A Perfect Storm in the Amazon Wilderness:

Development and Conservation in the Context of the Initiative for the Integration of the Regional Infrastructure of South America (IIRSA)

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Preface

This study is intended to review and revitalize the dialogue about conservation and development in the Amazon Wilderness Area and in the two adjacent Biodiversity Hotspots, the Cerrado and the Tropical Andes. Although our discussion touches on a variety of factors influencing the possible paths for conservation and development in the region, including the trade-offs emerging from different scenarios, the central theme and motivating factor for the study is the *Initiative for the Integration of the Regional Infrastructure of South America (IIRSA*). IIRSA is rapidly becoming the organizing principle behind the push to improve physical links among the South American countries via highways, hydrovias, energy projects and other initiatives.

The study attempts to evaluate IIRSA objectively by examining the likely changes it will bring to the region. It is not intended to be an anti-IIRSA diatribe. We recognize that IIRSA is, potentially, a visionary initiative — one that can promote cultural exchange and stimulate economic growth. Regional integration can offset the harsher aspects of globalization and provide an alternative to the boom and bust cycles caused by an over-reliance on the export of commodities. IIRSA can become a solid step in the direction of economic growth and poverty reduction and an essential ingredient for the future well-being of South America.

Our hope is that this document will stimulate IIRSA to become an even more important and relevant initiative, one that incorporates the vision of an ecologically and culturally intact Amazon. Recent experiences in participatory democracy have shown that infrastructure investments can be modified to respond to the environmental concerns and social priorities of civil society. These forums have made important contributions to biodiversity conservation and provided economic opportunity for local communities. Since the natural resources of the Amazon are the foundation of the regional economy, all sectors of society should have input on their use and management.

We believe that our study provides a novel perspective on development in the Amazon, questioning the sustainability of the current forest management model, as well as the long-held assumption that large-scale agriculture is inherently nonviable in the wet tropics. A special effort was made to describe the risk posed by global climate change and its potential impact on forest function. If there is a term that describes this analysis, it is the identification of linkages — between climate change and wildfire, deforestation and precipitation, forest fragmentation and species extinction, ore mines and hydroelectric power, to name a few.

These issues are part of the larger question of "What constitutes sustainable development?" The current paradigm has taken us halfway to our goal but has not (yet) succeeded in changing the essentially exploitive nature of natural resource-based development in the Amazon. In most cases, it manages only to mitigate the most egregious negative impacts. The Amazon needs a new development paradigm that will promote economic growth and reduce poverty, while simultaneously promoting the conservation of natural resources and the long-term economic health of the region.

How then can we improve IIRSA or, more importantly, how can we make "development" work better in its environmental, social and economic dimensions? This study provides the first regional-scale analysis (albeit preliminary) of the costs and benefits associated with the proposed infrastructure investments. There must be a serious effort to document the projected replacement cost in carbon emissions from deforestation; preliminary estimates are in the tens of billions of dollars. Might not these resources be used to subsidize productions systems that do not entail clearing forest? At the very least, the costs and benefits from IIRSA must be reevaluated in the context of one the most important issues of our time: the role of Amazonian development in either mitigating or exaggerating the impact of global warming. We need to understand how deforestation and climate change will impact precipitation patterns in other parts of the continent, because even a small reduction could reduce agricultural yields with enormous economic consequences.

South America contains the largest expanses of pristine tropical forests remaining globally. This feature must be recognized as the foundation for development and the region's principal comparative advantage. South America has an enormous economic incentive to conserve the ecosystem services provided by the Amazon, along with achieving real and effective regional integration. These are not mutually exclusive goals. We are fully aware that this will require the participation of all sectors of society, but most importantly the communities that reside in the Amazon and the enterprises that transform the wealth of the Amazon into marketable goods and services. Local and national governments must lead this effort as part of their obligation to regulate the interactions among different sectors of society. Conservation International presents this publication to these audiences in order to join with them in a common effort to save the Amazon.

