secure property rights. Open-access forestry is efficient in this region.

Finally, the standing forest located beyond point B is also an open-access resource, but extraction from this forest is not economically attractive. This forest is usually the stewardship responsibility of the forest ministry or national park agency. Many of the forests of interior Alaska, northern Canada, Siberia, and some of the Rocky Mountains in the United States, and most remaining tropical forests, including much of the Amazon, fall into this category. This economically residual resource accounts for a significant part of most recorded measures of global forest inventories despite its uneconomic nature because the universal convention for forest inventories is a physical measure taken without regard for access costs. Therefore, access and harvest costs for industrial users and the opportunity costs of labor for subsistence forest collectors create very real limits on the extraction of resources, and the costs of ensuring tenure create a very real burden for alternative strategies for resource management.

These arguments and the description shown in figure 1 accommodate many nonmarket forest values as well as the obvious commercial forest values. Fuelwood, forage, fodder, fruits, and nuts, for example, actually do exchange in local markets, and subsistence users of the forest choose the levels of their market participation according to the opportunity costs of the labor used in collecting the fuelwood, forage, and so on. Therefore, the costs of deforestation, land conversion, and property rights do not reflect the magnitude of the losses that would be implied by an absence of markets.[1] Nevertheless, some nonmarket environmental values do remain (notably watershed protection or erosion control, biodiversity or genetic reserves, and carbon sequestration to protect against global climate change), and these will be discussed later.

Scarcity and Increasing Prices

Deforestation, climate change, and biodiversity are largely concerned with the deterioration of the residual stock of natural forest to the right of point B in figure 1. This is a dynamic problem. It is affected by policy changes, and it will change as resource extraction continues over time. It is reasonable to expect that extraction from the natural forests will continue until the prices of forest products attain a level that induces investments in trees or forests. The key issue for policy formulation should be the relative magnitudes of eventual prices for forest products, the eventual location of active tree or forest management, and

the final combined inventory of planted trees and natural forests—or the final status of world deforestation.

In brief, as the extraction of forest resources continues, the margin of the natural forest (point B in figure 1) must shift outward (to the right), forcing the residual natural forest to decline. If society continues to consume forest resources, then extraction must continue; access and harvest costs, including the opportunity costs of subsistence labor, must rise; and the market price of forest products must rise with them. As the stock of natural forest declines and access costs and market prices continue to increase, the function representing forest resource value in figure 1 rises until market prices (or the opportunity costs of subsistance households) eventually justify the costs of investments in trees and of securing and protecting their property rights. If these combined costs are less than the price represented by the forest land value gradient at some point to the right of A (say A′), new plantations will appear between that point and point A to its left.

Land Tenure Rights

Agricultural land extends to point A, where the agricultural gains are equal to the costs of securing agricultural property rights. If the cost of securing the rights to forest property is comparable to the cost of securing agricultural rights—which is the general case—a discontinuity in the use of forest land can be anticipated. Once the initial harvest of the natural forest between points A and B has been completed, agricultural use extends to point C. The extraction of forest products continues at the ever more-distant margin (point B shifts to the right), and the values of market and subsistence forest-based goods continue to increase. Eventually prices of forest products will overcome the costs of securing rights to forest property and the costs of local reforestation and forest management. Once these prices rise further to the level of the agricultural opportunity, trees will compete as an agricultural crop in the neighborhood of point A. This pricing sequence argues that trees will become an efficient activity somewhere closer to the market center than some extensive agricultural activities.

The increasing recognition that private investment responds to declining natural forest stocks and increasing prices for forest resources is usually associated with fuelwood and other subsistence forest products (Hofstad 1995; Mercer and Soussan 1992; Cline-Coal, Main, and Nichol 1990; Dewees 1989). Farmers commonly plant trees near their households or in rows along well-traveled fences, paths, and nearby embankments to provide better protection for their higher-value forest resources. (Regular surveillance is more difficult and theft is easier at the more distant fringe of the household's agricultural lands.) Rural households follow this strategy in developing countries around the world. Their private plantings may consist of only a few trees (not enough to be called forest "plantations"), but in a few cases these private plantings have been sufficient to replace all the resources removed from the open-access natural forest.

Commercial forest plantations in industrial countries also tend to follow this model. Although they do not compete with the highest agricultural values, they often produce a more valuable crop than agricultural uses such as grazing. The land-use sequence (see figure 1) ranges from high-value agriculture to commercial forest plantations to livestock grazing to timber harvests (from the remaining natural forests) to an unharvested residual forest. Sedjo and Lyon (1990), for example, project that this pattern will prevail for the foreseeable future, with at least half the world's harvest of industrial wood in 2050 originating from natural forests. Therefore, periodic harvests from natural forests will play a large role in industrial timber supply beyond 2050.

