18 Balancing Agricultural Development and Environmental Objectives

ASSESSING TRADEOFFS IN THE HUMID TROPICS

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MANY CONCERNS, CONFLICTING INTERESTS

This volume so far has presented numerous issues, opportunities, and concerns from specific national and thematic perspectives on tropical forests and deforestation. This chapter attempts to pull these together through analysis of tradeoffs across those various perspectives. And, indeed, everyone in the world seems to want something from tropical forests. Forest dwellers want to continue aspects of their traditional way of life based on hunting and gathering while improving the welfare of themselves and their families. They are losing their land to migrant smallholders, who clear small amounts of forest to earn a living by raising crops and livestock. Both these groups tend to lose out to larger, more powerful interests—ranchers, plantation owners, large-scale farmers, or logging concerns—whose aim is to convert large areas of forest into big money. Outside the forests is the international community, who want to see forests preserved for the carbon they store, which would otherwise contribute to global warming, for the wealth of biological diversity they harbor, and for the many other ecosystem services they provide.

Deforestation continues because converting forests to other uses is almost always profitable for the individual, household, or firm that engages in it. However, society as a whole bears the costs of lost biodiversity, global warming, smoke pollution, and the degradation of water resources. Every year the world loses about 13 million ha of tropical forest, an area more than three times the size of Belgium. None of the land use systems that replace this natural forest can match it in terms of biodiversity richness and carbon storage. However, the land use systems that replace the forest vary greatly in the degree to which they combine at least some environmental benefits with their contributions to economic growth and poor peoples' livelihoods. Therefore it is always worth asking what will replace forest (and for how long), both under the current mix of policies, institutions, and technologies and compared with possible alternatives, some of which may leave forests largely intact. In other words, what can and should be done to secure the best balance between the conflicting interests of different groups, including some who are poor and experience chronic hunger?

FORCES DRIVING TROPICAL DEFORESTATION

Most often, blame for tropical deforestation falls exclusively on specific groups, such as smallholders practicing shifting cultivation or large companies growing plantation crops or raising cattle. Few studies have attempted to gain an overall picture of forest uses and users by evaluating and comparing the evidence from a large set of locations.

A review by Geist and Lambin (2002) has provided a framework for analyzing and classifying the causes of deforestation. They examined and compared the factors at work in 152 cases of tropical deforestation in Africa, Asia, and Latin America. They distinguish between the proximate causes of deforestation—human activities on the ground at local level—and the larger driving forces that underlie these activities. This is an improvement on previous thinking because it recognizes that the people in the front line of deforestation—those wielding the chainsaws or driving the bulldozers—do not make their decisions in a vacuum but are strongly influenced by macroeconomic and social factors operating at the national, regional, or global levels, factors over which they have little control.

In their analytical framework, four broad clusters of proximate causes (agricultural expansion, wood extraction, infrastructure development, and other factors) are linked to five clusters of underlying causes (demographic, economic, technological, policy and institutional, and cultural). In each case, the clusters are subdivided into more specific factors (figure 18.1). For example, agricultural expansion may take the form of permanent cultivation, shifting cultivation, cattle ranching, or colonization.

A mix of causes normally is at work when deforestation occurs. The review goes on to identify what it calls causal synergies: associations of proximate and underlying causes that help to explain deforestation more convincingly than previous single-factor explanations. Together with other recent research, the review by Geist and Lambin tells us much about the real causes of tropical deforestation.

Although agricultural expansion was found to be at least one of the factors in 96 percent of the cases, shifting cultivation of food crops by smallholders, so often thought to be a major cause, was in fact a minor contributor to deforestation. Other forms of agricultural expansion, such as permanent cropping and cattle ranching, appear equally or more significant in most regions, although the agroecological and policy factors influencing this cause of forest loss vary widely across regions—with very different pathways identified for the Amazon, the Congo Basin, and Southeast Asia—and even within regions across countries.

Far more influential than shifting cultivation, or indeed any of the proximate causes of deforestation, are the macroeconomic forces that create the incentives to which individuals respond. Often, these forces manifest themselves as shocks that destabilize the lives of poor people; for example, an increase in urban unemployment may trigger reverse migration into the countryside. These shocks punctuate longer periods in which social and economic trends bring about more gradual changes in the opportunities available to poor rural people, such as the steady growth of the international timber trade or of demand for livestock products and the steadily expanding ecological and economic footprint of distant city markets. The economic integration of forest margins and the continual development of product and labor markets that accompany this process are factors at work in almost all cases.

Strongly associated with the influence of macroeconomic forces is the building of roads. Often paid for by logging companies or through international aid, new roads open up forest areas first for wood extraction and then for the expansion of agriculture. New migrants colonize roadsides and use roads to obtain inputs and deliver their produce to markets. By linking forested areas to the broader economy, roads lower costs and increase returns of conversion and thereby heighten the sensitivity of these areas to changes in macroeconomic conditions.

