12 The Western Brazilian Amazon

Judson F. Valentim
Embrapa Rio Branco, Acre, Brazil
Stephen A. Vosti
University of California Davis, California

The Brazilian Amazon has long been viewed as empty space contributing little to overall national economic development (Government of Brazil 1969). Federal and state governments have taken action over the past several decades to address this issue, and partly as a consequence of those actions the Brazilian Amazon has been the focus of national and international debate on issues such as tropical deforestation, global climate change, biodiversity conservation, regional integration, the production and transportation of illegal drugs, national security, and the rights of indigenous populations. Although perhaps seemingly unrelated at first glance, these issues often are closely linked. For example, regional integration might increase the demand for agricultural land, which can come at a cost to forests, the biodiversity they contain, and the carbon they store. Therefore, these issues must be examined jointly to identify possible links. If links exist, policy action must consider them.

Moreover, these issues generate more than just debate. Indeed, deforestation and its environmental and social impacts have led to social conflict involving Amerindians and rubber tappers displaced from forested areas on one hand and agriculturalists and cattle ranchers on the other (Hecht 1984; Myers 1984; Denslow 1988; Valentim 1989; Lisboa et al. 1991; Homma 1993; Smith et al. 1995;). Some of these displacements—and other encroachments into forested lands that do not spark social conflict—are directly linked to policy actions, and others result from more general economic trends that may themselves be beyond the reach of policymakers. Under both sets of circumstances policy action or policy reform may be needed. But what policy action is called for, and what should be the targeted agents or geographic areas? And—the question that is rarely asked—what will be the implications of corrective policy actions for broad development objectives (Vosti and Reardon 1997)? Finally, and most important for this chapter, do we have the knowledge needed to confidently respond to these policy questions? If not, has a process capable of identifying and filling knowledge gaps been initiated?

This chapter reviews past national priorities for the region, policy action taken to populate and integrate the Amazon into the national economy, and the environmental and social consequences of this action. Against this backdrop, we assess past and potential future contributions of the Alternatives to Slash and Burn (ASB) Program to promoting and guiding research and policy action in the region, with particular emphasis on the western Amazonian states of Acre and Rondônia, and ASB activities at the benchmark sites there (Ávila 1994).

We begin by examining national development priorities from the early 1960s to mid-1980s as they relate to the Amazon, including policies implemented by the Brazilian government to occupy and integrate this region into national and international markets. We then focus on the direct and indirect consequences of past regional and local policies on migration, deforestation, the expansion of agricultural activities, and their consequences for economic growth, human development, and environmental sustainability. We then look at future challenges stemming from past and ongoing widespread land degradation and the exhaustion of extensive agricultural frontier. These challenges are set alongside new opportunities provided by new and better-performing markets; new technology; some marked shifts in the political climate at the local, state, and international levels; and the emergence of a new vision of development that aims to reconcile economic growth, poverty alleviation, and natural resource conservation in the Amazon. The final section highlights the contributions of ASB's research and outreach activities in the western Brazilian Amazon and sets an agenda for future ASB-Brazil activities.

DEVELOPMENT IN THE AMAZON (1960s–1990s)

The largest tracts of the world's remaining tropical moist rainforests are located in the Amazon Basin, which occupies about 7.86 million km^2 in nine countries and covers about 44 percent of the South American continent (Valente 1968). About half of the Amazon forest (3.87 million km^2) is located in northern Brazil. This forest covers more than 52 percent of Brazil's national territory (IBGE 1997), an area larger than the whole of Western Europe (INPE 2003) (figure 12.1).

Since the early 1960s, the Amazon region has been viewed by the federal government of Brazil as a source of natural resources (e.g., forests, agricultural land, minerals) that could be used to fuel regional and national economic growth. Low population density (about 0.9 inhabitants per square kilometer in 1970) was an obstacle to exploiting the region's resources and integrating it into the national economy. Labor needed to tap and transport resources was scarce, and the low population density was perceived as a threat to national security, particularly given the production and transportation of illicit drugs in neighboring countries (Fórum Sôbre a Amazônia 1968;

Figure 12.1 Map of Brazil, with the North Region highlighted (INPE 2003).

Government of Brazil, 1969, 1981; SUDAM 1976; Smith et al. 1995; IBGE 1997; Santana et al. 1997; Homma 1998).

But two objectives, tapping the resources of the Amazon and developing the region, often became decoupled by policy action. There were several reasons, some of them known before the task began and others discovered after the processes had begun. First, huge distances separated the Amazon from major population and transportation centers, thereby making inputs needed in the Amazon more expensive and products from the region less valuable. Second, the Amazon was found to be a huge mosaic of different ecosystems rather than a homogenous forested area. This latter discovery had both positive and negative consequences. Biophysical scientists were introduced to the world's greatest cache of biodiversity, but development planners were faced with the unforeseen need for expensive niche-specific projects and support programs. Third, the biodiversity of the Amazon forest and the carbon stored in it were increasingly viewed as belonging to groups both larger and smaller than the Brazilian federal government, which held legal claim to much of this vast area. Indigenous communities were increasingly vocal about their claims to large tracts of land and the resources on and beneath them. Simultaneously, the international community, under the banners of greenhouse gas emissions and biodiversity conservation, provided much advice on what portions of the Amazon should be used and how (Myers 1984).

In the 1960s, the federal government decided to implement policies aimed at occupying the Amazon region and integrating it with the rest of the national economy. The development process was launched with policymakers hoping that research undertaken alongside development, and at times supported by the financiers of development activities, would provide answers needed for wise stewardship of the Amazon. We now know that knowledge was insufficient to appropriately guide development policy action at that time and that research could not close that gap in the dynamic decades of the 1960s, 1970s, and 1980s.

Operation Amazon, established in 1966, set out a broad geopolitical and economic plan for the region (Government of Brazil 1969; Mahar 1979; Santana et al. 1997). In support of Operation Amazon, new policy objectives and policy instruments were created that were to supply the legal and financial means, labor, transportation networks, and electrical power needed to establish migrants and industry in the Amazon. In addition, new regional development agencies such as the Amazon Development Agency (Superintendência de Desenvolvimento da Amazônia), the Amazonian Duty-Free Authority (Superintendência da Zona Franca de Manaus), and the Amazonian Regional Bank (Banco da Amazônia S.A.) were established to organize and support development activities, often via the provision of subsidized credit to agriculture, particularly extensive beef cattle ranching, and mining projects (Forum Sôbre a Amazônia 1968; Government of Brazil 1969, 1981; SUDAM 1976; Smith et al. 1995; IBGE 1997; Santana et al. 1997; Faminow 1998).

Since the establishment of federal subsidized credit in the late 1960s, thousands of agricultural and industrial projects have been approved and implemented in the Amazon. In the western Brazilian states of Acre and Rondônia alone, thirty-three projects were approved from 1965 to 1996 for agricultural and industrial activities. This was roughly 12 percent of the 392 projects implemented throughout the Amazon during that time (Santana et al. 1997).

To support these projects, large hydroelectric dams, such as the Tucuruí Dam in the state of Pará, were built. In addition, several highways were planned and partially constructed to provide access to the region. The Trans-Amazon highway, from the Atlantic Coast to the Peruvian border, was to comprise about 5000 km of all-weather roads but is yet to be finished. Other major highways were completed, such as the BR-364, linking Acre and Rondônia to São Paulo and southern Brazil, and the Belém–Brasília road, linking Pará with the rest of the country (SUDAM 1976; Santana et al. 1997).

In the early 1970s, world economic and oil crises led to a severe economic recession in Brazil. When combined with changes in agricultural technology and consequent changes in farm structure, this generated large increases in unemployment and landlessness in southern and southeastern Brazil, and consequent social conflicts in these regions. The Federal Government saw the opportunity to solve two problems simultaneously. Moving unemployed and especially landless people to the Amazon region and establishing them in settlement projects there would reduce social pressures in the southern regions of the country and increase the labor available for development in the Amazon (SUDAM 1976; Government of Brazil 1981; Bunker 1985).