Classification of Forest Land

The investment response to the increasing scarcity of forest resources creates four or possibly five categories of forest land. The first is an economically residual standing natural forest to the right of point B in figure 1. The second is a region of mature natural forest from which timber or other forest products are currently harvested (the neighborhood of point B itself). The land area and forest inventory in this second category are highly responsive to short-run changes in prices, harvest and access costs, or forest sector policies. Higher prices for forest products, technical changes that reduce extraction costs, new roads into previously inaccessible regions, and the reduction of public policy constraints on harvesting each expand the area and volume of current resource extraction. Declining markets and tighter policy constraints reduce the size of this category of forest land and decrease or delay current extraction. These two categories of land use are the common focus of most forest policy discussions.

The third category of forest land covers the region of previous resource extraction to the left of point B. It supports repeat or pulse harvests as the depleted natural forest grows to some minimum economic size. Access to the resources in this region remains open because the cost of obtaining and protecting property rights exceeds the potential return to forest investment.

A fourth category of forest land may appear in the neighborhood of the extensive agriculture (to the right of point A) if the expected in situ return on forest investments exceeds the costs of protecting rights to forest property. This land-use category is more likely in subsistence communities where common ownership offers a lower cost and a more secure regime of property rights than do individual private rights. The initial cost of converting forests to agriculture identifies the boundary between this fourth category of forest land and extensive agricultural uses of land.

This category cannot exist when the cost of secure property rights exceeds the expected return on investment in forest resources. The prices and costs of forest products continue rising until increasing demand eventually shifts some forest production for both subsistence and industrial uses to a fifth category of higher-valued (previously agricultural) land. The in situ forest product prices for

this land must justify the cost of trees managed as an agricultural crop, including the important cost of secure property rights. This land-use category is a recent phenomenon in forest history that was unnecessary before deforestation-induced scarcity.[2]

These observations suggest that three categories of forestry are sustainable: commercial plantations, household tree plantings, and the uneconomic residual natural forest. The regions of current resource extraction and pulse harvests will always be subject to open-access extraction because the cost of securing tenure in these regions exceeds the value of the resource. These regions can become sustainable only with effective, and perhaps expensive, public regulation or forestry ministry management. That expense may be unacceptable in many developing countries, and the degradation of forests in these regions may be inevitable and economically efficient.

The Empirical Evidence

Data on these five categories of land use are exceedingly difficult to obtain. Table 1 gives a rough impression of the importance of each category in a cross-section of five countries. These data were collected in a variety of formats. None were collected with the intention of identifying the economic distinctions of land use, and they seldom provide the means to estimate the areas of pulse harvests. These areas of degraded forests no longer appear in the forest statistics of many countries. Nevertheless, a few points are clear. Plantations and trees planted for household uses account for significant areas, even in some developing countries, and the areas of uneconomic residual forest are extensive in all five sample countries. The evidence on nontimber products is limited; the evidence in table 1 refers to harvests of commercial timber. The margin of natural forests is an important source for commercial harvests in the United States. It is

Table 1. *Classification of Forested Regions*
(thousands of hectares)

Country	*Commercial and household plantations*	*Pulse harvests of forest products*	*Current harvests from natural forests*	*Uneconomic residual natural forests*
Belize	3	—	3	2,000
Philippines	290	—	316	7,830
Chile	1,400	—	Negligible	16,200
United States	2,000	—	1,250	238,400
Finland	12,650	7,000	—	4,000

— Not available.

Source: Derived from Chomitz and Gray (1994); Republic of the Philippines (1987); Hyde and Chamberlain (1995); U.S. Department of Agriculture (1992); Aarne (1995); Bailey (1995); World Resources Institute (1994).

the site of agricultural land conversion, if not for commercial timber, in Belize and the Philippines.

The evidence in table 1 is static. The real support for this argument depends on changes in land use and the increasing scarcity of forest resources over time. Scattered evidence on rapidly changing patterns in land use for both industrial and developing countries supports the contention that scarcity does generate investments in forestry.

Industrial Forestry: The United States

There is no reliable long-term record of stumpage prices (the value of standing timber) in the United States, but lumber prices have risen at an inflation-corrected annual rate of 1.8 percent since 1870 and perhaps longer. This is the only long-term real price increase in U.S. history for any primary natural resource (Barnett and Morse 1963; Ruttan and Callahan 1962). Of course, prices cannot continue to climb indefinitely; Barnett and Morse (1963) and Berck (1979) predicted that the rate of increase would decline, and more recently Sedjo and Lyon (1990) contended that the upward movement came to an end during the past twenty years.

As the stock of natural forests was drawn down during this long period, its depletion drew the attention of the American Association for the Advancement of Science in 1873 and provided the justification for the Forest Reserve Act of 1897, which became the basis for the National Forest System. The U.S. Forest Service, in approximately decennial projections from 1909 to the present, continues to anticipate timber shortfalls, but Clawson (1979) pointed out that Forest Service projections have never been correct, largely because they always underestimate future production and price-induced improvements in wood use and harvest technologies.