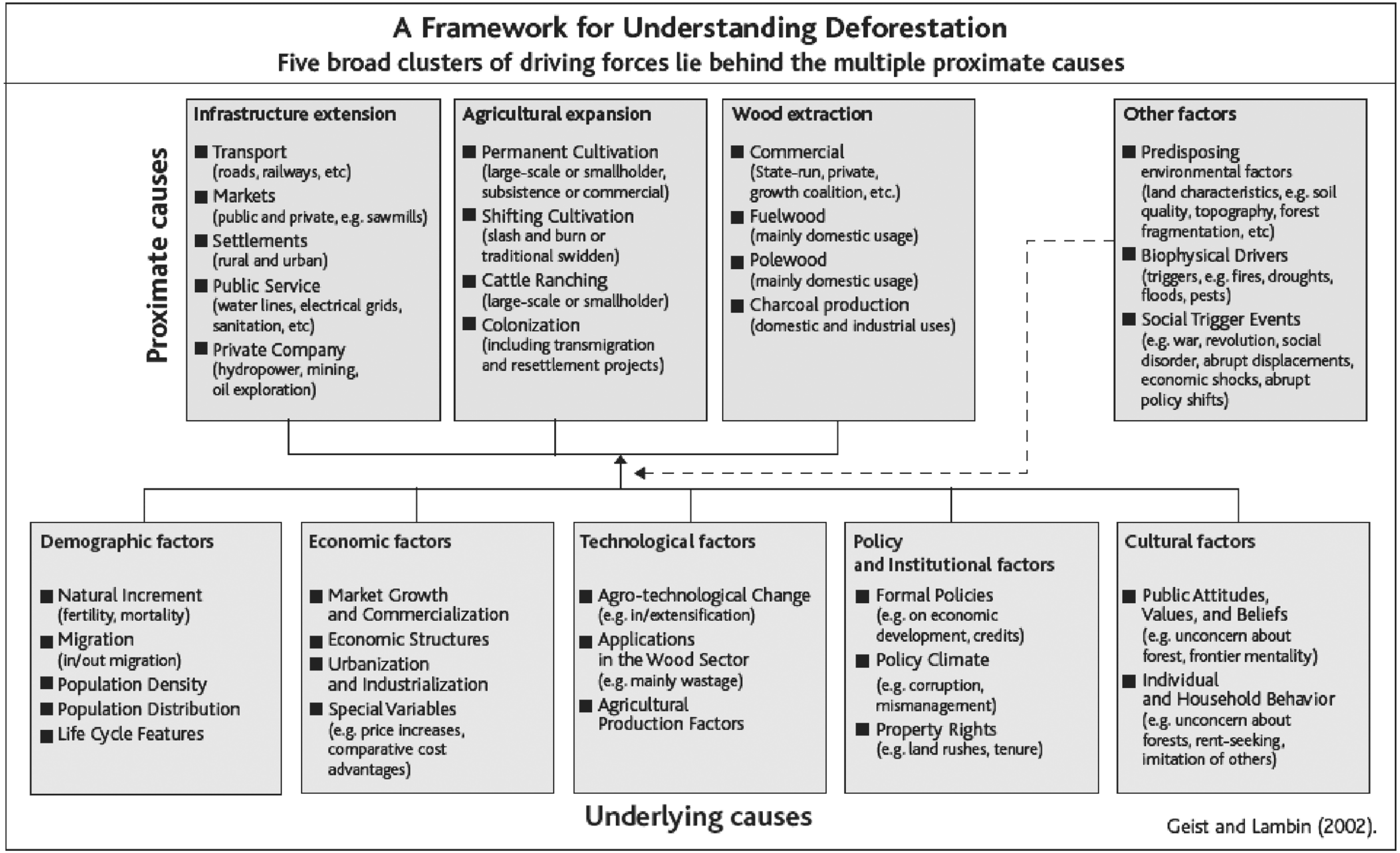

Figure 18.1 Causes of deforestation: Five broad clusters of underlying driving forces underpin the proximate causes of tropical deforestation (Geist and Lambin 2002).

The findings of Geist and Lambin confirm those of the location-specific studies conducted by Alternatives to Slash and Burn (ASB) and by colleagues at the Center for International Forestry Research (CIFOR) in tropical forests of Southeast Asia, the western Amazon, and the Congo Basin, as shown in the following examples.

Brazil: How Macroeconomic Factors and Roads Combine to Influence Deforestation

Logging, cropping, and ranching (not necessarily in that order) often are identified as the proximate causes of deforestation in the Brazilian Amazon. However, the underlying macroeconomic factors influencing these land uses, some of which can be addressed by policy change, are not often explored and have become more important as new roads have linked activities in the Amazon with other parts of the Brazilian economy.

For example, ASB researchers modeled the effects of various macroeconomic changes on the region's development (chapter 7, this volume; Cattaneo 2003). They found that a 40 percent devaluation of the Brazilian real against the U.S. dollar would lead to increases in deforestation of 6 percent in the short term and 20 percent in the long term, with an increase in logging of 16 to 20 percent. The production of annual crops and livestock would expand rapidly to fill the shortfall in national demand for foodstuffs as other regions switched to export crops. Building more roads—planned under a government development strategy for the region—would reduce transport costs by 20 percent, driving an increase in deforestation of 15 to 40 percent as the returns to cultivating arable land rose.

Cameroon: How Macroeconomic Shocks Affect Farmers' Actions

Cameroon is the only ASB case study country in which shifting cultivation appears as a significant proximate cause of deforestation (chapter 14, this volume). Yet even here, macroeconomic policies and economic shocks drive change. Cameroon provides a textbook case of how economic signals alter the attractiveness of different cropping systems to small-scale farmers, with major implications for deforestation rates (Mertens et al. 2000; Ndoye and Kaimowitz 2000; Sunderlin et al. 2000; Gockowski et al. 2001). From 1977 to 1985 Cameroon enjoyed an export-led boom based on oil, coffee, and cocoa. Migrants from the countryside flocked to take up jobs in the cities, while the rural population switched from subsistence farming to growing tree crops for cash. This boom period was followed by an abrupt decline in the second half of the 1980s as the country's oil ran out and the international prices of all three of its export commodities slumped. In 1989 shrinking export revenues forced the government to stop subsidizing agricultural inputs and to halve the prices of coffee and cocoa offered to farmers. These measures were followed, in the early 1990s, by imposed structural adjustment measures that resulted in draconian cuts in public sector employment and wages. Finally, Cameroon's currency was devalued in 1994.

The crisis had a dramatic effect on Cameroon's rural areas. Satellite imagery shows that in 1986 to 1996, annual deforestation had doubled over its 1973 to 1986 level in areas close to the capital city and quadrupled in more remote, thickly forested areas (Sunderlin et al. 2000). As the crisis deepened, rural–urban migration first slowed and then went into reverse as impoverished city dwellers returned to the countryside to take up farming. The population of rural villages grew by only 1.6 percent in the 1976 to 1987 period, but by 24 percent in 1987 to 1997 (Sunderlin and Pokam 2002). Most of the returnees put their efforts into growing food crops to ensure family food security and also produced some food for the market.

Existing farmers also grew more food crops while maintaining or expanding their area in tree crops in the hope that high prices would return. The switch to food crops, which was more pronounced in remote, thickly forested areas, greatly accelerated deforestation because food crops tended to be established on newly cleared land rather than on old plantations (Sunderlin et al. 2000).

Four other factors in the larger economy drove the expansion of food cropping: Demand for food crops rose as food imports declined during the crisis, the phasing out of subsidies for inputs forced farmers to cultivate larger areas to meet production goals, some flexibility in gender division of labor allowed an increase in labor inputs, and logging, which clears the way for food and cash crops, accelerated after the 1993 currency devaluation.

The Cameroon case reveals how the effects of macroeconomic forces are mediated by the responses of thousands of small-scale farmers. But it also shows that these forces affect the pace, location, and proximate causes of deforestation rather than whether it happens at all. In other words, changes in macroeconomic conditions can replace one cause of deforestation with another.

Indonesia: How Multiple Actors Jostle for Profitable Opportunities

Forest conversion in Sumatra, Kalimantan (Indonesian Borneo), Sulawesi, and other "Outer Islands" of Indonesia involves a range of actors and objectives. Local smallholders, migrants, loggers, large-scale tree crop estates (including industrial timber plantations), and government-sponsored resettlement schemes (called transmigration) all play a role in forest conversion. A large volume of literature exists documenting aspects of land use, cover change, and forest conversion in Indonesia, but much of the data in these documents is unreliable or extremely difficult to interpret beyond the scale of case studies. So although smallholders often receive much of the blame for forest conversion, it is very difficult to place accurate numbers on areas converted by the various agents responsible for deforestation in Indonesia.