Gustavo Fonseca
Team Leader, Natural Resources
The Global Environment Facility

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Executive Summary

The *Initiative for the Integration of the Regional Infrastructure of South America* (IIRSA) is a visionary program that will transform the countries of South American into a community of nations. Unlike past diplomatic efforts and customs unions, IIRSA is an eminently practical initiative that proposes to physically integrate the continent — long an historical goal of South America's democracies. However, many of IIRSA's planned investments will take place on parts of the continent with ecosystems and cultures that are extremely vulnerable to change. This includes the world's largest intact tropical forest, the Amazon Wilderness Area, which is situated between the Tropical Andes and the Cerrado Biodiversity Hotspots, two geographic regions characterized by an extraordinarily large number of species found nowhere else on the planet. In addition, the Amazon is home to numerous indigenous communities that are struggling to adapt to a globalized world. Unfortunately, IIRSA has been designed without adequate consideration of its potential environmental and social impacts and thus represents a latent threat to these ecosystems and cultures. A visionary initiative such as IIRSA should be visionary in all of its dimensions, and should incorporate measures to ensure that the region's renewable natural resources are conserved and its traditional communities strengthened. Failure to foresee the full impact of IIRSA investments, particularly in the context of climate change and global markets, will bring about a combination of forces that could lead to a perfect storm of environmental destruction. At stake is the greatest tropical wilderness area on the planet, which provides multiple strategic benefits for local and regional communities, as well as the entire world.

THE NEED FOR IIRSA AND A CONCURRENT CONSERVATION STRATEGY

IIRSA is motivated by the very real need to stimulate economic growth and reduce poverty among its member nations. As such, it contemplates a series of well-defined investments in three strategic sectors: transportation, energy, and telecommunications. Some of its most important investments will upgrade roads that span the Amazon, Andes, and Cerrado and link the Pacific and Atlantic coasts to create a modern continental-scale highway system. Although the financial institutions responsible for IIRSA have relatively high standards for environmental and social evaluation, environmental assessments are linked to individual projects and do not consider the collective impact of multiple investments. Nor do they adequately address the long term drivers of change, such as agriculture, forestry, hydrocarbons, minerals, and biofuels. For example, no environmental assessment has addressed the link between improved highways, increased deforestation, and carbon emissions, nor how deforestation might impact local and continental precipitation patterns.

Conservation International (CI) is developing a comprehensive strategy to evaluate and monitor IIRSA and other infrastructure investments. This document examines how development in the region involves local and regional actors, the importance of global commodity markets, and how climate change might impact these phenomena individually and collectively. For example, agriculture is the largest driver of land-use change in the region and will expand even faster and further in response to global markets, as IIRSA highways make previously remote land accessible and as new agricultural technologies make production more profitable. Modern transportation systems will lead to more intensive logging over wider areas, particularly in the previously remote western Amazon as it is linked to Asian markets via Pacific Coast ports.

Improved river transport systems (hydrovias) will make agricultural commodities, biofuels, and industrial minerals from the southern and eastern Amazon more competitive in international markets. Forest fragmentation and degradation caused by clearing and logging will bring about an increase in wildfires, which may also be exacerbated by regional manifestations of global warming. Accelerated deforestation will create a dangerous feedback loop with global atmospheric and ocean systems, accelerating global warming and perhaps altering rainfall patterns at the local, continental and global scale. These are all risks that need to be evaluated in an integrated analysis, and IIRSA must incorporate measures to avoid or mitigate the most dangerous of these impacts.

IIRSA and similar investments will profoundly affect the region's unique and vulnerable biodiversity. All but one of the ten IIRSA corridors intersect a Biodiversity Hotspot or High Biodiversity Wilderness Area—highly vulnerable regions that contain species found nowhere else in the world. In the montane forests of the Andes where there are extremely high levels of local endemism, any and all investments run a risk of creating an extinction event. In lowland Amazonian rain forests renowned for the regional uniqueness of their biodiversity, deforestation belts around highways will lead to fragmentation that will interfere with the ability of species to shift their geographic ranges in response to climate change. The natural grasslands of the Cerrado will continue to feel the brunt of agricultural development, with current rates of habitat conversion there leading to the complete disappearance of natural habitats by 2030. An increase in effluents from changing terrestrial landscapes will degrade aquatic ecosystems, while rivers will be fragmented by hydroelectric power plants and waterways, compromising the sustainability of fish populations.