Libecap and Johnson (1979) observed that settlers of the forested American frontier harvested the forests and claimed the land as soon as the land had value—to the point at which all value was dissipated in the costs of acquiring the property rights. Furthermore, in separate analyses, Johnson and Libecap (1980) and Berck (1979) observed that fears of excessive harvesting from the natural forests in the Great Lakes region from 1880 to 1920 and from the Pacific Northwest since 1950 were unwarranted. Indeed, for these two great timber-producing regions, real stumpage prices rose at less than the rate of interest, and harvests of the natural stock occurred at rates considerably below expected returns on private capital. After a long period of apparently rational private extraction, the accompanying price increases have slackened, forest investments have become profitable, and the modern U.S. forest industry supports more than 5 million hectares of private plantations.[3]

Industrial Forestry: Other Countries

Chile is another industrial wood basket of the late twentieth century, and it provides a similar story—although without the supporting econometric litera-

ture. In the nineteenth century, the demand for mine timbers led to extensive depletion of the country's natural forests. The large mining interests responded by planting experimental forests to supply their future needs. Agricultural cultivation kept the natural forest in abeyance, and pulse harvesting of the natural forest growth largely satisfied the remaining domestic demand until the 1950s. Since then, expanding demand from Europe, the development of Chile's ports, and (arguably) a government program of forestry assistance, have provided a supporting environment for more than 1.4 million hectares of forest plantations. These plantations are generally located at the margin of good agricultural land; but within much easier acccess to the ports and processing facilities than the natural forests (Vincent and Binkley 1992; Amacher and others 1996).

Several developing countries have begun the transition to plantation production of industrial wood. In Costa Rica the conversion of forests to agricultural land and the growth of industrial and subsistence forest consumption have contributed to deforestation. Little of the original forest remains, and the remaining natural forest is insufficient to ensure sustained operation of the local wood-processing industries. One firm, recognizing the potential long-run gains to continued operation of its mills, has invested in natural forest management on 10,000 hectares in an area in which it has secure property rights (Rice 1993).

In Kenya 90 percent of the industrial wood came from the natural forest in the 1950s. Today 80 percent comes from 180,000 hectares of pine and cypress plantations, and less than 10 percent is harvested from natural forests (World Bank 1992). Although it is clear that land conversion for agriculture is the primary source of deforestation, it is reasonable to assume that forestry only recently began to offer the satisfying financial return necessary to induce private investment. Scherr's (1995) historical evidence for western Kenya paints a clear picture of scarcity-induced household investments in trees following permanent settlement in that region early in this century.

In Malawi, tobacco farmers are the largest consumers of industrial wood, both for posts and for fuel in flue curing. They relied on natural forests on customary lands (lands largely open to first claimants) until Malawi's 3.5 percent annual rate of deforestation and more than 5 percent increase in the price of fuelwood induced both a new wood-saving technology for curing tobacco and self-sufficiency in wood production. Some of the new forest plantations are in large blocks in less populous regions where forest trespass is not a serious problem. Other tree plantings, in more populated regions where trespass is more likely and the protection of forest property rights is more difficult, tend to be in fence rows, farm yards, and along paths and roads near farm operations (Hyde and Seve 1993).

In the Mekong delta of Vietnam, small farmers have responded to the high export price for wood chips (for pulping) by introducing a new tree species, *eucalyptus camalduensis*, for sale to the new export market. They cultivate this new species in private stands and along paths and paddy edges, but always close to the household where private investments are most secure (Byron 1993).

Forest Production for Household Consumption

Farmers in many developing countries have responded to higher prices by planting trees to satisfy household consumption. Several examples from Nepal serve as nice illustrations, in part because Eckholm (1976) made the world so aware of deforestation in that country. Most of the evidence is cross-sectional and is restricted to fuelwood, although many other forest resources (fruit, nuts, forage, and fodder) consumed by subsistence households also exchange in local markets. The patterns of forest extraction and investment for these resources are probably similar to those observed for fuelwood.

Shifting cultivators receive much of the blame for Nepal's deforestation, but careful observations show that they respond to increasing scarcity by settling, establishing common and then private property rights and ultimately introducing more land-intensive and longer-term agricultural technologies (Eggertsson 1990 reviews this literature). The Gurung population of the Annapurna Sanctuary followed precisely this pattern during the course of this century (Stevens 1988). Early in the century this region was isolated, even for Nepal, and the Gurungs cut the forest, grew subsistence crops for a few years, and moved on to cut more forest. Over time population pressures, deforestation, declining agricultural yields, and growing familiarity with new agricultural technologies induced major social changes. The indigenous population is now settled. Private property rights are well defined, and the Gurungs use agricultural technologies such as terracing that are widespread throughout Nepal. Some Gurung landowners plant trees, and the remaining forest has stabilized.

Gautam and others (forthcoming) surveyed small landowners in five communities in Nepal's hills. Many farmers own trees and use them for fuel and construction, as a source of fruit and fodder, and for other purposes. Their private plantings of trees have increased in the past ten years as the forest inventory on common lands has declined. More often, it was the wealthier and better educated landowners who planted trees and adopted other conservation techniques.