The island of Sumatra was chosen to represent the lowland humid forest zone of Asia for the global ASB project (Tomich and van Noordwijk 1996; Tomich et al. 1998b; Murdiyarso et al. 2002; chapter 13, this volume). Most of the ASB work in Sumatra has concentrated on benchmark sites in Jambi and Lampung provinces, both of which are located in Sumatra's broad peneplain agroecological zone. The peneplains have been the focus of government-sponsored transmigration schemes, large-scale logging, and various large-scale public and private land development projects since the 1970s.

As with Indonesia as a whole, there are too many holes and inconsistencies in the data to distinguish with any precision the impacts of the various actors, large and small, on deforestation in Sumatra. However, three broad conclusions can be inferred from an overview of the literature (Lewis and Tomich 2002), drawing particularly on extensive reviews of available evidence conducted by Dick (1991) and Holmes (2000) and cross-checked by ASB researchers using a geographic information system. Specifically, for the period 1980 to 1998, approximately one-quarter of total deforestation in Sumatra can be attributed to large-scale estates, and a roughly equal share can be attributed with some confidence to smallholder activity, although the available statistics probably skew this overall percentage downward. However, about half of Sumatran deforestation remains largely unattributable for that period, representing the actions and interactions of smallholders (both local and migrant), large-scale tree crop and industrial timber estates, medium-scale absentee investors in tree crop plantations, illegal encroachment on "protected" forest and clear-cutting of large-scale timber concessions, and periodic fires.

Dick (1991) and Holmes (2000) both concluded that deforestation resulting from individual actions of small-scale farmers was the most difficult category to assess for large areas. Moreover, the term *shifting cultivator* has been consistently criticized as being both misleading and inaccurate as a category of smallholder activity. This is particularly true in the case of Sumatra, where the textbook version of traditional shifting cultivation (annual crop rotations with bush fallow) had nearly disappeared by the 1990s (Tomich and van Noordwijk 1996). This is consistent with ASB researchers' estimate of very low returns to labor in shifting cultivation and attractive returns to tree crop–based systems (table 18.3 later in this chapter).

Three groups of smallholders were studied in detail in ASB research in Sumatra: local people, spontaneous migrants, and government-sponsored transmigrants. The general features of the livelihood strategies of these three groups are remarkably similar. Although food crops are produced after initial forest conversion, food production per se does not appear to be the primary objective. Hence, food production insecurity was not a major driving force in Sumatra in the 1990s. And although poverty clearly plays a role as a driving force, for reasons elaborated in this chapter, it is clear that certain measures to raise income run the risk of increasing deforestation. Thus, poverty alone is too simplistic an explanation, and numerous push and pull factors affecting migration must be considered.

Although shifting cultivation has largely disappeared in Sumatra, all households, whether local farmers, government-sponsored transmigrants, or spontaneous migrants, use slash-and-burn for land clearing. When slash-and-burn is used by smallholders in Sumatra's peneplains, it often is to clear and replant old rubber agroforests ("jungle rubber"). With increasing pressure on land, however, a method of "internal rejuvenation" by gap replanting appears to have become an attractive alternative to the slash-and-burn of rotational rubber systems (chapter 9, this volume). Migrants (mainly from Java) have been quick to adopt rubber-based systems similar to those developed and used by the indigenous Sumatran population since early in the twentieth century. The rapid spread of rubber as a smallholder crop in Sumatra since the beginning of the twentieth century has been a major force behind forest conversion.

Thus, deforestation caused by slash-and-burn by Sumatran smallholders has been driven in large part by profitable income-generating opportunities, specifically production of tree crops. Some of main lessons from Sumatra for the global ASB project are that some tree crop–based systems are economically attractive alternatives to extensive food crop–based systems, and these alternatives to slash-and-burn help to alleviate poverty. But, as pointed out by Angelsen (1999), these profitable alternatives also can speed up rather than slow down the rate of natural forest conversion because they attract an inflow of migrants seeking a share of the economic benefits of these systems.

It is revealing that Lampung Province is sometimes described as "North Java," indicating its role as a focal point for migration from densely populated Java. The movement of people between Java and Lampung, and additional efforts by government during various periods in the twentieth century, are key to understanding the landscape dynamics. Only a minority of residents of Lampung can claim Lampungese decent.

Macroeconomic forces fundamentally affect households' livelihood options and thereby reduce (or intensify) forces that push migrants to forest margins; macroeconomic, trade, and sectoral policies also affect resource management decisions once they get there. In times of rapid economic growth and industrialization, migration to urban and industrial areas has been a major escape route from rural poverty. A number of these migratory forces reversed during the Southeast Asian monetary crisis in the late 1990s. Beginning in August 1997, Indonesia had one of the greatest real exchange rate depreciations experienced by any country in the last half century. Simulations by ASB researchers using partial equilibrium models of financial returns to various land uses suggest that profitability of many tree-based systems (which produce commodities for export) increased substantially because of that exchange rate collapse, which would boost incentives for conversion of forests to tree crops by both smallholders and large-scale operators (Tomich et al. 1998b:101–102). A survey of more than 1000 households in the "Outer Islands" (Sunderlin et al. 2001) found that these farmers did significantly increase conversion of forest to tree crops during the monetary crisis. (Nevertheless, sample households felt worse off during the crisis, despite income from export crops.)

Jambi Province became a popular destination for migrants (more than 80 percent of whom are from Java) later than Lampung and only after completion of the

Trans-Sumatra Highway in the 1980s. Secondary roads built by logging companies, transmigration projects, and other large-scale actors contributed to forest conversion by making forest access easier for migrants. But construction of main roads such as the Trans-Sumatra Highway and other infrastructure investments probably had even more powerful effects on people's access to forest resources and the marketing links that condition land use choices. To examine the complex issue of the two-stage deforestation process in which smallholders "encroach" on logged-over forest, a sample of 9477 data points was drawn from lowland forest logged in Jambi in the 1980s using a 1-km grid and, following Chomitz and Gray (1996), a multivariate econometric model was used to control for biophysical differences and estimate effects of distances to main roads and rivers on probability of conversion to rubber agroforests and other uses. Site characteristics (soil and topography) were highly significant, indicating that smallholders are selective in their choice of sites. This model indicated that conversion of logged forest was much more likely within 10 km of main (asphalted) roads (Chomitz et al. 1999).