The process of assisting migration and colonization of landless people to meet these dual objectives was rapid and intense. The federal government handed over millions of hectares of forested land to small- and large-scale migrants and local people with little knowledge of the potential for these areas to support agricultural activities of any kind. These small-scale farms (in the Brazilian context), ranging in size from 50 to 100 ha, came to be known as "dumb rectangles" because few soil, water, or watershed conditions were taken into consideration during their demarcation (Valentim 1989; Walker and Homma 1996; Wolstein et al. 1998).

CONSEQUENCES OF THE DEVELOPMENT PROCESS

The policy-driven occupation of the Amazon has been under way for more than 30 years. Policy action, conditioned by economic forces and biophysical factors, has had direct and indirect consequences for economic growth, human welfare, environmental sustainability, and especially demographic change.

Migration

From about 1965 to 1995, more than 500,000 families settled in new colonization projects or spontaneously invaded forest areas along the highways that were opened throughout the Amazon. In the western Brazilian Amazon, population growth was substantial but uneven. In the state of Acre, the population grew from just over 100,000 in 1950 to nearly 500,000 by 1996. In the state of Rondônia, population grew from 36,000 in 1950 to more than 1.2 million in 1996, a staggering increase in 46 years. As a consequence, population density in Acre and Rondônia rose from 1.4 and 0.5 people per square kilometer in 1970 to 3.2 and 5.2 people per square kilometer in 1996. Although they were initially rural populations, by 1996 almost twice as many people lived in urban as in rural areas, as shown for Rondônia in figure 12.2 (IBGE 1997).

Starting in 1970, the western Brazilian Amazon also experienced a rapid process of urbanization. By 1996 more than 60 percent of the region's population was already in cities and towns, although rural–urban migration patterns differed by state. In Acre, rural population tended to be stable between 1970 and 1996, while the urban population grew. In Rondônia, rural population growth continued until about 1991.

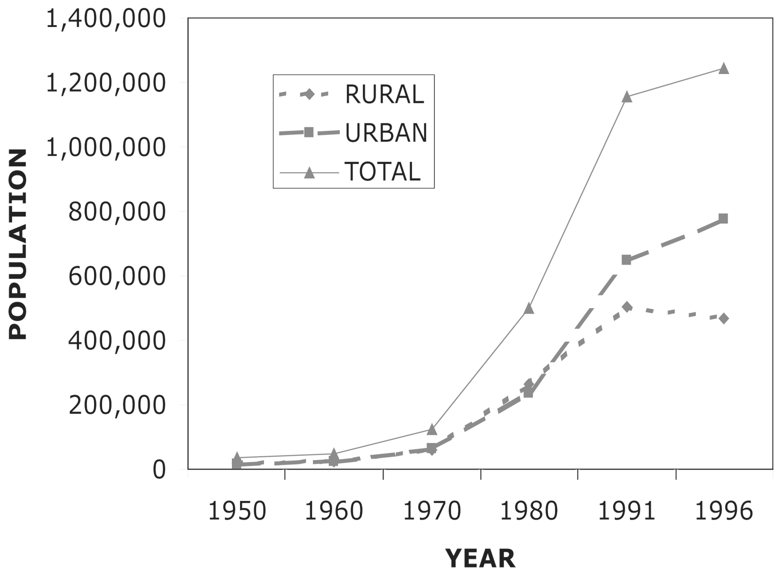

Figure 12.2 Population growth in the Brazilian ASB benchmark state of Rondônia between 1950 and 1996 (IBGE 1996).

Upon arrival in these areas, settlers cut and burned primary forests, and the cleared areas were put under plow for a series of agricultural activities. But hardships awaited many settlers. Most of the newcomers were stricken by malaria, a disease that significantly reduced their capacity to work, generated medical expenses that further reduced already precariously low household financial resources, and was sometimes fatal (Bartolome and Vosti 1995). Promised social services generally were lacking in the early years of colonization: Health care facilities were built but not staffed, and schools often were constructed, but qualified teachers were hard to find and retain. By those measures, poverty probably increased for early settlers (Vosti et al. 1998).

Deforestation

The environmental consequences of the policies pursued in the Amazon were substantial and generally negative. In the past 30 years, forest cover in the Amazon has been substantially reduced, with consequent increases in emissions of CO_2 and other greenhouse gases, loss of biodiversity, nutrient leaching, soil erosion, and land degradation (Valentim 1989; Smith et al. 1995; Homma 1998; Wolstein et al. 1998; Embrapa 1999a; INPE 2003).

In some areas, forest conversion was particularly aggressive. For example, in Rondônia, accelerated settlement and agricultural programs have resulted in the conversion of approximately 23 percent of that state's forests to agriculture in the past 20 years, with annual deforestation rates reaching 2.8 percent of the total area of the state in 1995 (Fearnside 1991; Lisboa et al. 1991; INPE 2003). In Acre, migration and forest conversion to agriculture have been less rapid, resulting in the deforestation of approximately 9.3 percent of the total area of the state in the same period, with the peak annual deforestation rate also reached in 1995, about 0.8 percent of total state land, as shown in figure 12.3 (INPE 2003).

The predominant land use system in the area begins with the clearance of forests using slash-and-burn techniques for annual crops, which can be grown without the use of external nutrient inputs on a given plot of land for 2 to 3 years. The establishment of cultivated pastures for dual-purpose, extensive cattle ranching generally follows on plots that can no longer support annual crop production.

Most of the land clearing in the Brazilian Amazon, even in the large enterprises was done by slash-and-burn. There was only one case of a big international company that used herbicides to kill 10,000 ha of forests in Pará and then burned it. Bulldozers were not really used, with only a few exceptions, in the context of the Brazilian Amazon.

There is a tendency for farms of all sizes to decrease the area remaining of forest and increase the area under pasture over time. Other land uses (monoculture coffee [*Coffea canephora* Pierre ex Fröhner] or agroforestry systems) can contribute substantially to household income and absorb considerable amounts of family and hired labor, but the amount of land usually dedicated to these other uses remains small, relative to pasture, as shown in figure 12.4 (Dale et al. 1993; Browder 1994; Fujisaka et al. 1996; Vosti and Witcover 1996; Vosti et al. 2002).

Soil Degradation

Lack of knowledge even among soil scientists of the degree of heterogeneity of Amazonian soils and their ability to support different agricultural activities, and failure on the part of planners and policymakers to put to effective use the partial knowledge that was available, led to the settling of thousands of farmers on land that could not support agriculture of almost any kind, certainly not the types of agriculture settlers were likely to pursue, given their experience in the south or northeast. As a result, soils became degraded and unproductive after just a few years, further fueling deforestation in the region as farmers sought to add to their stocks of usable soils. Moreover, and perhaps ironically, many farmers began to experience water scarcity in the world's largest and most productive watershed. The search for on-farm alternatives and supplements to annual cropping increased water needs, especially for livestock, and the deforestation needed to clear land for and to finance the establishment of alternative production systems may have decreased surface water supplies (Valentim 1989; Smith et al. 1995; Serrão et al. 1996; Wolstein et al. 1998; Amaral et al. 1999, 2000b).

It is estimated that by 1997, about 55 million ha of forests in the Brazilian Amazon (14 percent of the total area) had been converted to agriculture and that roughly one half of that deforested area (about 25 million ha) was already degraded (INPE