Amacher, Hyde, and Joshee (1993) examined household production of fuelwood in two hill districts of Nepal. Fuelwood prices, distance from common forest lands, and the standing forest inventory differed significantly in the two districts. Not all households bought or sold fuelwood, but many did, and all had the opportunity to participate in local markets. Households in the district characterized by lower prices, briefer travel time, and a larger forest inventory (all indicating that scarcity is less serious) relied on fuelwood from the forested commons. Households in the district where fuelwood was scarcer produced more fuelwood on their own lands. Scarcity was also more likely to induce households in the latter district to substitute combustible agricultural residues for fuelwood and to adopt improved cook stoves. A broader survey of households in twenty-nine (of fifty-nine) districts in Nepal's more populated hill and tarai regions produced econometric production and consumption results consistent with the first analysis and with the hypothesis that subsistence households respond to

increasing resource scarcity by increasing their plantings of trees on private land (Amacher, Hyde, and Kanel forthcoming).

In another study on Nepal's tarai, Kanel (1993) reported annual price increases of 16 percent for fuelwood and more than 20 percent for construction wood. He also reported a 1.3 percent rate of annual deforestation regionwide and total deforestation of the region's public forestlands. Private plantations totaled 10,000 hectares in 1981 but expanded to 150,000 hectares by 1991. Barnes and others (1993) made similar observations for the more populated periurban areas of Java, and Krutilla, Hyde, and Barnes (1995) drew similar conclusions for an even broader collection of thirty-three periurban areas in Africa, Asia, the Middle East, the Caribbean, and Latin America.

The counterargument to scarcity-induced investment is that some species and associated forest resources grow only in natural environments. These species are unresponsive to scientific intervention and cannot be domesticated. Brazil nuts are the common example, but Viana and others (1996) have shown that deforestation and higher prices induce successful plantations even in this extreme case. Industrial examples of rubber, oil palm, and coffee trees, and subsistence economy examples of many fuelwood, forage, and fodder species are only better-known cases of the same effect.

Nonmarket Values and Resource Degradation

The argument that market-induced responses to increasing scarcity will correct many forest allocation problems is appropriate for commercial timber as well as for many nontimber forest resources. It leaves unaddressed three issues of great importance: erosion control, biodiversity or genetic reserves, and the control of global climate change.

Controlling Erosion

Erosion is a local problem caused by livestock, shifting cultivation, and logging activities on forested uplands. It affects the adjacent lowlands and watercourses within a watershed. Its solutions must also be local. One solution arises with the shift from forest extraction at the economic fringe to plantation management in higher-value lowland areas. This shifts the eroding activity away from more fragile upland environments and also provides tree cover for more heavily used lowlands. Both steps lessen erosion, but the problem will remain in many areas. Two empirical analyses demonstrate the potential for regional economic gain. Anderson (1987) estimated the expected effects of reforestation on wind control and increased agricultural productivity in northern Nigeria. Yin and Hyde (1995) calculated an 8 percent gain in agricultural productivity attributable to increased tree cover in northern China since 1974.

The evidence from industrial countries (for example, McConnell 1983 and Miranowski 1984) argues that individual landowners correct for the problems of erosion when they own both the sources and the effects of soil loss. This finding suggests that any system that improves private rights for forested property and enables communal arrangements for addressing transboundary problems would also decrease erosion. Where improved property rights and community-imposed landowner rules are insufficient, reforestation and broader restrictions on human access to the forested uplands may be necessary. Enforceable property rights are a prerequisite, however, for effective broader controls and successful public interventions. Their absence may justify custodial responsibility by the forest ministry, but effective administration of custodial responsibilities is an uneasy challenge. Few forest ministries have shown that they are up to it.

Preserving Biodiversity

Biodiversity and genetic reserves are broad international values conferred by highly specialized and generally local forest resources. There is some evidence of a rising international market for the protection of genetic resources (Simpson, Sedjo, and Reid, forthcoming) and some evidence that these values are not large in any aggregate sense (Sedjo 1992; Mendelsohn and Balick 1995). In any event, the market is thin, and these resource values often have to be protected with specialized management criteria or in specialized local forest reserves. The problem is to arrange secure rights for specialized habitats.

Protecting biological diversity is all the more difficult because neither flora nor fauna respect property boundaries. Moreover, protecting a few select individuals or even an ecosystem does not guarantee either diversity within a species or the species' long-term survival. Protecting biodiversity requires land-use arrangements that are more complex than fences and permanent restrictions on forest management in national parks and wildlife preserves.

Furthermore, the protective land-use arrangements must change depending on the type of forest. In tropical forests, local endemism and species specialization are greater. The key issue is ensuring undisturbed regeneration cycles in individual, site-specific populations. In boreal forests the key issue is a shifting forest mosaic with respect to species and age structures. Species turnover or progression is more rapid in boreal forests. Therefore, tropical forests may contain more species diversity, but boreal forests may require larger areas to protect a single species (Vehkamaki and Simula 1995).