Deforestation by Sumatran smallholders also is driven by their desire to establish claims over land. Planting tree crops such as rubber is a well-established mechanism for securing informal land tenure in Sumatra. Where communal forest land has to be cleared before it can be claimed by individual families, this tenure arrangement accelerates forest conversion. Within smallholder communities, slash-and-burn followed by tree planting is the chief means to establish private claims over (formerly) communal land (Otsuka et al. 2001; Suyanto et al. 2001). This is one reason for the existence of extensively managed jungle rubber. In addition to direct effects on conversion, appropriation of large tracts of land for public and private projects can have important effects on smallholders' perception of their tenure security. Even the expectation of new projects can accelerate forest conversion as a preemptive strategy to retain control of land.

As emphasized earlier, smallholders are not the only actors converting forest, nor are they the only group using slash-and-burn in Sumatra. Forest concessionaires, industrial timber estates, tree crop plantations, and transmigration projects all have played a role too. Large-scale operators also use slash-and-burn because it is the cheapest method to clear land. Logging concessions, especially of the 1960s to 1980s, followed by an inflow of spontaneous settlers attracted by opportunities in rubber and other perennial-based agriculture, have completed the process to the point that there is hardly any lowland primary forest left.

Population Pressure from Within and Outside the Forest Margins

Deforestation has often been attributed to population growth per se—the growth resulting from location-specific human fertility. But the Geist and Lambin review, like the Cameroon and Indonesia case studies, shows that migration is a far more important factor: People move, as they have always done, to where the opportunities exist. But institutional and policy-related factors also can be significant underlying causes of deforestation via their effects on population movements. This category of policy-induced causes of deforestation includes colonization in Brazil, transmigration in Indonesia, and other government-sponsored resettlement schemes as well as public investment in transportation infrastructure, subsidies for farming, and policies and institutions affecting property rights, resource access, and land tenure.

At all ASB benchmark sites, managing interregional migration will be key to future land use patterns. Any technology or policy innovation that increases the productivity and profitability of farming in the humid forest region runs the risk that additional land and labor resources will be attracted to that particular activity and bring increasing deforestation. So far, in Cameroon, customary tenure institutions have been sufficiently robust to prevent large-scale interregional migration (Diaw 1997). However, traditional institutions are changing (rapidly in some cases) and cannot be relied on to solely (and peacefully) manage future population movements. Policy action to address these issues is exceptionally difficult.

THE ASB MATRIX: LINING UP THE FACTS IN WAYS USEFUL TO POLICYMAKERS

Policymakers need accurate, objective information regarding the private and social costs and benefits of alternative land use systems on which to base their inevitably controversial decisions. To help them weigh the difficult choices they must make, ASB researchers developed a tool known as the ASB matrix (Tomich et al. 1998b; see also chapter 1).

In the ASB matrix, natural forest and the land use systems that replace it are scored against different criteria reflecting the objectives of different interest groups. To enable results to be compared across sites, the systems specific to each site are grouped according to broad categories, ranging from agroforests to grasslands and pastures. The criteria may be fine-tuned for specific locations, but the matrix always comprises indicators for the following:

- Two major global environmental concerns: carbon storage and biodiversity
- Agronomic sustainability, assessed according to a range of soil, nutrient, and pest trends
- Policy objectives: economic growth and employment opportunities
- Smallholders' concerns: returns to their labor and land, their workload, food security for their family, and startup costs of new systems or techniques
- Policy and institutional barriers to adoption by smallholders, including the availability of credit and improved technology, and access to and the performance of input and product markets

Over the past 10 years, ASB researchers filled in this matrix for representative benchmark sites across the humid tropics. (See tables 18.1, 18.2, and 18.3 for simplified matrices emphasizing quantitative indictors for ASB study sites in three countries; full sets of quantitative and qualitative indicators and complete explanations are available for Brazil in Vosti et al. 2001b and Lewis et al. 2002, for Cameroon in Kotto-Same et al. 2000 and Gockowski et al. 2001; and for Indonesia in Tomich et al. 1998b, 2001.) The social, political, and economic factors at work at these sites vary greatly, as does their current resource endowment, from the densely populated lowlands of the Indonesian island of Sumatra, through a region of varying population density and access to markets south of Yaoundé in Cameroon, to the remote forests of Acre state in the far west of the Brazilian Amazon, where settlement by small-scale farmers is recent and forest is still plentiful. At each site, ASB researchers have evaluated land use systems both as they are currently practiced and in the alternative forms that could be possible through policy, institutional, and technological innovations. A key question addressed was whether the intensification of land use through technological innovation could reduce both poverty and deforestation.

Understanding the Tradeoffs

The ASB matrix allows researchers, policymakers, environmentalists, and others to identify and discuss tradeoffs between the various objectives of different interest groups and to discuss ways of promoting land use systems that seem likely to benefit all groups but were not broadly adopted. The studies in Indonesia and Cameroon have revealed the feasibility of a middle path of development involving smallholder agroforests and community forest management for timber and other products. In Brazil, small-scale managed forestry poses the same potential benefits. Such a path could deliver an attractive balance between environmental benefits and equitable economic growth. *Could* is the operative word, however, because whether this balance is struck in practice depends on the ability of these countries to deliver the necessary policy and institutional innovations (see Tomich and Lewis 2001a, 2001b; Vosti et al. 2002, 2003).

Take the examples of Sumatran rubber agroforests and their cocoa and fruit counterparts in Cameroon. These systems offer levels of biodiversity that, though not as high as those found in natural forest, are nevertheless far higher than those in monocrop tree plantations or annual cropping systems (chapter 4, this volume). Like any tree-based system, they also offer substantial levels of carbon storage (chapter 2, this volume). It is also interesting to note that there are several tree-based systems in Cameroon with similar levels of carbon storage but drastically different profitability and hence attractiveness to farmers (table 18.2 and figure 18.2); this example clearly illustrates the value of the ASB matrix. Crucially, technological innovations have the potential to increase the yields of the key commodities in these systems, thereby raising farmers' incomes substantially, to levels that either outperform or at least compete well with almost all other systems. However, to realize this potential it will be vital to find