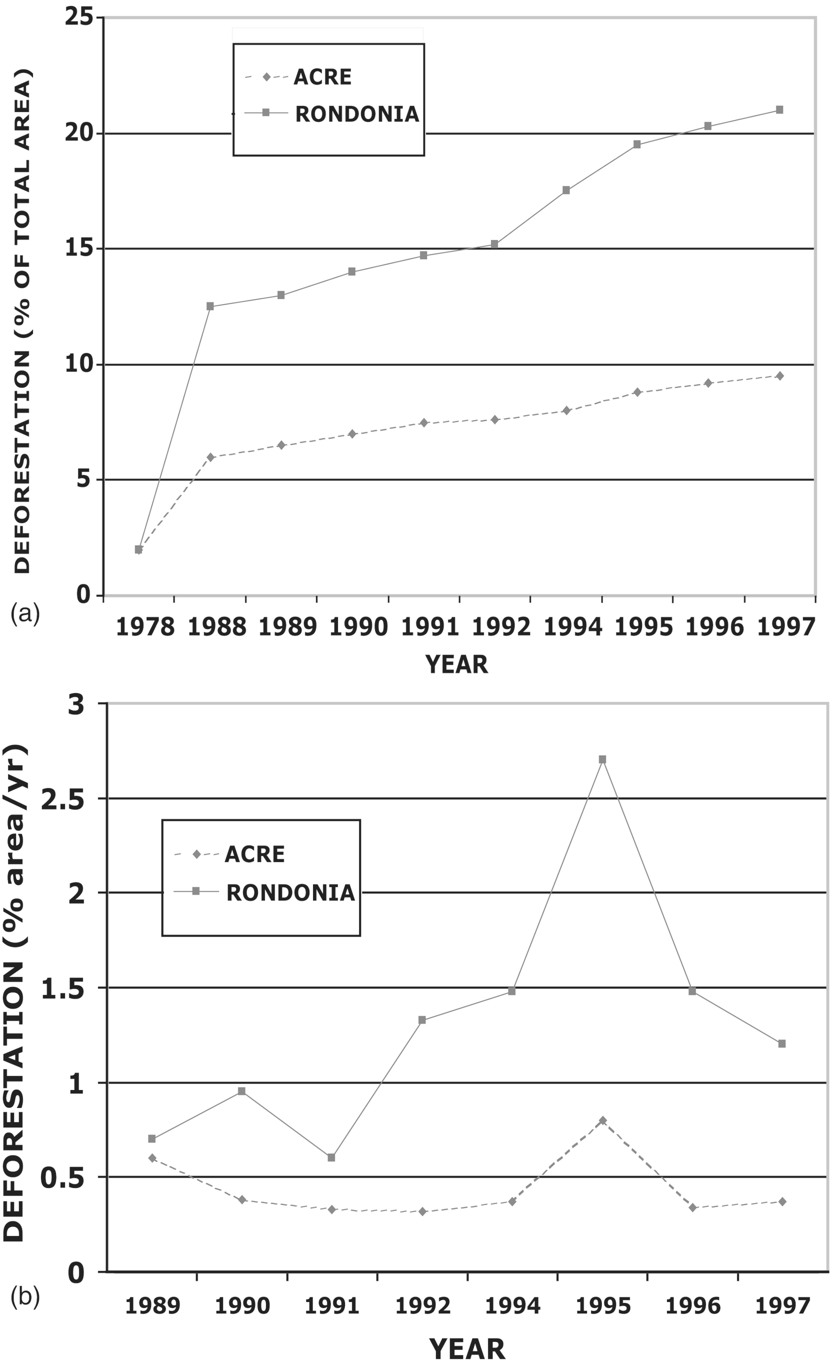

Figure 12.3 Deforestation in the Brazilian ASB benchmark states of Acre and Rondônia between 1978 and 1997: (**a**) cumulative percentage of area and (**b**) annual rates (INPE 2003).

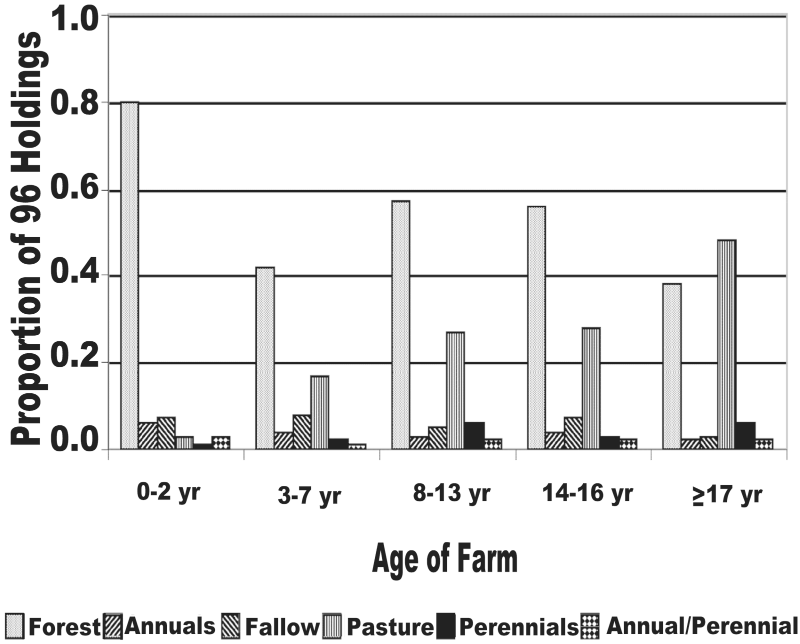

Figure 12.4 Land uses, by farm age, in the Pedro Peixoto Settlement Project in the state of Acre, Brazil, in 1996 (Vosti et al. 2002).

2003). The states of Rondônia and Acre have an estimated 1.5 million and 450,000 ha of degraded pasture and 540,000 and 140,000 ha in secondary fallow (*capoeira*), respectively (Embrapa 1999a; INPE 2003).

Economic Growth

Although the policies, economic forces, and biophysical factors guiding the occupation, use, and integration of the Brazilian Amazon have resulted in waves of migration and significant deforestation, progress in economic growth has been substantial over the past 30 years, with marked increases in gross domestic product and regional value added.

For example, Rondônia (with 5.4 million ha of forests converted to agriculture) became the third largest cocoa-producing and fifth largest coffee-producing state in Brazil by 1995. And, with 70 percent of the deforested area (3.8 million ha) planted to cultivated pastures, the state now has roughly 4 million head of cattle (IBGE 1997). Gross domestic product per capita in Rondônia rose from US$2025 in 1970 to US$6448 in 1996 (table 12.1), close to the national average for Brazil for that year (IBGE 1997; Faminow and Vosti 1998; UNDP 1999).

In Acre, economic progress over the past 25 years also has been substantial. Farmers have deforested only about 9.3 percent (1.4 million ha) of the total area, convert-

Table 12.1 Changes in Indicators of Human Welfare for Acre, Rondônia, and All Brazil, 1970–1996

Socioeconomic Indicator	Year	Acre	Rondônia	Brazil
Grammar school matriculation (% of school-aged children registered)	1970	36.1	31.7	49.2
	1980	48.5	50.7	61.2
	1991	59.0	63.0	67.8
	1995	74.1	69.8	75.7
	1996	74.1	70.7	76.8
Literacy rates (%)	1970	47.3	64.7	67.0
	1980	55.2	68.5	74.7
	1991	65.7	80.4	80.6
	1995	70.2	84.3	84.4
	1996	70.2	85.8	85.3
Per capita gross domestic product (US $ purchasing power parity)	1970	1302	2025	2315
	1980	2343	3426	4882
	1991	3767	4185	5023
	1995	5499	5562	5986
	1996	5741	6448	6491
United Nations Development Program human development index	1970	0.376	0.474	0.494
	1980	0.506	0.611	0.734
	1991	0.662	0.725	0.787
	1995	0.752	0.782	0.814
	1996	0.754	0.820	0.830

The UNDP human development index is a summary index that incorporates life expectancy, literacy, and standard of living.
Sources: IBGE (1997a), UNDP (1999).

ing roughly 80 percent of the cleared areas to pastures (1.2 million ha), and now manage about 1 million head of cattle (Embrapa 1999a). Annual gross domestic product per capita in Acre (table 12.1) rose from US$1302 in 1970 to US$5741 in 1996 (IBGE 1997a; UNDP 1999).

Human Welfare Improvements

There also have been large social benefits from the policies implemented in the last three decades in the western Brazilian Amazon. Poverty has been reduced, school matriculation rates have risen, incomes have increased, and nutritional status has improved. Total primary and secondary school matriculation in Acre and Rondônia more than doubled in 26 years, rising from 36 and 32 percent in 1970 to 74 and 71 percent in 1996, respectively. Over the same period, life expectancy at birth in both Acre and Rondônia rose from 53 years to more than 67 years, and illiteracy rates among adults decreased in Acre from 53 to 30 percent and in Rondônia from 35 to 14 percent. The UNDP human development indices for Acre and Rondônia rose from

0.38 and 0.47 in 1970 to 0.75 and 0.82 in 1996, respectively, although these are still below the value for Brazil as a whole, which was 0.83, as shown in table 12.1 (IBGE 1997a; UNDP 1999).