As figure 1 shows, the critical forested regions for both erosion and genetic reserves are the open-access forest between points C and B and the region of extraction from mature forests in the neighborhood of point B. The residual natural forest beyond point B is undisturbed by forestry activities; its soil and genetic reserves also remain undisturbed. Forest plantations, in the region of point A, protect the soil, but this region long ago lost most of

its contributions to natural genetic diversity. It is in extensive agriculture (A-C) or the open-access forest (C-B) and the exploitable mature natural forests (the neighborhood of B) where local enclaves of nonmarket environmental values such as watershed protection (erosion) and genetic diversity justify public policy interventions.

Global Climate Change

The importance of global climate change is an unresolved issue, but, if it is important, there can be no doubt that trees provide an important carbon reserve and protection against further global change. All trees store carbon. The storage of carbon increases as trees are planted, grown, cut, stored, and new trees planted. Incorporating a value for protection against global climate change enhances the value of standing forests. In terms of figure 1, it raises the forest value functions and shifts point A to the left, which means that it would have been socially optimal for commercial forest to compete successfully with agriculture at lower forest product prices and at an earlier time. It expands the socially optimal area of land in commercial forests. The social valuation of carbon sequestration, however, is difficult to calculate and even more difficult to impose on land management because this value is held by many consumers who have little personal contact with the forest itself. Furthermore, policies addressing global climate change would also have significant administrative costs and high costs per tree or hectare protected. Therefore, one might hypothesize that correcting those policies in other sectors that have large deleterious spillover effects to forestry and improving the security of property rights to the forest may cause greater shifts in land use at points A and B and save more trees for carbon sequestration than would altering prices and policies to reflect optimal adjustments for global change.

Policy Implications

The first conclusion of a model that shows responses to rising prices is that deforestation is not the ultimate issue often portrayed in popular discussions. Rather, the market sets a limit on the extent of deforestation once prices rise to a level equal to the "backstop" costs of plantation forestry (that is, the cost of planting and managing trees or forests plus the cost of ensuring the rights to this investment).

Important delays may precede the initial investment in tree planting. The first delay occurs while the natural forest is drawn down to the point where its harvest and access costs equal the plantation backstop price. Investor uncertainty due to the long production cycles typical for forests may cause an additional delay. These delays could be arguments for policy intervention, but there is no empirical evidence of their economic importance. One problem is the difficulty

of measuring the aggregate scarcity response of many small landowners. Byron (1984), for example, reported that three-quarters of all fuelwood consumed in Bangladesh comes from forest stands that are too small to be included in the national forest inventory.

Sedjo and Lyon (1990) found that the economic limit on deforestation has been attained for industrial timber demands. Nevertheless, they project that pulse harvests of the world's residual forest stock will provide the majority of industrial timber for the foreseeable future. There is no similar aggregate analysis for worldwide consumption by subsistence communities. In two self-contained local markets where deforestation has been extreme, the situation appears to have moderated. Bluffstone (1995) found that deforestation is stable in Nepal, and Hyde and Seve (1993) projected that plantation investments may offset forest removals in Malawi within ten years. Therefore, continued worldwide deforestation is not as critical an issue as it sometimes seems, either for market-based industrial timber values or for subsistence household values for a wide variety of forest resources.

Spillover Policy Effects

Policies designed for other sectors of the economy often spill over to increase deforestation. Macroeconomic policies that discourage either long-term investments and or a preference for holding real assets, policies that encourage agricultural production, and policies that affect the establishment and transfer of land tenure are common examples.

Forestry's low value means that policies with small economic impacts on other sectors tend to have relatively large unintended spillover effects on forest land use. In terms of figure 1, the shallow slopes of the land-use value functions mean that small increases or decreases in the levels of any of these functions cause larger shifts to the left or right in the location of points A and B and therefore larger shifts in forest land use. Thus, the effects of policy spillovers may be more notable in terms of hectares of forest than in terms of net forest value.

A comparison of Chile and Argentina provides a good example of macroeconomic policy impacts. Large parts of Chile and Argentina have similar forest-growing conditions. Argentina has the advantage of proximity to their mutual European markets. (Chilean exports must pay the duty for passage through the Panama Canal.) Nevertheless, Chile is a major wood exporter, while Argentina's wood exports are almost nonexistent. Argentina's high inflation and real interest rates and its unstable macroeconomic policies discourage long-term investments in all sectors, including forestry. Chile's stable macroeconomic environment permits long-term planning with confidence, and one result is extensive investment in plantation forests. Chile's macroeconomic policies raise the value of forest plantations, provide an earlier incentive for forest plantations, and expand the region of successful plantations, marked in figure 1 by the neighborhood around point B.[4]

For many countries, subsidies on agricultural inputs and price supports on agricultural outputs ensure that the market value of agricultural land is greater than its social optimum. This shifts point A in figure 1 to the right, increasing the land area devoted to agriculture, extending the amount of time before forest values are competitive with agriculture, delaying investments in trees, and decreasing the number of hectares of tree crops. There are few empirical analyses of the effects of agricultural policies on the forestry sector, but extensive worldwide intervention in agriculture supports an argument that agricultural policies can be important sources of deforestation.