Table 18.1 The ASB Summary Matrix for the Brazil Benchmark Site

Land Use System	Global Environmental Concerns		Agronomic Sustainability[a]			National Policymakers' Concerns		Smallholders' Concerns and Adoptability by Smallholders	
	Carbon Storage	Biodiversity	Plot-Level Production Sustainability			Potential Profitability[b]	Labor Inputs	Returns to Labor[b]	Household Food Security[c]
	Above-Ground t C/ha (time-averaged)[d]	Above-Ground Plants (no. species per standard plot)	Soil Structure	Nutrient Export	Crop Protection	Returns to Land (private prices, R/ha)	Labor (person-day/ha/yr)	$/Person-Day (private prices)	Entitlement Path (operational phase)
Forests	148	80	0	0	0	–2	1	1	NA
Managed forestry	~148	NM	0	0	0	416	1.22	20	$
Coffee–bandarra	56	27	0.5	–0.5	–0.5	1955	27	13	$
Coffee–rubber	56	16	–0.5	–0.5	–0.5	872	59	9	$
Traditional pasture	3	10	0 to –1	–0.5	–0.5 to –1	2	11	7	$, consumption
Improved pasture	3	NM	0 to –1	–0.5	–0.5 to –1	710	13	22	$, consumption
Annual–fallow	7	34	0 to –0.5	0 to –0.5	–0.5 to –1	!17	23	6	$, consumption
Improved fallow	~3–6	26	0 to –0.5	0 to !0.5	–0.5 to –1	2056	21	17	$, consumption

NA, not applicable; NM, not measured.

[a]For agronomic sustainability, 0 indicates no difficulty, –0.5 indicates some difficulty, –1 indicates major difficulty.

[b]Prices are based on 1996 averages and expressed in December 1996 reais (US$ = R1.04), discounted at 9% per annum.

[c]For food security, "consumption" and "$" reflect whether the technology generates food for own consumption or income that can be used to buy food, respectively.

[d]Indicates time-averaged above-ground carbon (see chapter 2, this volume).

Sources: Adapted from Vosti et al. (2001b), Gillison (2000a), and chapters 2, 6, and 17, this volume.

Table 18.2 The ASB Summary Matrix for the Cameroon Benchmark Site

Land Use System	Global Environmental Concerns		Agronomic Sustainability[a]			National Policymakers' Concerns		Smallholders' Concerns and Adoptability by Smallholders	
	Carbon Storage	Biodiversity	Plot-Level Production Sustainability			Potential Profitability[b]	Labor Inputs	Returns to Labor[b]	Household Food Security[c]
	Above-Ground t C/ha (time-averaged)[d]	Above-Ground Plants (no. species per standard plot)	Soil Structure	Nutrient Export	Crop Protection	Returns to Land (private prices, $/ha)	Labor (person-days/ ha/yr)	$/Person-Day (private prices)	Entitlement Path (operational phase)
Forest	211	76	0	0	0	NM	NM	—	$
Oil palm	61	NM	–0.5 to –1	–0.5	–0.5	722–1458	93	1.81–2.44	$, consumption
Extensive cocoa	61	63	–0.5	–0.5	–1	424–943	65	1.63–2.13	$, consumption
Intensive cocoa	61	63	0	–1	–1	889–1409	107	1.95–2.36	$, consumption
Food crop–long fallow	63	53	–0.5	0	0	283	44	1.70	$, consumption
Food crop–short fallow	4	63	–1	–1	–1	623	115	1.79	$, consumption

NM, not measured.

[a]For agronomic sustainability, 0 indicates no difficulty, –0.5 indicates some difficulty, –1 indicates major difficulty.

[b]Prices are based on the averages of the different establishment systems, from forest or fallow, for oil palm and whether fruits are sold in the cocoa systems and are expressed in Central African francs (US$ = 577 fCFA), discounted at 10% per annum.

[c]For food security, "consumption" and "$" reflect whether the technology generates food for own consumption or income that can be used to buy food, respectively.

[d]Indicates time-averaged above-ground carbon (see chapter 2, this volume).

Sources: Adapted from Gockowski et al. (2001), Kotto-Same et al. (2000), Gillison (2000a), and chapters 2, 6, and 17, this volume.

Table 18.3 The ASB Summary Matrix for the Indonesian Benchmark Sites

Land Use System	Global Environmental Concerns		Agronomic Sustainability[a]			National Policymakers' Concerns		Smallholders' Concerns and Adoptability by Smallholders	
	Carbon Storage	Biodiversity	Plot-Level Production Sustainability			Potential Profitability[b]	Labor Inputs	Returns to Labor[b]	Household Food Security[c]
	Above-Ground t C/ha (time-averaged)[d]	Above-Ground Plants (no. species per standard plot)	Soil Structure	Nutrient Export	Crop Protection	Returns to Land (private prices, $/ha)	Labor (person-d/ha/yr)	$/Person-Day (private prices)	Entitlement Path (operational phase)
Forest	306	120	0	0	0	0	0	0	NA
Community-based forest management	120	100	0	0	0	5	0.2–0.4	4.77	$, consumption
Commercial logging	94	90	–0.5	0	0	1080[e]	31	0.78	$
Rubber agroforest	79	90	0	0	–0.5	0.70	111	1.67	$
Rubber agroforest with clonal planting material	66	60	–0.5	–0.5	–0.5	878	150	2.25	$
Oil palm	62	25	0	–0.5	0	114	108	4.74	$
Upland rice–bush fallow	37	45	0	–0.5	–0.5	–62	15–25	1.47	Consumption
Continuous cassava–*Imperata*	2	15	–0.5	–1.0	–0.5	60	98–104	1.78	$, consumption

NA, not applicable.

[a]For agronomic sustainability, 0 indicates no difficulty, –0.5 indicates some difficulty, –1 indicates major difficulty.

[b]Output prices are based on 10-yr (1988–1997) averages and expressed in U.S. dollars in 1997 (US$ = Rp2400 in 1997), discounted at 20% per annum.

[c]For food security, "consumption" and "$" reflect whether the technology generates food for own consumption or income that can be used to buy food, respectively.

[d]Time-averaged carbon from Tomich et al. (1998b) and chapter 2.

[e]Social prices, rather than private prices, were used for logging (see chapter 17, this volume).

Sources: Adapted from Tomich et al. (1998b, 2001), Gillison (2000a), and chapters 2, 6, and 17, this volume.