NEED FOR A NEW DEVELOPMENT PARADIGM

It is clear that over the past three decades, the western Brazilian Amazon has experienced rapid socioeconomic and environmental change. But can, or should, this process continue? We argue that it cannot and need not continue for several reasons.

First, the forested land suitable and available for conversion to agriculture is becoming scarce. Most soils in Acre and Rondônia near roads and rivers with known and reasonable agricultural potential have already been used or soon will be. Remaining forested areas (some of which may have agricultural potential) are increasingly off-limits because of local, state, federal, or international agreements, especially concerning Amerindian and extractive reserves. Federal law since 1989 has prohibited public credit programs from extending loans to clear forests for agricultural purposes in the Brazilian Amazon. Rondônia, in particular, has almost exhausted its agricultural frontier and must now search for other means of increasing agricultural production. Productivity increases will be the primary source of future agricultural growth.

Second, soil degradation is pervasive in the western Brazilian Amazon, and this increasingly limits product choice and productivity. For example, 50 percent of the 532,000 ha of pasture land in Acre is located on soils now judged to be unsuitable for traditional braquiarão or brizantão (*Brachiaria brizantha* [Hochst. ex A. Rich.] Stapf) pastures. These pastures either already have suffered or will soon experience rapid decreases in carrying capacity (Valentim et al. 2000). With area for new pasture expansion increasingly limited, improved and more intensive pasture and cattle management systems will be needed, as will investments to establish them.

Third, water resources in this humid tropical region are becoming scarce in colonization projects and urban areas. Water pollution is also becoming a problem, especially in and around urban areas (Knight 1998).

Fourth, because of a shifting geographic focus and fiscal limitations, the federal agencies that played such broad and fundamental roles in opening up the western Brazilian Amazon and linking it to the rest of the country have substantially reduced their activities and shifted investments in established areas (Government of Brazil 1998). State and local governments, often working with other groups, are struggling to fill these gaps (Vosti et al. 1998).

Therefore, with new agricultural land becoming scarce, productivity on cleared land falling, water scarcities developing, and traditional funding sources eroding, a new regional development paradigm is needed. And the overall environment seems conducive to change; new economic circumstances, new technologies, and potential policy and organizational and institutional changes combine to offer development options that were not available even a decade ago (Almeida and Uhl 1995). The main reasons are as follows.

First, the western Brazilian Amazon is no longer the very distant outpost it was when development began 30 years ago. All-weather roads link most major urban centers, and recent investments in water transport have dramatically altered the potential for regional and international trade. So markets exist today that did not 20 years ago, and general market performance seems to be improving with economic integration and increased competition.

Second, new and better technology is now available to support agriculture, from production to harvesting, processing, and marketing. New technologies made available by the private and public sectors expand the product mix available to farmers and can improve profitability, too.

Third, and perhaps most important, some areas in the western Brazilian Amazon are experiencing broadening local support to better manage agricultural growth and integrate it with modern, sustainable forest stewardship. In Acre, for example, a state government of the forest was recently elected, with sustainable development driven by both forestry and agriculture as a fundamental part of its party platform.

What specific solutions might spur sustainable development in the face of the challenges and opportunities noted in this chapter? What can policymakers do to promote these solutions? What role remains for research? We briefly address these

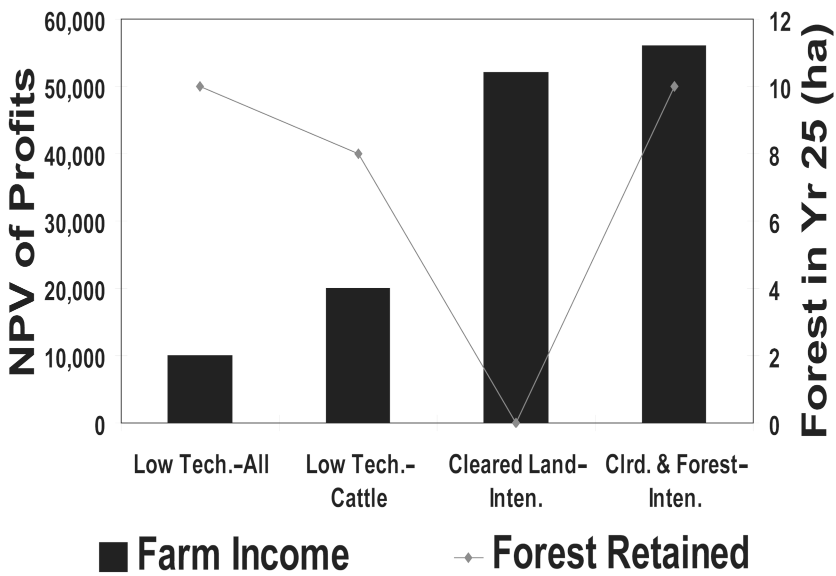

Figure 12.5 Tradeoffs between forest area and income for different farm activities as a result of a bioeconomic simulation model in a small farm holding in the Pedro Peixoto Settlement Project in 1996 (Carpentier et al. 1998). Low Tech–All, traditional practices; Low Tech–Cattle, intensified cropping but traditional cattle pasture management; Cleared Land–Inten., intensification of all crop and cattle activities; Clrd. & Forest–Inten., intensification of all crop and cattle activities and forest management; NPV, net present value.

issues in the context of one promising land and forest use system: small-scale managed forestry (see also chapter 8, this volume).

Past policies failed to add value to the forest and usually achieved just the opposite, generally by design. As a result, even short-term gains from low-productivity agriculture were, and often continue to be, greater than the private financial returns to the types of forest extraction activities that would be practiced given policy and price conditions. Forests will continue to be cleared for agriculture until this broad profitability gap is closed. One way of doing so is to permit small-scale managed forestry, a best-bet alternative to slash-and-burn developed by Empresa Brasileira de Pesquisa Agropecuária (Embrapa) as part of the ASB program, which has been demonstrated under experimental conditions to be profitable, to reduce but not eliminate deforestation, and to be capable of retaining the resiliency and productivity of forest ecosystems (figures 12.5 and 12.6).

This managed forestry technology has not been easy or cheap to develop. Years of research on the response of forest systems to different types and intensities of logging were needed to identify a small subset of sustainable forest management techniques.

Figure 12.6 Aspects of the Low Impact Sustainable Forest Management in Legal Reserves of the Pedro Peixoto Colonization Project: (**a**) the legal reserve areas being managed, (**b**) wood planks extracted from this forest area, (**c**) the house made with wood extracted from the managed area where the family of the small farmer lives, and (**d**) a field day demonstrating the research and development results to other farmers and extension agents.

Research was also needed to determine the farmer and market conditions under which it was profitable to pursue these techniques when alternative uses of farmers' time, land, and financial resources were considered (Homma 1993; Araújo 1998; Oliveira et al. 1998; Vosti et al. 2002; Vosti and Valentim 1998; Embrapa 1999b; Santos et al. 1999; Carpentier et al. 2000a, 2000b).

But experimental techniques are not easy to promote, refine, or replicate without enabling policies. Promoting these managed forestry systems beyond their experimental stages will entail policy action, such as changes in legal and practical impediments to timber management and credit programs to support investments in small-scale implements, as well as institutional change, such as the formation of groups of smallholders that can manage and monitor forest extraction activities. Refining systems in response to changes in farming and forest circumstances will entail new and continuing research and scientific monitoring. Replication on a broad scale will necessitate research into the effects of doing so on market and ecosystem conditions. If broad adoption is recommended, extension services will have to be retooled.