Rules for establishing land tenure are the third example of policies designed for other purposes that can have an unusual effect on forestry. Any government's formal rules of tenure are designed to be general to any land use or claimant. The costs they impose are relatively constant per hectare for any land use; thus their relative impacts are often greatest on low-value land uses such as forestry. There is no problem where a country is still developing, the rules are informal, and local customs for recognizing land claims arise on their own. This has been the experience in the agricultural conversion of forest land in West Africa, and the resulting land-use patterns are efficient (Migot-Adhola and others 1991).

The legal codes of industrial countries and developing countries in Asian with long histories of formal government structure spell out the rules for establishing tenure. These codes often constrain the initial allocation of claims on the forest frontier, but the final allocation is efficient wherever the code permits initial claimants to transfer the land to higher-value uses. Libecap and Johnson (1979) showed that this was the experience for western U.S. expansion in the nineteenth century. Government policy required the initial claimants to be small farmers, but these claimants had full rights to exchange their new property after some minimal period, and many farmers (and speculators who called themselves farmers) quickly sold their rights to other economic enterprises.

Often, however, the formal rules of tenure establish preference among initial claimants and restrict land transfers by the claimants. For example, many countries permit claims on the forest frontier only with evidence of capital improvements such as fences and forest removal. This rule prevents claims for natural forest management. Binswanger (1989), Mahar (1989), and Schneider (1993), for example, showed that preferential treatment for the livestock industry (and the implicit restriction on comparable claims for forest management) played an important role in Amazonia's deforestation in the 1980s.

Restrictions on land transfers can be an important problem in countries with established formal institutions but without the means to enforce the formal claims on the forest. For example, Feder and others (1988) showed that the inability of Thailand's Royal Forestry Department to enforce government claims on the forest, together with its reluctance to transfer land to trespassing (and probably higher-valued) users, created inefficiencies in land use. In general, government restrictions on transfers to high-valued agricultural uses also remove the incen-

tives for conservation practices and long-term agricultural management by settlers at the forest fringe in many Asian countries. Because the forest ministries are ineffective in restricting illegal access to the forest, squatters and other trespassers engage in short-term agricultural and forestry practices that increase deforestation and increase erosion (Cruz, Francisco, and Conway 1988; Amacher and others 1995).

Two hypotheses emerge from this discussion. First, restoring macroeconomic stability and correcting policy failures that inadvertently spill over to affect forestry may have a greater positive effect on the forestry sector and on the amount of residual land that remains in forest than do all preferential forestry sector policies. Second, permitting transfers of land use rights to the highest-valued use and permitting future land exchanges as values eventually instruct would improve long-term land use, limit erosion, and improve the conditions of indigenous peoples. Neither hypothesis suggests a total solution; both suggest that current policy distortions are worse than an unfettered market.

Forest Rent

The magnitude and allocation of forest charges (rent) are subjects of some contention. Gillis (1988) and Vincent (1990) argue that forest rent is large, that it belongs to the government, and that its assignment makes a difference in efficient levels of output. Paris and Ruzicka (1991) and Hyde and Sedjo (1992) argue that its magnitude varies from case to case and that its best allocation (to the government or to forest concessionaries) is a distributive matter of undetermined merit, but one that does not alter efficient land use. These arguments are valid for the publicly owned share of the forest. The rent in question is generally associated with mature natural forests and commercial harvests (in the neighborhood of point B in figure 1). Net resource values in this region are too low to justify long-term management. The fact that most public forest lands went unclaimed by earlier commercial interests is evidence that the rents accruing to public forest management are not always large and economically important.

Where the forest ministry claims the property rights and charges royalties for resource extraction, it is often the case that either the minimum fee is too high and there are no bidders or that the ministry must subsidize harvests. Both conditions suggest a low value for standing forest resources and point to the financial efficiency of open-access management. The U.S. Forest Service, for example, recently noted that 62 of its 156 national forests suffer net financial losses on overall timber sales. Many more national forests suffer net losses on individual timber sales. In other examples, the Philippine Bureau of Forestry Development operates at an overall net loss on its timber sales (Boado 1988), and the industrial forests of northeastern China suffer a similar shortfall. Maintaining mill employment is the key objective in northeastern China, and the government

subsidizes industrial forests to ensure harvest levels sufficient to protect mill employment.