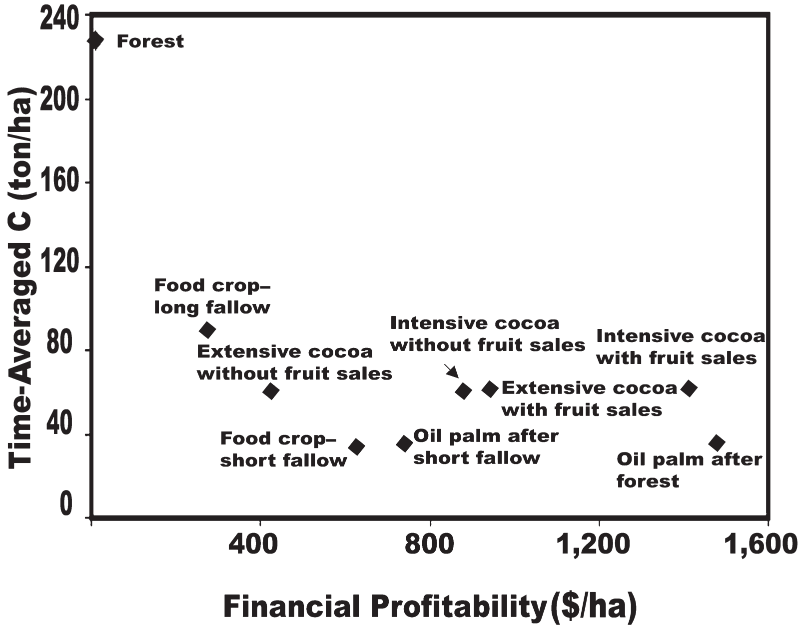

Figure 18.2 Financial profitability of the different land use systems in Cameroon and the above-ground time-averaged carbon stocks. Adapted from table 2.2 and chapter 17.

ways of delivering improved planting material, the key input needed. Other obstacles to more widespread adoption of these agroforestry systems are the higher labor inputs compared with other systems (tables 18.1, 18.2, 18.3), the costs of establishment, and the number of years farmers must wait for positive cash flow (table 18.4).

In contrast, the Brazilian Amazon presents much starker tradeoffs between global environmental benefits and the returns to smallholders' labor. Here the most commonly practiced pasture–livestock system, which occupies most converted forest land, is reasonably profitable and provides the best fit for the situations and needs of smallholders but entails huge carbon emissions and biodiversity loss. Systems that are preferable to this one from an environmental point of view, such as coffee combined with bandarra (*Schizolobium amazonicum* Huber ex Ducke), a fast-growing timber tree, can pay better but have prohibitively high labor costs and are riskier for farmers. An alternative, "improved" pasture–livestock system, in which farmers are expressing interest, offers even higher returns to land and labor but only slightly improves biodiversity and carbon storage. In other words, the land use alternatives that are attractive privately are those most at odds with global environmental interests. Only a radical overhaul of the incentives (or disincentives) facing land users—including smallholders—is likely to change land use patterns.

Just how radical would the overhaul have to be? Depending on the policy instrument chosen, it would have to be very radical—even for a small effect—according to ASB research (Vosti et al. 2002). Consider, for example, the gathering of Brazil nuts

Table 18.4 Establishment Costs and Years to Positive Cash Flow for the Different Land Use Systems for the ASB Benchmark Sites in Indonesia and Cameroon

Meta–Land Use	Establishment Costs[a] ($/ha)		Years to Positive Cash Flow	
	Sumatra	Cameroon	Sumatra	Cameroon
Forest				
Managed	NA	NA	NA	NA
Logged	352	NA	2	NA
Tree Crop–Based				
Complex	117–1119	1188–1304	7–10	7–8
Simple	869–3350	1200	10	5
Crops–Fallow				
Short fallow	NA	NA	Never	NA
Annual crops	NA	NA	2	NA

NA, not applicable.
[a]A calculated using private (financial) prices and discount rates of 10% for Cameroon and 20% for Indonesia.
Sources: Tomich et al. (1998b) and Kotto-Same et al. (2000).

(*Bertholletia excelsa* Humb. & Bonpl.) from the natural forest, one of the most environmentally benign uses of the Amazon's forests. Settlers in Brazil's Acre state clear forest gradually over the years, with pasture for cattle becoming the dominant land use. In addition, approximately 50 percent of farm families in the ASB study sample harvested nuts from the part of their farms that remained forested. Using a specially developed bioeconomic model, ASB researchers explored how labor, capital, and land would be allocated to different on-farm activities over a 25-year period under different price and market scenarios. When the model was used to examine the effects of changes in the farmgate price of Brazil nuts, researchers found that doubling the farmgate price of nuts would not decrease and might even increase the rate of deforestation because farmers probably would reinvest the extra cash they earned in clearing forest faster. This would be a sensible response from the farmers' perspective because, even at the higher Brazil nut price, cattle production would remain by far the more profitable activity. Only in the unlikely event that prices quadrupled over their current level might the rate of deforestation slow, but even then the braking effect would be slight and the modest saving in forest probably would be short-lived. At current prices offered to smallholders, Brazil nut harvesting pays well below the going rate for wage labor. The researchers concluded that subsidizing the price of Brazil nuts would not, by itself, be an effective policy measure for conserving forests, and even if it were effective, the highly charged political issue of paying for the subsidy looms large. Carpentier et al. (chapter 10) found a similar result with coffee systems in the Brazilian Amazon; policy-induced expansion of smallholder coffee production slowed but did not halt deforestation.

Research by ASB scientists of the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) on the pasture–livestock system in the western Amazon of Brazil shows that, with a combination of legumes to enrich pastures and solar-powered electric fences to control the pattern of grazing by their cattle, smallholders could double milk production per cow, triple the carrying capacity of their land, and earn substantially higher profits. And because this pasture system is sustainable without annual burning to control weeds, seasonal smoke pollution would be reduced (see Tomich and Lewis 2002).

So why have these practices not been widely adopted already? First, most smallholders cannot get access to the necessary credit, seeds, or hired labor and are too far from markets to be able to sell the increased milk supplies. Second, aiming for these higher profits entails increased risk, in part because of the higher initial investment costs and the increased dependence on product and input markets. But even if these barriers were eliminated, widespread adoption of such improvements probably would increase—not decrease—the pressure on neighboring forests for two reasons. First, established smallholders probably would use increased profits to clear more forest for agriculture. Second, the greater profitability of the improved system would make the agricultural frontier more attractive to new settlers. Thus under the present mix of policies and institutions, and the incentives they create, the forests in Brazil's western Amazon will continue to fall whether the smallholder succeeds or fails, although the pace of forest conversion and the prevalence of poverty will vary depending on which of the two scenarios plays out.

A case in Lampung Province in southwest Sumatra provides a more encouraging example in which policy action has ensured the continuation of productive and sustainable agroforestry. The Krui people of the area grow rice (*Oryza sativa* L.) in permanent irrigated plots as their staple crop, whereas in the uplands they cultivate a succession of crops, building to a climax that mimics mature natural forest. The tall-growing timber species they plant include the damar tree (*Shorea javanica* Koord. & Valeton), a source of valuable resin that provides a steady flow of income over the long term. The Krui system is able to deliver broad-based growth in which the poor can participate. Combining environmental and economic benefits, the Krui system offers advantages over many other systems that replace or exploit natural forest.