THE MULTIPLE IMPACTS OF ASB

As indicated earlier, scientific and technical knowledge to support and guide development in the western Brazilian Amazon in the 1960s was insufficient. Although some measures were taken at that time to augment it, they were generally too small in scale or too narrowly focused to deliver new knowledge at the necessary pace. We know much more today about Amazonian ecosystems and the agents occupying these lands. However, we still do not have the knowledge we need for economically and ecologically sound planning on a regional or subregional basis (Valentim 1989; Smith et al. 1995; Homma 1998), but progress in filling knowledge gaps has quickened over the past 10 years. Multi-institutional, interdisciplinary research teams have been largely responsible for this broader knowledge base, and ASB is a leader among these teams, especially in Acre. Of course, there were other multidisciplinary groups of researchers working on development problems in the region, such as the Grupo de Pesquisa e Extensão em Sistemas Agroflorestais do Acre (PESACRE, a local research consortium) and the Universidade Federal do Acre. The ASB provided strong scientific and institutional leadership. In what follows, we focus on ASB impacts on Embrapa, but there were substantial spillovers to other research- and service-oriented organizations (especially PESACRE and Empresa de Assistência Técnica e Extensão Rural, the agricultural extension service).

From the outset, ASB's mandate, research methods, and research partners have had profound effects on Embrapa and the potential for Embrapa to effectively contribute to changing development objectives and policies in the western Brazilian Amazon. The ASB's research mandate was to better understand biophysical and socioeconomic processes and outcomes and the links between them and—based on new knowledge—to identify entry points for policy actions needed to achieve broad development objectives in the region. The specific outcomes of research on these issues are reported elsewhere in this publication. Here, we highlight the impacts of ASB in Brazil on the focus and nature of research, on the search for and development of new technologies, and on policy change in Embrapa Acre and Rondônia.

The Focus and Nature of Research

With the arrival of ASB, its new research paradigm, collaborators, and financial resources, there was a substantial shift in the focus and nature of Embrapa's biophysical and social science and policy research at the two benchmark states (Ávila 1994).

First, biophysical research that traditionally examined single food production activities over short periods of time was expanded to include multiproduct land use systems practiced over much longer periods of time. And because the biophysical consequences of agricultural and other changes are not restricted to the boundaries of the farm, transects of land including but not restricted to farm land were studied. It was clear that these land use systems should not be examined in isolation but needed to be jointly analyzed at the landscape level and in the context of important on- and off-farm variables.

Second, the ways in which much of Embrapa's biophysical research is carried out have also changed, in part because of collaboration with ASB. In the past, most Embrapa research was carried out in plots located on experiment stations. The degree of farmer involvement in determining research topics or methods was limited, and the biophysical and socioeconomic contexts in which farmers made product, technology, and resource allocation decisions were not part of researcher-led experimental designs. For some scientific problems, such as fertilizer response trials, this de-linking of experiments from smallholder situations is effective and efficient. For many other problems, such as the potential for establishing legume-based pastures in farmers' fields, it is not.

Most of ASB's biophysical research was carried out on farmers' fields, often with the direct participation of farmers in developing, monitoring, and managing experiments.

Where scientifically appropriate, this emphasis on farmer participation and farm-based experimentation continues at Embrapa today. For example, research conducted in farmers' fields rose from less than 10 percent in 1994 to approximately 60 percent in 1998 in Embrapa Acre, with consequent increases in the use of participatory research methods and the validation of research products by farmers in their own socioeconomic and environmental situations.

Third, Embrapa's research traditionally focused on agronomic factors of immediate or short-term relevance to farmers. Links with ASB and its national and especially international network of research institutions expanded the geographic and temporal foci of Embrapa research. For example, the long-term consequences of particular land use patterns are now of central concern. In addition, identifying the impacts of land use and land cover change on local, regional, and even international communities is now very important in Embrapa research. The ASB is chiefly responsible for Embrapa's new focus on international environmental externalities (e.g., CO_2 emissions, changes in above- and below-ground biodiversity).

Socioeconomic Research

Like biophysical researchers, social science researchers had spent little time on farmers' fields or in farm households collecting data. The ASB brought a substantial shift toward socioeconomic field research, especially the collection and use of field data. Efforts to develop and use secondary data, such as those containing comprehensive product and input price series, were also expanded with ASB guidance.

Perhaps the most important contribution of ASB to Embrapa's socioeconomic and policy research was the increased priority given to predicting the impacts of different price and technology changes and to developing the analytical tools to generate these predictions (Vosti et al. 2001a). For example, ASB and Embrapa collaborated to develop, test, and use a farm-level bioeconomic model capable of predicting the impact of changes in policy on land use patterns, deforestation, and household income (see also chapter 10, this volume). Simulated land uses over a 25-year period produced by this model and based on conditions for a typical small-scale farmer whose characteristics were derived from field research in Acre. Model simulations, under socioeconomic and policy conditions prevalent in 1994 to 1996 and subject to the biophysical and especially farm household labor constraints, show that forest will continue to fall in the western Brazilian Amazon and cleared land will be allocated predominantly to pasture (Carpentier et al. 2000a; chapter 10, this volume).

Combining information generated by model simulations can be much more informative. Figure 12.5 summarizes results of several simulations based on different policy and technology scenarios. Tradeoffs can be examined as we move from one scenario to another between household income (measured in terms of net present value of profit streams and represented by bars in figure 12.5) and the amount of forest retained on farms (measured in terms of hectares of forest remaining in year 25 of the scenario and represented by diamonds connected by lines in figure 12.5). In the scenarios examined here, increasing the scope of agricultural intensification (moving from left to right, beginning with no intensification on cleared or forested land to a scenario that permitted intensification of all activities on cleared lands, the third scenario) increases household income and decreases forest cover. Note that only when agricultural *and* forestry activities are intensified (final scenario in figure 12.5) do both income *and* forest cover increase (Carpentier et al. 2000b). Absolute levels of farm household income may seem high at first glance. Readers are reminded that figures reported represent the present discounted values of income streams earned over the 25-year time horizon of the farm household model. General equilibrium effects are not taken into consideration, nor is risk included explicitly into the model, except in the case of edible bean (*Phaseolus vulgaris* L.) production.

At a much higher level of spatial and economic aggregation, ASB also developed an economy-wide model capable of predicting the impact of changes in macroeconomic policy and region-wide changes in agricultural technology on deforestation in the Amazon. This model, the only one of its kind in Brazil, predicts, for example, that in response to a major devaluation of the Brazilian currency, in the Amazon region taken as a whole the area dedicated to coffee would double, extractive activities would experience a boom, production of consumer staples would decrease substantially, but logging would only be slightly affected (Cattaneo 1999; chapter 7, this volume).

Biophysical Research

The ASB collaboration has also modified the focus of and methods for Embrapa's technology development activities. Historically, Embrapa's research had focused on economic practices undertaken on cleared land and on traditional agricultural activities. Under the economic premise that adding value to the forest is fundamental to saving it, the search for new technologies has been expanded to include those that can be practiced on forested lands.

In addition, research has shifted somewhat from agricultural practices imported to the region from other areas in Brazil, such as upland rice (*Oryza sativa* L.) and bean production, to those involving native species, primarily woody perennials. Examples of these are agroforestry systems such as that of the Projeto Reca with mixtures of tree species such as peach palm (*Bactris gasipaes* Kunth), cupuaçú or theobroma (*Theobroma grandiflorum* [Willd. ex Spreng. K. Schum.]), and Brazil nut (*Bertholetia excelsa* Humb. & Bonpl.) (figure 12.7). Another is the cultivation of pimenta longa (*Piper hispidinervum* C.DC.), a native bush containing an essential oil (Safrol) that is used in cosmetics production (as a fixing agent of fragrances) and as a synergistic agent in the production of domestic insecticides. Embrapa has domesticated this species and developed the agricultural and agroindustrial production systems. Research on these emerging products focuses not only on their sustainable cultivation but also on post-harvest processing and marketing issues.

Finally, given the demonstrated attractiveness of dual-purpose (milk, beef) cattle ranching to local smallholders, special efforts are under way to make these systems more agronomically sustainable and to limit the need for and incentives to expanding new pasture lands. For example, in the Ramal da Enco farmers' association in Acre, research on the use of solar-charged, battery-powered electric fences for managing pastures and cattle herds is under way. Preliminary results suggest that pasture carrying capacity can be increased and pasture life extended by using these fences, which are inexpensive to establish and maintain (Vaz and Valentim 2001). To take another example, new legumes such as perennial peanut (*Arachis pintoi* Krap. & Greg.) and tropical kudzu (*Pueraria phaseoloides* [Roxb.] Benth.) are being recommended for the establishment of grass–legume pastures to increase the profitability and sustainability of cattle production systems in the western Brazilian Amazon (Valentim and Carneiro 2001; Valentim et al. 2001), as shown in figure 12.8.