Conservation strategies and mitigation programs for this development must be based on a thorough understanding of the regional nature of Amazonian biodiversity and must go beyond direct, immediate impacts of individual projects to account for long-term and collaborative impacts. At risk is not only the region's rare abundance of biodiversity but the economic and social sustainability of the development that IIRSA is intended to stimulate.

VALUING CONSERVATION AS PART OF A SUSTAINABLE DEVELOPMENT STRATEGY

The Amazon Wilderness Area and the Andes and Cerrado Hotspots provide ecosystem services to the world via their biodiversity, carbon stocks, water resources, and climate regulation. Locally, the region's biological resources provide subsistence and income to inhabitants in the form of fish, wildlife, fruit, and fiber, while natural, intact ecosystems contribute enormous value to the world's economy. Unfortunately, current production systems tend to be exploitive, emphasizing short-term economic returns that are generally cyclical in nature, as well as economically and ecologically unsustainable. Worse still, economists tend to discount ecosystems goods and services, as they are intangible and cannot be monetized in a traditional market. There is currently no mechanism or market that translates the Amazon's ecosystem services into the financial resources necessary to pay for its conservation or to subsidize the sustainable management of its renewable natural resources.

The flora and fauna of the Amazon has obvious intrinsic value, although there are limits on the ability of biodiversity to directly generate revenue. Nonetheless, it plays an irreplaceable role in supporting local economies and provides potential for economic growth through commercial ventures such as aquaculture and ecotourism. The largest— and as yet unexploited — economic asset in the Amazon is its carbon stocks, which we estimate to be worth $2.8 trillion if monetized in today's markets. Beyond that academic calculation, there is the potential to generate revenue using more realistic models discussed within the U.N. Framework Convention on Climate Change (UFCCC). For example, if the Amazonian countries agreed to reduce their deforestation rates by 5 percent each year for 30 years, this would potentially qualify as a reduction in greenhouse gas emissions and generate about $10 billion annually over the life of the agreement. Distributed equally among the approximately 1,000 Amazonian municipalities, this amount would constitute about $6.5 million per community per year that could be used to support health and education, the top two priorities in most communities.

IIRSA AND SOCIAL SUSTAINABILITY

No one can deny the urgent and palpable need to provide Amazonian residents with a dignified standard of living. The impending changes that will emerge from IIRSA investments in combination with global markets will definitely have a large impact on current inhabitants of the Amazon, particularly traditional communities and indigenous groups that depend on natural ecosystems for their sustenance. On the positive side, IIRSA projects will greatly reduce the isolation of rural communities and promote economic growth and new business opportunities. History shows, however, that these benefits will not be evenly distributed and, in some instance, may further marginalize the rural poor if proper precautions are not taken.

For example, highway corridors will stimulate the migration of hundreds of thousands, or even millions, of people into the region; new migrants will vie for resources with traditional communities, most of whose residents are ill-prepared to compete with the more sophisticated immigrants. The creation of secure land registries and the recognition of traditional use rights will be vital to ensuring that the current residents and indigenous communities are not shortchanged in the eventual—and inevitable— reconfiguration of Amazonian society.

Rapid cultural change also will bring increased incidence of alcoholism, suicide, prostitution, and HIV infection. Local residents will need new skills to compete in modern economies and function well in the new societies. In addition, health concerns need to be addressed: widespread forest fire will increase risk of lung diseases related to smoke inhalation, and forest pathogens will colonize new settlements. None of these are insignificant challenges, and they need to be addressed as an integrated part of sustainable development plans in order to ensure the development of a vibrant society in the Amazon.

CAN IIRSA BE A POSITIVE FORCE FOR CONSERVING THE AMAZON?

Multilateral financial agencies and their partner governments have often been harshly criticized for failing to identify and mitigate the environmental and social impacts associated with infrastructure investments. In response, they have committed to conducting comprehensive strategic environmental assessments (SEA) and ensuring the active participation of local communities in identifying both environmental and social impacts. However, this evaluation process must be enhanced in several ways if development is to be truly sustainable while mitigating some of the impacts this document raises: First, SEAs should be conducted well in advance of the feasibility study so that recommendations can be realistically included in project design. Second, assessment must begin taking into account secondary impacts and the cumulative impacts that accrue from multiple projects, including those financed by other agencies and private sector investors. In addition sustainable development plans, which are intended to avoid, mitigate or compensate for the impacts identified in the SEA, need to go beyond community based initiatives—as important as those may be—to address the economic motivations of the individual land holder. The Amazon is not being deforested by communities; it is being cleared and degraded by the actions of individuals, family and corporate, and if the Amazon is to be saved from destruction, individuals must be motivated to change their behavior.