In 1991 the Krui system came under threat. The Suharto government, which had a long history of appropriating traditionally managed land and reallocating it to public or private ownership, declared large areas of the Krui agroforests to be State Forest Land, a classification that would allow logging followed by conversion to oil palm plantations. A forestry company was awarded the right to harvest an estimated 3 million trees—trees that had been planted by the local people.

The Krui stopped planting damar and other tree species, saying that they would not resume until they were certain they would be able to reap the benefits of their work. A consortium of research institutions, nongovernment organization (NGOs), and universities was able to provide support to these local communities through convincing scientific evidence on the social and environmental benefits of the Krui system precisely when it was needed. The scientific evidence helped to legitimize the Krui system in the eyes of professional foresters and refute arguments by vested interests intent on taking the land. The consortium conveyed requests to the government from village leaders for dialogue on the status of their land, arranged field visits for key government officials, and organized a workshop to present research results and discuss the tenure issue. The activities of the consortium were reported in detail to the Minister for Forestry, who signed a new decree in 1998 reversing the official position. This historic decree declared the Krui system to be a unique form of forest use, recognized the legitimacy of community-managed agroforests in Lampung Province, and restored the rights of the Krui to harvest and market timber and other products from the trees they plant. The decree is a powerful instrument for restoring social justice and promoting sustainable development. In the short term it benefits at least 7000 families in the 32,000 ha of reclassified Krui lands. This principle of local management could be extended to benefit hundreds of thousands of rural Indonesians in similar areas. Although it would not work everywhere, Indonesian NGOs have identified at least fifty other communities across the archipelago that have developed production systems comparable to the Krui case that would be ripe for replication of this approach to reform.

The Balancing Act

Based on these results and others presented in this publication, what can be done to balance the objectives of forest conservation and poverty reduction in these tricky settings? Some assert that the best opportunities for meeting both objectives lie in the harvest of various products from community-managed forests. In practice, such extensive systems require low population densities plus effective mechanisms for keeping other groups out if they are to prove sustainable. Where forests are converted, agroforests often represent the next best option for conserving biodiversity and storing carbon while also providing attractive livelihood opportunities for smallholders. However, for both economic and ecological reasons, no single land use system should predominate at the expense of all others. Mixes of land uses increase biodiversity at a landscape level, if not within individual systems, and also can enhance economic and ecological resilience. A mixed landscape mosaic is an especially attractive option in cases such as Brazil, where no single system (with the exception of the experimental small-scale managed forestry system) offers a reasonable compromise between profitability and environmental objectives.

Where the productivity of the natural resource base has already sunk to very low levels, concentrating development efforts on the simultaneous environmental and economic restoration of degraded landscapes is an option well worth exploring. The precise mix of interventions needed—hence the benefits and costs of restoration—varies from place to place. In Cameroon, improved cocoa (*Theobroma cacao* L.) and fruit tree systems could be a win–win proposition in place of unsustainably short-fallow rotations (chapter 14, this volume). In Indonesia, millions of hectares of *Imperata* grasslands are the obvious starting point (chapter 11, this volume; Garrity 1997), as are the millions of hectares of degraded pastures in Brazil. The direction of change in land use systems determines the environmental consequences. For example, if farmers replace unsustainable cassava production with an improved rubber agroforest, they help restore habitats and carbon stocks. But if such a system replaces natural forest, the environment loses.

Intensification of land use through technological change is a two-edged sword. It has great potential to increase the productivity and sustainability of existing forest-derived systems, thereby raising incomes. By the same token, however, these higher incomes attract more landless people to the agricultural frontier in search of a better living. Therefore technological innovation to intensify land use may not be enough to stop deforestation. Indeed, it often can accelerate it (see Angelsen 1999; Angelsen and Kaimowitz 2001a). If both objectives are to be met, policy measures intended to encourage intensification must be accompanied by measures to protect those forest areas that harbor globally significant biodiversity.

RESEARCH INNOVATIONS AND NEW DIRECTIONS FOR ASB

Numerous methodological and organizational innovations were necessary to analyze these tradeoffs between the concerns of poor households, national development objectives, and global environmental concerns. In its early phases, ASB focused on understanding and ultimately quantifying these contrasting perspectives. Standardized methods were used across sites to assess the environmental and agronomic sustainability of the various land use alternatives found on farms in each benchmark site, and participatory methods were used in the same sites to understand household problems, opportunities, and constraints. Similarly, consultations with local and national policymakers provided insights about their perceptions of problems, opportunities, and constraints. In this way, participatory research and policy consultations guided the iterative process necessary to identify and develop policy, institutional, and technological options that are workable and relevant. The ASB's multidisciplinary thematic working groups—on biodiversity, climate change, agronomic sustainability, and global synthesis of implications for policy, institutional, and technological options—developed new methods as needed and ensured that data were comparable across sites. They share a commitment to measurement techniques that are reliable, cost-effective, and therefore readily adoptable by national partners. The ASB researchers have developed and tested innovative indicators of above- and below-ground biodiversity, carbon stocks and greenhouse gas emissions, agronomic sustainability, returns to labor and other determinants of adoptability by smallholders, and national policymakers' concerns. These methods have been applied to a range of land use systems at ASB benchmark sites, and these integrated results enabled the analysts to the link global environmental benefits to sustainable land use alternatives. The basic concepts and methods were made available for education systems at postgraduate level (van Noordwijk et al. 2001b; Wunder and Verbist 2003).

Instead of supporting the simple sustainable–unsustainable dichotomy, ASB results indicate that a remarkably wide range of smallholder land use options can be agronomically sustainable and profitable, depending on the larger environmental and economic context. A key policy insight from this work is that these (locally) sustainable options differ significantly in their environmental impacts and their profitability and adoptability by poor households.

Much of the institutional innovation and reorientation necessary to produce this integrated assessment of tradeoffs and alternatives occurs at the national level as ASB scientists work with partners in national research systems to develop research strategies that combine environmental and development concerns. In Brazil, for example, scientists from Embrapa have taken the lead in incorporating the environmental insights derived from their collaborative work with ASB into Embrapa's agricultural research agenda. In addition, Embrapa scientists are achieving impact at the national level by assisting government officials as they set national priorities for sustainable agricultural and silvopastoral development in the Amazon. With the support of ASB research, Embrapa scientists also collaborated with Brazil's Ministry of Environment in designing a new Forest Code that will have large and widespread implications for Brazil's land use and deforestation policies.

Although no forest-derived system is a perfect substitute for the global environmental benefits of rainforest conservation, ASB results suggest that a middle path of development exists—involving smallholder tree-based systems and community-based and private forest resource management—that could attain an attractive balance between the environment and development. Whether this balance can be achieved depends on a range of policy and institutional innovations, including means to effectively protect natural forests and compensate households for foregone opportunities.