Figure 12.7 The simple agroforestry system of the Projeto Reca in Rondônia, which includes peach palm, cupuaçú, and Brazil nut trees.

Embrapa's Role in Regional Policy Dialogue

In part as a result of ASB research, Embrapa's position in local, state, regional, and national policy debates has been strengthened, allowing it to offer more concrete policy advice on a broader array of issues and to help avoid costly policy mistakes. In most cases, the mechanisms for Embrapa input into policymaking predate ASB, but it was the ASB program that brought policy implications to the forefront in research design and also sought to extract policy-relevant lessons from all research projects. Moreover, the predictive power of the household and economy-wide models developed by ASB has provided Embrapa with greater voice and credibility in policy debates. The following are examples of the types of policy debates to which Embrapa is contributing:

Land use zoning was undertaken during the early period of modern occupation in Acre, and the resulting land use potential recommendations are 87 percent of the area for crops, 12 percent for pastures, and less than 1 percent for forest plantations. Less than 0.5 percent of the land was considered to have no agricultural potential. At that time, much of the state's land was deemed suitable for nearly any type of agricultural pursuit, at any scale. An Embrapa reevaluation of land use potential (carried out in part with ASB assistance) revealed a very different suggested set of land use options, this time highlighting the limits to traditional large-scale agricultural activities and the major role that small-scale agriculturalists, agroforestry, and forestry activities should

Figure 12.8 Photographs *(clockwise)* of dairy cattle grazing a protein bank of perennial peanut (cv. Belmonte); dairy cattle grazing guineagrass (*Panicum maximum* Jacq.) cv. Massai, a new grass developed by Embrapa based on selection of ecotypes introduced from Africa; beef cattle grazing guineagrass cv. Tanzania, also a new grass developed by Embrapa based on selection of ecotypes introduced from Africa; and grass–legume pastures consisting of Tanzania grass and tropical kudzu.

play (Amaral et al. 2000a) (figure 12.9). This updated land use assessment is one of the cornerstones of state development planning and policy today.

A separate set of Embrapa-led land use zoning exercises has helped identify where subsoil impediments to drainage are causing the death of brizantão-based pastures over very broad areas (Valentim et al. 2000). Research is under way to identify replacement grasses.

Embrapa is routinely asked to provide suggestions for targeting subsidized agricultural credit in the region. Based on the results of collaborative forest ecology and farm household economic research, Embrapa has proposed that farmers or farmer cooperatives preparing plans to implement small-scale managed forestry schemes be eligible for special credit from a fund managed by the Amazonian Regional Bank.

In May 1999, the federal government of Brazil and the state government of Acre organized a workshop involving government and nongovernment organizations and representatives of the private sector to discuss a positive agenda for the Brazilian Amazon aimed at addressing growth, poverty, and environmental issues together. Embrapa was asked to provide the scientific and technical basis on which regional and state-level

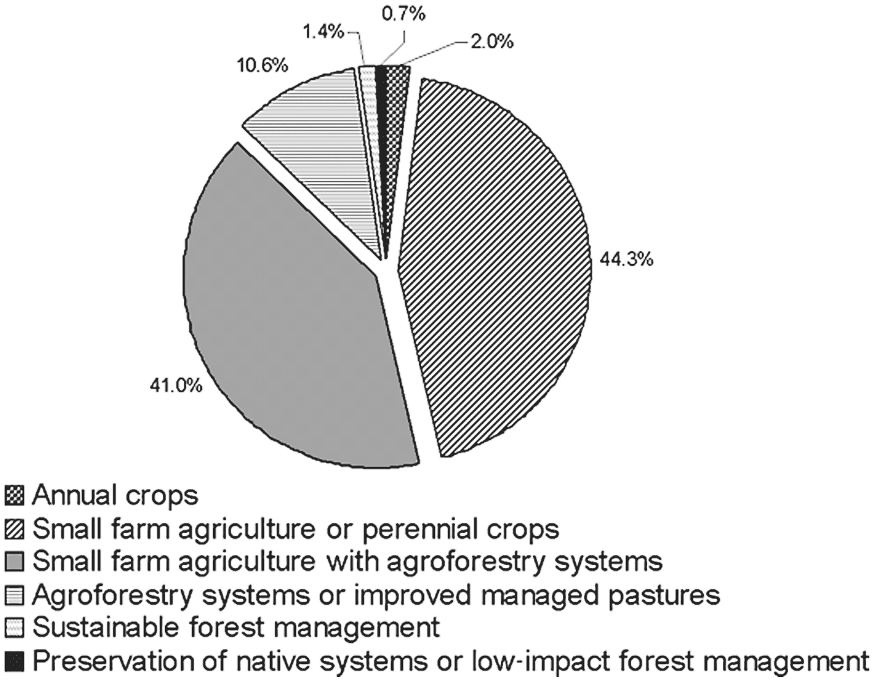

Figure 12.9 Land use recommendations for Acre in 1999, focusing on small-scale agriculture, agroforestry, and small-scale forestry, based on work of Embrapa and ASB (Amaral et al. 2000a).

policies would be developed. Research results, methods, and experiences provided by ASB collaboration greatly assisted Embrapa in this task. The most important proposals to emerge from this workshop were to

- Gradually decrease deforestation rates in Acre.
- Establish a targeted amount of cleared land, initially set at 14 percent of total state area, to be reached by the year 2020.
- Establish policy disincentives to forest conversion for agricultural purposes and policy incentives to reclaim degraded land and increase the efficient and sustainable use of forests.

Although it attracts less attention now than in the past, the formal colonization process in the region is still ongoing, though at a much slower rate than in earlier decades. So the problems of where and how to settle smallholders and what sorts of support are needed to increase the chances of success remain. Embrapa (supported by ASB research results and research tools) is changing the way colonization projects are conceived and implemented.

For example, a settlement project recently approved for joint implementation in the Seringal São Salvador by Embrapa Acre, Instituto Nacional de Colonização e Reforma Agrária Acre (National Colonization Institute), PESACRE, the municipality of Mancio Lima, SOS Amazonia (an environmental organization), and the Brazilian Institute for the Environment and Natural Resources envisions land distribution and land and forest use patterns quite different from those implemented under traditional colonization schemes. In traditional colonization schemes, land allocation to farmers was done without much thought given to the potential and limits of the natural resource base (forests, soils, water) or to the socioeconomic circumstances of migrant families, and the legal reserve areas were established within individual plots and left to farmers to manage.

The current approach to settling smallholders pays much more attention to assessments of the natural resources done beforehand to determine land use potential and constraints, the possibility that some lands may not be suitable for settlement purposes and therefore should be set aside for conservation, the socioeconomic circumstances of candidate families, farmer participation in colonization planning and implementation phases, the potential for locating legal reserves to ensure that continuous blocks of forest remain in or around colonization projects, and the management of these legal reserves to sustainably produce timber and nontimber forest products. This new approach reduces settlement costs and limits deforestation to no more than 30 percent of the total colonization project area (as opposed to the 50 percent allowed in the traditional schemes).

Embrapa also played an important role in providing scientific and technical support to the federal government's decision in November 1999 to prohibit establishment of new settlement projects in forest areas of the Brazilian Amazon.

Finally, Embrapa input, some of which was based directly on ASB research results and research tools, has provided a sounder basis for establishing price policy at state and regional levels. For example, policymakers in Acre were contemplating a subsidy for upland rice and bean production, alleging that it would reduce deforestation. The ASB–Embrapa research results based specifically on simulations of the bioeconomic model demonstrated that such a price policy would not reduce deforestation, although it would improve smallholder incomes. The choice was left to policymakers, but with the predicted impacts of the proposed policy change more clearly articulated.

Organizational and Institutional Impacts of ASB

Collaborative Embrapa and ASB research provided and promoted the establishment of links with the international research community and consequently provided access to new individuals and institutions, new views, and new tools. In part as a result of Embrapa's support to ASB, there was a marked change in the profile and training of Embrapa's research staff. New specialists in the fields of forestry, economics, soil classification, and soil fertility were recruited and retained, and the level of research staff training rose considerably: The proportion of staff holding Ph.D. degrees rose from 6 to 19 percent between 1995 and 1999.