The document concludes by providing a series of recommendations on how to improve IIRSA so that it can serve as a role model for development throughout the region, as well as the world. These policy recommendations are organized into two broad categories: Traditional approaches to environmental mitigation (i.e., the establishment of national systems of protected areas, complemented with indigenous reserves and the stewardship of private land for conservation and sustainable forest management), and nontraditional approaches that focus on the potential for generating income from environmental services to subsidize economic growth that avoids deforestation and rewards conservation. These nontraditional approaches include such recommendations as:

- **Creating revenue by monetizing carbon credits** — Saving the Amazon will require resources. Carbon markets and voluntary mechanisms can raise these resources and, at the same time, can be structured to respect the sovereign rights of individual nations to manage their own natural resources.
- **Ecosystem services should pay for social services** — A system of economic subsidies for health and education must be created to compensate communities that protect ecosystem services and limit deforestation.
- **Quid Pro Quo** — Because conserving the Amazon will slow global warming, a worldwide security issue, the global community should respect South American demands to restructure the U.N. Security Council (i.e., granting Brazil membership) and reform international trade.
- **People by air, cargo by water** — Highways are only one form of transportation. The Amazon river system is ideal to transport bulk commodities (grains, minerals, timber and biofuels), while subsidies for air transport could meet the transportation needs of the Amazon's far-flung communities.
- **Reform the land tenure system** — The insecurity of land tenure is a major driver of deforestation and conflict; long-overdue changes in the normative framework could reverse this paradigm so that forest conservation is rewarded rather than penalized.
- **Change the development paradigm** — The Amazon needs production systems that are less subject to the fluctuations of international commodity markets. This can only be achieved by transforming commodities into manufactured goods and services, along with investing in technology-based industries independent of natural resources (i.e., Manaus Free Trade Zone).

The countries of the Amazon, Andes and Guiana have all recognized that the conservation of the Amazon is a strategic priority. However, they also are adamant that an even greater strategic priority is the need for economic growth to improve the social welfare of their populations. These combined priorities lead to one logical policy option: the use of direct and indirect subsidies to promote economic growth that simultaneously conserves crucial natural ecosystems. This is not aid, nor do the residents want charity or other hand-outs. They want decent jobs and opportunities for their children. Future development must provide them with both, or conservation efforts will fail. This new development paradigm must ensure the region's inhabitants a dignified level of prosperity while making important contributions to the economies of the nations that are custodians of the Amazon. If the Amazon forest is a global asset worth preserving, then it is only reasonable that the custodians be paid for their efforts.

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CHAPTER 1

Introduction

Despite decades of encroachment and degradation, the greater Amazon is still the world's largest tropical forest, containing over 6 million square kilometers of forest habitat (©Haroldo Castro/CI).

The Amazon Wilderness Area is the world's largest intact tropical forest. It is situated between the Tropical Andes Biodiversity Hotspot and the Cerrado Biodiversity Hotspot, two regions that are themselves characterized by an extraordinarily large number of species found nowhere else on the planet (Mittermeier *et al.* 1998, 2003). Although these three regions are linked by climates, ecosystems, river basins, and shared cultural experiences, the eight nations that share the Amazon have not succeeded in integrating their national economies. The Initiative for the Integration of the Regional Infrastructure of South American (IIRSA) was conceived to create a continental economy, forging links between all of the countries in South America. IIRSA is a visionary initiative and aspires to a level of integration that has long been an historical goal of all of the founding fathers of the continent's democracies. Its ultimate goal is to form a South American identity in which citizens see themselves as part of a single community with a common future. Although previous efforts toward integration have been undertaken through treaty initiatives such as the Amazon and Andean cooperation pacts and the Mercosur customs union, movement toward a common identity has been elusive due to political differences and asymmetries in the size and internal structure of the economies of member nations. IIRSA is an eminently practical initiative meant to complement diplomatic initiatives; its goal is to undertake specific actions to link the regions of the continent physically in ways that will foster trade and social interchange among nations (Figure 1.1). IISRA is not an end in itself, nor even another treaty mechanism, but a series of well-defined investments (IIRSA 2007) that will convert South America into a community of nations.