The ASB does not claim to have all the answers to these challenges in hand. However, by building on what is known about participatory research and development and by simultaneously considering the workings of coupled biophysical and socioeconomic systems, we feel that the various ASB consortiums can become vehicles for participation by diverse interests in the countries concerned. Examples include local community associations and conservation groups, local government and civic organizations, local and national NGOs, and policymakers and other officials at various levels.

Looking ahead, the ASB consortium plans to stick to its basic goals: to identify and articulate combinations of policy, institutional, and technological options that can raise productivity and income of rural households without increasing deforestation or undermining essential environmental services. However, the consortium recognizes it is both feasible and desirable to shift its emphasis as follows:

From plot to landscape: The ASB has made important contributions to clarification of tradeoffs between the welfare of poor rural households and global environmental concerns. However, hydrologic, ecological, and other more localized environmental services are a significant gap in this analysis in terms of impacts on local people, priorities of key policymakers, and their potential complementarity with global environmental objectives. The ASB will work to help fill this gap by developing replicable assessment techniques and policy-relevant databases on local environmental services that underpin the sustainability, resilience, and stability of rural production systems at various scales. These methods and databases will build on and extend ASB's repertoire of data and techniques to assess global environmental concerns, agronomic sustainability, household socioeconomic concerns, institutional options, and opportunities for policy reform. A working group on sustainable mosaics of land uses focuses and implements ASB's work in a broader landscape context.

From prescription to dynamic adaptation: The ASB works in a broader context of social, political, economic, and environmental change. Natural resource problems in the tropics are compounded by population growth, climatic shocks such as El Niño, and social, economic, and political turmoil. Clearly no single prescription can deliver a sustainable balance between human needs and environmental services under these shifting circumstances over time and space. The ASB will seek replicable ways to better meet the needs of various stakeholders for methods they can use to monitor and understand the impacts of ongoing change and develop workable responses under dynamic and uncertain conditions. A range of flexible tools—including participatory approaches, formal models, and practical methods to assess impact—will be identified and developed for communities, local government agencies, NGO activists, research managers, and policymakers and other officials. These diverse stakeholders can then better explore their options to influence the individual choices that ultimately determine the rate and pattern of land use change.

From assessment of tradeoffs to management of inevitable conflicts: The ASB's work to clarify tradeoffs between global, national, and local objectives is just the beginning, because achieving impact on natural resource problems depends on effective means to disseminate information to myriad stakeholders in forms they can use. But even more and better information is not enough because social and political mechanisms also are needed to address the inevitable conflicts between the interests of these stakeholders, who range from extractivists and farmers, to national research managers and policymakers, to environmental advocacy groups, multinational corporations, and international development agencies. Unless workable interventions can be identified and disseminated, the future in much of the tropics will include intensifying social conflicts over natural resources and environmental services. The ability to strengthen or create mechanisms for conflict management—between neighboring communities, upstream and downstream populations, and local, national, international, and global concerns—depends on a better understanding of collective processes of governance, including negotiation, identification, and implementation of incentive schemes and sanctions and monitoring and enforcement of agreements (van Noordwijk et al. 2001a). The ASB will seek to identify means and build capacities to manage inevitable conflicts between stakeholders at various scales, including mechanisms to compensate local people for foregone opportunities.

CONCLUSION

The challenge of preventing deforestation is complicated by two facts: In some cases halting deforestation would increase poverty, and in most cases deforestation has no single cause that can be easily identified and tackled. Regarding poverty in forest margins areas, knowing how and how much the forest can help reduce poverty is an essential factor in policy decisions. Regarding the causes of deforestation, it generally results from a combination of different factors, so a mix of policies, rather than a single measure, will be needed. Careful identification of the factors at work in a given location will be a prerequisite for getting the mix right while minimizing the cost to other legitimate development objectives. However, a common and dominant theme for all ASB sites, despite the variability of their socioeconomic and biophysical conditions, is that small-scale farmers cut down tropical forests because current national and international policies, market conditions, and institutional arrangements either provide them with incentives for doing so or do not provide them with alternatives.

If the development community is serious about preventing deforestation, it must pay more attention to powerful macroeconomic forces that drive people to clear land for other uses. At present, these forces can swamp local conservation efforts: The area of forest cleared by successive waves of migrants, facilitated by the building of roads and driven by the lack of opportunities elsewhere in the economy, vastly exceeds the area "saved" by projects focusing on sustainable forest use by individual farms or villages. A major weakness of past conservation efforts is that they have routinely limited their activities to technical interventions at the local level while failing to tackle the larger policy and institutional issues that also determine success or failure. Changing the economic incentives to clear forest into incentives to conserve it will be extremely costly, not only in terms of the direct costs of changing incentives at the local level but also perhaps in terms of the opportunity costs of forgone economic growth. Indeed, the developing countries that still have large areas of natural forest are unlikely to design their macroeconomic policies solely to protect these forests, because they face other pressing development imperatives.

But without tangible incentives linked to the supply of global environmental benefits, people will continue to cut down tropical rainforests. Results from ASB research at all the benchmark sites show that it is futile to attempt to conserve forests in developing countries without addressing the needs and objectives of local people, poor or not. But how can the necessary incentives to conserve be put in place? Only a limited number of policy instruments have been tried, and there is still much to learn about what does and does not work. Part of the answer lies in the developing countries themselves, which can take measures such as securing land tenure and use rights. But should these countries have to shoulder the entire financial burden of forest conservation when all face urgent development imperatives, such as educating and vaccinating rural children?

If the international community wants the global benefits of rainforest preservation, it is going to have to pay some of the costs. Opportunities for changing tropical land use patterns through the Clean Development Mechanism of the Kyoto Protocol are being explored as one of many possible approaches to environmental service payments. In Latin America, pilot carbon sequestration projects implemented after the Earth Summit in Rio de Janeiro have demonstrated the economic feasibility of carbon storage by smallholders at costs likely to be attractive in a global carbon market (CIFOR 2000; also see Smith and Scherr 2002). The ASB research provides evidence of the potential responsiveness of Brazilian smallholders to payments for carbon storage and forest conservation (Carpentier et al. 2000). If an institutional framework can be designed to efficiently deal with the significant transactions costs and monitoring issues associated with such pilot projects, there is the promising possibility of internalizing some of the environmental costs and benefits of various agricultural land uses along the forest margins. This could help shift incentives toward more environmentally benign land uses and provide resources for addressing the many constraints to the adoption of these systems. Moreover, ASB research has already provided some guidance to the international community regarding where forests might be most cheaply preserved via these mechanisms and where the greatest amount of poverty alleviation might be achieved per conservation dollar spent.

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