At the same time, laboratory infrastructure was significantly increased and improved. Soil fertility and physics laboratories that before 1995 had limited capacity and low levels of reliability are now certified by a national quality control program and analyzed more than 20,000 soil samples in 1999. Laboratories for food technology, seed analysis, seed certification and processing, animal nutrition, and plant analysis were recently constructed, and technical staff to run them were hired and trained. although these and other efforts to expand and improve laboratory capacity were only partially funded by ASB, ASB was central in helping identify them as priorities.

Improving and increasing computer services within Embrapa was also a high priority, to which ASB contributed significantly. In 1994, Embrapa Acre had only six microcomputers and one specialist in this field. By 1999, there were seventy-four microcomputers and a large staff to support them. Training in computer and software use (some of which was undertaken or financed directly by ASB) has resulted in the presence of a cadre of research and support staff that is highly computer literate and consequently much more productive.

FUTURE COLLABORATIVE RESEARCH WITH ASB

Future collaborative research involving Embrapa, ASB, and other organizations will focus on plot-level, farm-level, and landscape-level issues, always overlaying biophysical and socioeconomic factors in generating scientific contributions to help promote sustainable economic growth, increase incomes, and improve living conditions of small-scale farmers and conserve the natural resource base. At all levels, the search for new combinations of policies, technologies, and institutional arrangements to meet development objectives will continue.

Plot-level research will focus on identifying the links between land use and changes in above- and below-ground biodiversity. Establishing these links will help researchers identify the private benefits of biodiversity (i.e., those affecting farm profits) and develop policies to use these benefits as entry points for enhancing biodiversity conservation.

At farm level, research will expand the set of products and land use activities for which complete biophysical and socioeconomic information is available and incorporate this new information into predictive models. In addition, the focus of research will expand beyond settlement project areas to include extractive reserves, where small numbers of households are responsible for the stewardship of very large tracts of forest land, and large-scale farms, where small numbers of economic agents make decisions on large tracts of cleared and forested land.

At landscape level, land use mosaics within and across farms that are financially attractive and have beneficial environmental characteristics will be identified, and policies for promoting their establishment and maintenance will be explored.

Finally, at all levels research will endeavor to generate predictive capacity by developing models that will allow researchers and policymakers to assess a priori the impacts on environmental sustainability, economic growth, and poverty alleviation of alternative policy interventions or combinations of them.

References

Almeida, O.T. de, and C. Uhl. 1995. Developing a quantitative framework for sustainable resource-use planning in the Brazilian Amazon. World Dev. 23(10):1745–1764.

Amaral, E.F. do, E.A. de Araújo, A.W.F. de Melo, M.A. Ribeiro Neto, J.R.T. da Silva, and A.N. de Souza. 2000a. Solos e aptidão agroflorestal. pp. 37–49. *In* Acre. Governo do estado do Acre. Programa Estadual de Zoneamento Ecológico-Econômico do Estado do Acre: Indicativos para gestão territorial do Acre. Documento final da fase 1. Vol. 1. Secretaria de Ciência, Tecnologia e Meio Ambiente do Acre/Embrapa Acre, Rio Branco, Acre, Brazil.

Amaral, E.F. do, E.A. de Araújo, J.R.T. da Silva, A.W.F. de Melo, and A.N. de Souza. 1999. Os solos do Acre: Potencialidades e restrições. Secretaria de Ciência, Tecnologia e Meio Ambiete do Acre/Embrapa Acre, Rio Branco, Acre, Brazil. Relatório Técnico do Zoneamento Ecológico Econômico.

Amaral, E.F. do, E.A. de Araújo, J.F. Valentim, and J.F. do Rêgo. 2000b. Indicativos para agricultural familiar e empreendimentos agropecuários de médio e grande porte. pp. 78–97. *In* Programa Estadual de Zoneamento Ecológico-Econômico do Estado do Acre: Indicativos para gestão territorial do Acre. Documento final da fase 1. Vol. 3. Secretaria de Ciência, Tecnologia e Meio Ambiente do Acre /Embrapa Acre, Rio Branco, Acre, Brazil.

Araújo, H.J.B. de. 1998. Índices técnicos da exploração e transformação madeireira em pequenas areas sob manejo florestal no PC. Pedro Peixoto: Acre. Circular Técnica 23. Embrapa Acre, Rio Branco, Acre, Brazil.

Ávila, M. 1994. Alternatives to slash-and-burn in South America: Report of research site selection in Acre and Rondônia states of Amazon Region of Brazil. Alternatives to Slash-and-Burn Agriculture Programme. Conducted from 31 Aug. to 15 Sept. 1992. ICRAF, Nairobi.

Bartolome, C.A.M. de, and S.A. Vosti. 1995. Choosing between public and private healthcare: A case study of malaria treatment in Brazil. J. Health Econ. 14:191–205.

Browder, J.O. 1994. Surviving in Rondônia: The dynamics of colonist farming strategies in Brazil's northwest frontier. Studies Comp. Int. Dev. 29(3):45–69.

Bunker, S.G. 1985. Underdeveloping the Amazon: Extraction, unequal exchange, and the failure of the modern state. Univ. of Illinois, Chicago.

Carpentier, C.L., D.D. Bosch, and S.S. Batie. 1998. Using spatial information to reduce costs of controlling agricultural nonpoint source pollution. Agric. Resource Econ. Rev. (April):72–84.

Carpentier, C.L., S. Vosti, and J. Witcover. 2000a. FaleBEM: A farm-level bioeconomic model for the western Amazonian forest margin. Environment and Production Technology Div. Discussion Paper. IFPRI, Washington, DC.

Carpentier, C.L., S. Vosti, and J. Witcover. 2000b. Intensified production systems on western Brazilian Amazon settlement farms: Could they save the forest? Agric. Ecosyst. Environ. 1635:1–16.

Cattaneo, A. 1999. Brazil: Economic crisis and deforestation in the Amazon. Final Report to ICRAF. Markets and Structural Studies Div. IFPRI, Washington, DC.

Dale, V.H., R.V. O'Neill, M. Pedlowski, and F. Southworth. 1993. Causes and effects of land-use change in central Rondônia, Brazil. Photogramm. Eng. Remote Sens. 59(6):997–1005.

Denslow, J.S. 1988. The tropical rain-forest setting. pp. 25–36. *In* J.S. Denslow and C. Padoch (eds.) People of the tropical rain forest. Univ. of California Press, Berkeley.

Embrapa (Empresa Brasileira de Pesquisa Agropecuária). 1999a. Centro de Pesquisa Agroflorestal do Acre (Rio Branco, AC). Redução dos impactos ambientais da pecuária de corte no Acre. Rio Branco, Acre, Brazil. (Embrapa–Centro de Pesquisa Agroforestal do Acre. Impactos 1999).

Embrapa (Empresa Brasileira de Pesquisa Agropecuária). 1999b. Manejo florestal sustentâvel para projetos de assentamento. Embrapa–CPAF/AC. Impactos 1999. Embrapa Acre, Rio Branco, Acre, Brazil.

Faminow, M.D. 1998. Cattle, deforestation and development in the Amazon: An economic, agronomic and environmental perspective. CAB Int., Wallingford, UK.

Faminow, M.D., and S.A. Vosti. 1998. Livestock–deforestation links: Policy issues in the western Brazilian Amazon. pp. 88–103. *In* A.J. Nell (ed.) Livestock and the environment international conference, Wageningen, The Netherlands. 16–20 June 1997. World Bank, FAO, and the Int. Agric. Centre, Wageningen.

Fearnside, P.M. 1991. Rondônia: Estradas que levam à devastação. Ciencia Hoje Spec. ed. Dec.:116–122.

Forum Sobre a Amazônia, 2. 1968. Rio de Janeiro, RJ. Problematica da Amazônia. CEB, Rio de Janeiro.

Fujisaka, S., W. Bell, N. Thomas, L. Hurtado, and E. Crawford. 1996. Slash-and-burn agriculture, conversion to pasture, and deforestation in two Brazilian Amazon colonies. Agric. Ecosyst. Environ. 59:115–130.