IIRSA is motivated by the very real need to promote economic growth and reduce poverty among its member nations. However, it also threatens to accelerate the environmental degradation that is jeopardizing the natural ecosystems of South America. While it is true that the vast Amazonian Wilderness Area has acted as a barrier to cultural and economic interchange, it is arguably the world's most important biological asset, at least in terms of terrestrial biodiversity, holding a disproportionate amount of the biological resources of the planet. Many of IIRSA's development projects will directly intersect with areas that contain unique and vulnerable species (Figure 1.2).

IIRSA is being pursued with a deliberate speed that reflects the political commitment of its member states. However, the rush to integrate the economies of the region should not be made at the expense of the natural resources that are the foundation of these same national economies. IIRSA will unleash economic forces that will provoke human migration into areas that are extremely important for the conservation of biodiversity, and it will do so at scales and rates of change that the designers of IIRSA have not yet considered, despite more than three decades of experience in evaluating environmental impacts. Like the initial thrust of Amazonian development in the early 1960s, many proposed IIRSA investments are heedless of the environmental consequences and indifferent to social impacts. A visionary project such as IIRSA should be visionary in all its components; most importantly, it should incorporate measures that guarantee the conservation of the region's natural resources and the social welfare of the region's traditional populations. Failure to foresee the full impact of IIRSA investments will bring forth a combination of effects that will create a perfect storm of environmental destruction, thereby degrading the greatest tropical wilderness area on the planet.

Figure 1.1. IIRSA is composed of ten hubs that incorporate investments in modern paved highways, railroads, waterways, and grids. The upgraded road networks will span the Amazon, while waterways (hydrovias in IIRSA terminology) will open up vast areas of the western Amazon to commerce and development (map modified from IDB 2006).

This document provides an overview of the Amazon, Andes, and Cerrado regions. It describes the processes of economic development in relationship to local, regional, and global phenomena. It also examines the nature of biodiversity in these three ecologically complex regions in order to highlight the vulnerability of their ecosystems to the impacts associated with IIRSA projects. In addition, the document highlights conservation and development initiatives that have been successful and that could be replicated. Finally, a series of policy recommendations are provided that would avoid the most deleterious environmental impacts of IIRSA. These recommendations are formulated not in opposition to IIRSA, but to provide alternatives that would consolidate IIRSA's mission to promote economic growth and development.

IIRSA GOVERNANCE AND STRUCTURE

IIRSA involves all the countries of South America and was created to promote growth and development by investing in the physical integration of three strategic economic sectors: transportation, energy, and telecommunications. Although IIRSA is not a free trade agreement, it addresses regulatory issues that are barriers to the economic and social exchange among the nations. IIRSA promotes common industrial standards and communication protocols, while facilitating border crossings for rail, maritime, and airline transport. IIRSA also sponsors meetings and studies to promote commerce, and it facilitates technological exchange, integration of markets, and standardization of regulations (IDB 2006). However, IIRSA's most important investments are focused on improving the physical infrastructure of transportation. IIRSA projects are organized within one of ten integration hubs (*ejes* in Spanish and *eixos* in Portuguese), each with several corridors composed of highways, hydrovias,[1] and railroads, as well as electrical grids and pipelines (Figure 1.1). IIRSA is not a funding agency; rather, it is a coordinating mechanism among the governments and the multilateral institutions that are responsible for financing most of the public works investments in South America. IIRSA is governed by an Executive Steering Committee (CDE) and a Technical Coordinating Committee (CCT). The CDE

[1] The term hydrovia is used by IIRSA to denote a river waterway used for transportation.