If this argument is correct, it also begs the question of why the payments for some new timber concessions are so high. Where large rents are apparent for lands at the margin of previous forest resource extraction, they must be created from some recent relaxation of a restriction on forestry activity. In this case, the rent is truly a return to relaxing the restriction. (Deacon 1994 and 1995 more broadly suggests that these rents, and deforestation in general, are largely determined by the uncertainty of widely variable political conditions.) If the forest had value without the restriction, it would have been harvested earlier when its net value was newly positive and still small. Surely all private operators would have had sufficient incentive to harvest each year all the way to the geographic point where their access and harvest costs depleted the entire value of the standing resource. Rents in subsequent years can appear only where previous extraction was incomplete, and incomplete extraction would occur only where harvest policies were restrictive.

What kinds of restrictions create rents? Limited access to the forest and public policies that make harvest uneconomical are two examples. As for the former, much of the forest in northeastern Thailand, Liberia, the Amazon, and the interior of Canada and the United States would not be open for harvest had roads not been built, and forest resource values alone often cannot justify these roads. The "allowable cut" policy that restricts timber harvests to biological timber rotations is an example of the latter.[5] The allowable cut policy is taught at Dehra Dun, India, and Los Banos, Philippines, in two of the oldest and largest forestry schools in the world. It is common to western European and North American forest ministries and probably to most of the forest ministry officials and schools around the world.

This perspective should change the debate on forest rent. In sum, forest rent is seldom large, and it is often smaller than expected because analysts overlook the costs of administering timber sales. In those important but specialized cases where the rent is large, it begs questions about the forest management activity or policy change that created the rent. Does the same policy exist elsewhere? What are its advantages? Could more rents be captured by applying the same management activity or the same change in forest policy to other timbersheds and other forests in the same region? If so, should that activity or policy be expanded?

Forestry Research and the Effect of New Technologies

The theme of forestry as a low-value and low-cost resource continues as an important explanatory factor, this time for its effect on locating successful opportunities for research and technical change. Successful research is defined by technological breakthroughs and the adoption of new technologies that lower

production costs. Yet production costs are already very low throughout most forestlands. Therefore, the opportunities for research and technological change are small. Indeed, too often, the experimental successes of forestry research are uneconomic in broad field applications because the costs of new, higher biological yields are greater than the costs of harvesting natural forest resources. Consider the potential impacts of research and the likely adoption of new technologies for the five categories of forest land use.

- *Residual forest land.* Shifting cultivation and parks for recreational uses are the only productive activities. Only research on subsistence agriculture or research that extends nonconsumptive recreational and aesthetic opportunities from a given preserved area can affect them; research on production forestry cannot.
- *Degraded open-access forests and mature natural forests.* Production costs are zero in these regions. The only costs are those relating to access and to the harvest operation itself. Therefore research impacts in this region are restricted to technologies such as improved saws or cheaper transportation systems that reduce harvest or access costs, or to institutional changes that decrease the costs of establishing and protecting secure rights to the land. The technologies serve to extend the region of current harvests farther into the residual forest (or farther to the right in figure 1). The institutional changes enable land conversion from the region of open-access pulse harvests to sustainable forest plantations.
- *Private tree plantings and commercial plantations.* Only in these regions can growers take advantage of the full range of new cost-saving forest production technologies. In addition, wood-saving technologies such as improved stoves (in subsistence economies) and improved wood utilization practices in the mill (for industrial forestry) are candidates for adoption in regions where the price of wood is high enough to justify investments in plantations. (See Scherr 1995 and Patel, Pinckney, and Jaeger 1995 for findings on household plantations in Kenya; Amacher, Hyde, and Rafiq 1993 on seedling distribution in Pakistan; Amacher, Hyde, and Joshee 1992 on stoves in Nepal; and Barnes and others 1993 on the adoption of improved stoves in general.)

The policy instructions indicate that biological research must focus on the species and forest types that are appropriate for industrial and smallholder plantings—and only in locations where such planting will soon or already occur. Fortunately, the increasing practice of farm forestry indicates that the opportunities for biological forestry research are increasing. Biological research should refrain from activities designed to improve species and forest products characteristic of the areas of mature and open-access natural forests. New biological technologies for these regions will not be adopted.

Social science research and institutional change, of course, may still offer possibilities in the regions of open-access harvests that might become pri-

vate property or well-managed commons. The research objective should be to find cheaper ways to establish and protect the full range of long-term property rights to these forests, including the right to legal transfer. Successful applications of this research would probably be concentrated in countries where established and inflexible formal institutions hamper private land claims and transfers, or in any country with serious erosion problems or important sources of biodiversity.

Conclusions and Final Observations

Market responses to commercial forest values and subsistence household responses to available forest resources create limits to potential deforestation. Both economic intuition and empirical evidence from a broad array of industrial and developing countries, temperate and tropical, support this argument. Furthermore, policy interventions to correct problems associated with forest land tenure, deforestation, and forest management do not necessarily improve on market-based solutions because forest resources and forest land generally have low values and are widely dispersed. Finally, forest policy interventions are often ineffective because they require extensive monitoring and administrative costs—which the low-value resources at risk cannot support.