Government of Brazil. 1969. Amazônia: Instrumentos para o desenvolvimento. Ministerio do Interior, Banco da Amazonia, Belem, Pará, Brazil.

Government of Brazil. 1981. III Plano nacional de desenvolvimento, 1980/85. Presidencia da Republica e Secretaria de Planejamento, Brasília, Brazil.

Government of Brazil. 1998. Programa Brasil em Ação: Dois anos. Presidência da República, Brasília, DF, Brazil.

Hecht, S.B. 1984. Cattle ranching in Amazonia: Political and ecological considerations. Pp. 366–398. *In* M. Schmink and C.H. Wood (eds.) Frontier expansion in Amazonia. Univ. of Florida Press, Gainesville.

Homma, A.K.O. 1993. Extrativismo vegetal na Amazônia: Limites e oportunidades. Empresa Brasileira de Pesquisa Agropecuária. Centro de Pesquisa Agroflorestal da Amazonia Ocidental. Embrapa–Serviço de Produção de Informação, Brasília.

Homma, A.K.O. (ed.). 1998. Amazônia: Meio ambiente e desenvolvimento agrícola. Embrapa Centro de Pesquisa Agroflorestal da Amazonia Oriental. Belem, Pará, Brazil.

IBGE (Instituto Brasileiro de Geografia e Estatistica). 1996. Anuário estatístico do Acre. IBGE, Rio de Janeiro.

IBGE (Instituto Brasileiro de Geografia e Estatística). 1997a. Anuário estatístico do Brasil. IBGE, Rio de Janeiro.

INPE (Instituto Nacional de Pesquisas Espaciais). 2003. Monitoramento da floresta amazônica brasileira por satellite: Projeto PRODES. Available at www.obt.inpe.br/prodes.html.

Knight, D. 1998. Environment bulletin—Water: Worldwide water shortage to worsen. Available at http://www.ips.org//Critical/Enviroment/Environ/env1209006.htm (verified 7 Dec. 2003).

Lisboa, P.L.B., U.N. Maciel, and G.T. Prance. 1991. Perdendo Rondônia. Ciência Hoje (Vol. Especial Amazonia, Dez.):74–82.

Mahar, D. 1979. Frontier policy in Brazil: A study of the Amazonia. Praeger, New York.

Myers, N. 1984. The primary source: Tropical forests and our future. W.W. Norton, New York.

Oliveira, M.V.N. d', E.M. Bráz, D.F.R.P. Burslem, and M.D. Swaine. 1998. Small-scale natural forest management: A new model for small farmers in the Brazilian Amazon. Trop. For. Update 8(1):5–7.

Santana, A.C. de, M.I.R. de Alencar, P.N. Mattar, R.M.Q. da Costa, J.L. d'Ávila, and R.F. Souza. 1997. Reestruturação produtiva e desenvolvimento na Amazônia: Condicionantes e perspectivas. Banco da Amazônia S.A., Belem, Pará, Brazil.

Santos, J.C. dos, C.P. de Sá, and H.J.B. de Araújo. 1999. Aspectos financeiros e institucionais do manejo florestal madeireiro de baixo impacto em áreas de reserva legal de pequenas propriedades, na Amazônia. *In* Congresso Brasileiro de Economia e Sociologia Rural, 37, 1999, Foz do Iguacú. Anais. 1999, CD, Seção Trabalhos Científicos. Soc. Brasileira de Econ. Rural, Brasília DF, Brazil.

Serrão, E.A.S., D. Nepstad, and R. Walker. 1996. Upland agricultural and forestry development in the Amazon: Sustainability, criticality and resilience. Ecol. Econ. 18:3–13.

Smith, N.J.H., E.A.S. Serrão, P.T. Alvim, and I.C. Falesi. 1995. Amazônia: Resiliency and dynamism of the people. United Nations Univ., New York.

SUDAM (Superintendência de Desenvolvimento da Amazônia). 1976. II Plano de Desenvolvimento da Amazônia: Detalhamento do II Plano Nacional de Desenvolvimento (1975–79). Belem, Pará, Brazil.

UNDP (United Nations Development Program). 1999. Human development report. Oxford Univ. Press, New York.

Valente, M.G. 1968. A Amazônia brasileira e as outras amazônias. pp. 277–295. *In* Forum sobre a Amazônia, 2. Problemática da Amazônia. CEB, Rio de Janeiro.

Valentim, J.F. 1989. Impacto ambiental da pecuária no Acre. Documento Base do Curso de Avaliação do Impacto Ambiental da Pecuária no Acre. Embrapa–Unidade de Execução de Pessquisa de Âmbito Estadual Rio Branco/Inst. de Meio Ambiente do Acre, Acre, Brazil.

Valentim, J.F., E.F. do Amaral, and A.W.F. de Melo. 2000. Zoneamento de risco atual e potencial de morte de pastagens de *Brachiara brizantha* no Acre. Embrapa Acre. Boletim de Pesquisa, 29. Embrapa–Acre, Rio Branco, Acre, Brazil.

Valentim, J.F., and J. da C. Carneiro. 2001. Pueraria phaseoloides e *Calopogonium mucunoides*. pp. 427–458. *In* A.M. Peixoto, C.G.S. Pereira, J.C. de Moura, and V.P. Faria (eds.) Anais do 18th Simpósio Sobre Manejo de Pastagens: A Planta Forrageira No Sistema de Produção. Fundação de Estudos Agrários "Luiz de Queiroz," Piracicaba, Brazil.

Valentim, J.F., J. da C. Carneiro, and M.F.L. Sales. 2001. Amendoim forrageira cv. Belmonte: Leguminosa para a diversificação das pastagens e conservação do solo no Acre. Rio Branco. Embrapa, Acre, 2001. Circ. Técnica 43. Embrapa, Acre, Brazil.

Vaz, F.A., and J.F. Valentim. 2001. Utilização de energia solar e cercas eletrificadas no manejo das pastagens no Acre. Circ. Técnica 40. Embrapa–Acre, Rio Branco, Acre, Brazil.

Vosti, S.A., C.L. Carpentier, J. Witcover, and J.F. Valentim. 2001a. Intensified small-scale livestock systems in the western Brazilian Amazon. pp. 113–133. *In* A. Angelsen and D. Kaimowitz (eds.) Agricultural technologies and tropical deforestation. CAB Int., Wallingford, UK.

Vosti, S.A., and T. Reardon (eds.). 1997. Agricultural sustainability, growth, and poverty alleviation: A policy and agroecological perspective. Johns Hopkins Univ. Press, Baltimore.

Vosti, S.A., and J. Valentim. 1998. Foreword. *In* M.D. Faminow (ed.) Cattle, deforestation and development in the Amazon: An economic, agronomic and environmental perspective. CAB Int., Wallingford, UK.

Vosti, S.A., and J. Witcover. 1996. Slash-and-burn agriculture: household perspectives. Agric. Ecosyst. Environ. 58:23–38.

Vosti, S.A., J. Witcover, and C.L. Carpentier. 1998. Final report: Convenio de Cooperación Técnica Regional No Reembolsable no. ATN/SF-4827-RG: Programa 1994 de Tecnología Agropecuaria Regional en América Latina y El Caribe of the Inter-American Development Bank. Environ. and Production Technol. Div. IFPRI, Washington, DC.

Vosti, S.A., J. Witcover, and C.L. Carpentier. 2002. Agricultural intensification by smallholders in the western Brazilian Amazon: From deforestation to sustainable use. IFPRI Res. Rep. 130. IFPRI, Washington, DC. Available at http://www.ifpri.org/pubs/pubs.htm#rreport (verified 7 Dec. 2003).

Walker, R., and A.K.O. Homma. 1996. Land use and land cover dynamics in the Brazilian Amazon: An overview. Ecol. Econ. 18:67–80.

Wolstein, A.R.P., E.M. Lima, E.F. do Amaral, E.M. Bráz, F.L.N. Pinheiro, I.L. Franke, et al. 1998. Metodologia para o planejamento, implantação e monitoramento de projetos de assentamentos sustentaveis na Amazonia. Embrapa–CPAF/AC/INCRA/FUNTAC, Rio Branco, Brazil.