This is a modest argument, and the basic points should be simple and clear. They are important only because today's policy environment overlooks them all too often. This encourages public forest management and broad-based forest policy interventions, despite general recognition of the historic inefficiencies of forest ministries and previous forestry regulations. Perhaps it is time to recognize that some of the merits of deregulation and structural adjustment commonly acknowledged by policymakers in other sectors also pertain to forestry.

How then do we identify the targets for further inquiry and useful intervention in forest policy? Such interventions typically occur at the margins of the various land-use categories. The first target is the collection of existing macroeconomic and agricultural policies that spill over to discourage forest investment. The second is the assortment of existing policies for establishing secure rights to forest land and for transferring these rights. Many formal rights to forest resources are static and final. They are unresponsive to economic change and to the developing economic validity of private (or well-managed common) ownership of natural forests. These policies also delay socially optimal forestry investments and conservation practices. Finally, both erosion of forested uplands and protection of genetic reserves may require more aggressive policy proscriptions. They call for interventions that constrain market solutions, but only in specific locations where erosion extends beyond the boundaries of any single ownership or where preserving a natural forest ecosystem is desirable. It is a myth that all forests everywhere support multiple and significant nonmarket values.

Self-correcting adjustments to scarcity may create two new problems, particularly for the poorest households in the lowest-income countries. Once local subsistence farmers begin planting trees, they must forgo other production on their scarce household land. The poorest landowners may be forced into trading trees for nutrition when they give up agricultural production for trees. Landless households may suffer even more because they do not have the option of planting trees on their own lands. Expanding markets for contract labor may solve the latter problem (Bluffstone 1995), but where the markets for contract labor are not expanding, the only options for landless households may be to trespass to obtain forest products or to incur the opportunity costs of collecting from the ever-more-distant open-access forests. The alternative scenario is that some landless households will supply forest labor, and the value of their labor will increase as the value of deforestation and forest products increase. In either scenario, the status of the landless, and not deforestation, may be the most serious result of increasing forest scarcity—and it is relatively unexamined as yet.[6]

Notes

William F. Hyde is professor and Gregory S. Amacher is assistant professor in the Forestry Department at Virginia Polytechnic Institute and State University; William Magrath is senior economist in the Agriculture and Forestry Production Systems Division of the World Bank. Matti Pallo, Marian S. de los Angeles, Luis Constantino, and Robert Anderson shared critical insights during the preparation of this article. Earlier versions were presented at the annual meeting of the International Association for the Study of Common Property in Manila, June 15–19, 1993, and the European Association of Environmental and Resource Economists in Dublin, June 22–24, 1994.

1. Several recent assessments confirm this model for a relationship between access and forest cover in Belize (Chomitz and Gray 1994), Bolivia (Robbins, Kenney, and Hyde 1995), the Philippines (Liu, Iverson, and Brown 1993), and Tanzania (Hofstad 1995).

2. Nevertheless, von Thunen (1875) also places forest plantations closer than agriculture to the town and the local value center. For isolated German states in 1875, as for some subsistence agricultural communities in the 1990s, land used for these plantations had a higher net value for fuelwood production than for agriculture.

3. Harvests from the public forests are a more contentious issue. The general view is that harvests have been too slow in some regions, too rapid in others, and seldom at rates justified by either private or social criteria. See Berck (1979), Hyde (1980), and Repetto (1988).

4. The analyses of general macroeconomic and trade policy effects on the forestry sector are scant. Binswanger (1989) identified a variety of fiscal and monetary policies that encouraged deforestation in the Brazilian Amazon. Browder (1987) observed that Brazil's general export promotion policy encouraged a predatory system of advance timber purchasing that, for one company alone, extended harvests on marginal forest land in Rondonia by 300,000 hectares. Boyd and Hyde (1989) concluded that in the United States a favorable capital gains tax policy had more effect than direct forest sector policies.

5. "Allowable cut" has many meanings. It variously can mean long- or short-run planned timber sales, successful bids for a harvest over a period of time, the model for determining a "planned" sale, or reported harvests for a preceding year. The term must be used with care.

The general model taught in forestry schools and applied by forest ministries around the world begins with a biological definition of productive timberland that generally overstates the economic forest land base. It estimates harvests from these lands as some variant

of the volume or area of mature forest divided by the harvest age at biological maturity, plus average annual growth for the full area. Biological rotations depend on the species, but they generally exceed economic rotations by 35 percent or more. For land that is economic, this model sharply constrains harvests. Because all land in the analysis is not economic, the net impact on harvest levels is uncertain and varies from case to case. The net economic effect is always negative. See Davis and Johnson (1987) or Hyde (1980) for statements of the allowable cut model and Hirshleifer (1974), Samuelson (1976), and Hyde (1980) for detailed critiques.

6. The exceptions in the economic literature are Kumer and Hotchkiss (1988), Barnes and Qian (1994), Larson and others (1996), and the work of N. S. Jodha, summarized in Jodha (forthcoming).

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