Figure 1.2. Principal IIRSA highway corridors and hydrovias are shown in the context of the Amazon Wilderness Area and the Cerrado and Andes Biodiversity Hotspots. Conservation International organizes priority action in these regions.

is charged with developing a unified vision, defining strategic priorities, and approving periodic action plans. It is composed of representatives from each of the twelve member states, usually from the planning ministries, but occasionally individuals from the foreign or financial ministries (Figure 1.3). The CCT comprises representatives from three regional financial agencies: the Inter-American Development Bank (IDB),[2] the Andean Development Corporation (CAF), and the Financial Fund for the Development of the River Plate Basin (FONPLATA). It provides financial and technical support, coordinates meetings, and is the repository for IIRSA's institutional memory. The CCT's principal functions are to identify eligible projects, involve the private sector, and organize the finances. Finally, IIRSA-approved projects for each integration hub are managed by Executive Technical Groups (GTE). These groups approve projects, review environmental and social studies, and manage IIRSA investments. Projects are selected based on the twin principals of sustainability and feasibility, with individual projects being analyzed in the context of a portfolio of investments and reflecting the consensus of the GTE (IDB 2006). In practice, approved projects are those that national planning ministries favor and present to the IIRSA executive and technical committees (Dourojeanni 2006). Currently, IIRSA's agenda contains 335 projects, with 31 priority projects totaling more than $6.4 billion to be implemented in the first phase of IIRSA, spanning the years 2005 to 2010 (Table 1; Figure 1.4).

Brazil has a complementary initiative, similar to IIRSA both in philosophy and geographic scale, in which federal, state, and municipal governments are constitutionally mandated to present a multiyear integrated development plan (Pluri-Annual Plan, or PPA by its Portuguese acronym) to their respective legislative bodies. The current PPA for 2004 to 2007, known as the "Plano Brasil de Todos," has three major objectives: 1) social inclusion and the reduction of social inequity, 2) economic growth and job creation in the context of sustainable development and the reduction of inequality among regions, and 3) strengthening democracy through participatory mechanisms. Because PPA's primary goal is to foster economic growth, many of its investments will improve the integration of the national transportation and energy networks with neighboring countries.

Most IIRSA projects are financed by loans from the three financial institutions of CCT; however, financial packages often include funds from national budgets, sovereign bond tenders, bilateral donors, and private sources arranged by the construction companies that are contracted to execute the project. PPA financing comes from different public sources; most comes from local, state, and federal budgets, but an important portion is provided by the National Social and Economic Development Bank (BNDES), a public entity associated with the Ministry of Development, Industry and Foreign Trade. In addition, BNDES finances Brazilian operating companies in neighboring countries via a program known as BNDES-EXIM that exists to promote the export of Brazilian goods and services.[3] As a result, some IIRSA contracts are awarded to consortia led by Brazilian construction companies that have access to credit provided by BNDES[4] or by other export promotion programs managed by the Banco do Brasil (Banco do Brasil 2007).

2 Institutional titles are provided in English, but their acronyms follow those used on the IIRSA portal and by speakers of Spanish and Portuguese.

3 In 2005, BNDES approved a total of $2.5 billion in loans to Brazilian exports; of this total approximately $1.06 billion was for exports to Argentina, Chile, Ecuador, Paraguay, and Venezuela.

4 BNDES has also increased its participation in CAF, recently increasing its shares from 2.5 percent to 5 percent, but not enough to have the same voting privileges as the Andean countries (the so-called A shares).

Table 1. A summary of IIRSA projected investments.

Integration Axis (Eje)	Corridors Segments	Individual Projects	Estimated Investment[1] ($ millions)	Priority Financing ($ millions)[2]
Amazonia	7	91	8,027	1,215
Andes	11	92	8,400	117
Peru – Bolivia – Brazil	3	21	12,000	1,067
Interoceanic	5	54	7,210	921.5
Guayana Shield	4	44	1,072	121
Southern	2	22	1,100	n.a.
Capricorn	4	27	2,702	65
Mercosur – Chile	5	70	13,197	2,895
Hydrovia Paraná – Paraguay	1	3	1,000	1
Andes del Sur	n.a.	n.a.	n.a.	n.a.
Total	42	424	54,708	6,403

[1]Modified from IIRSA (2007) and BICECA (2007).
[2]IDB (2006).

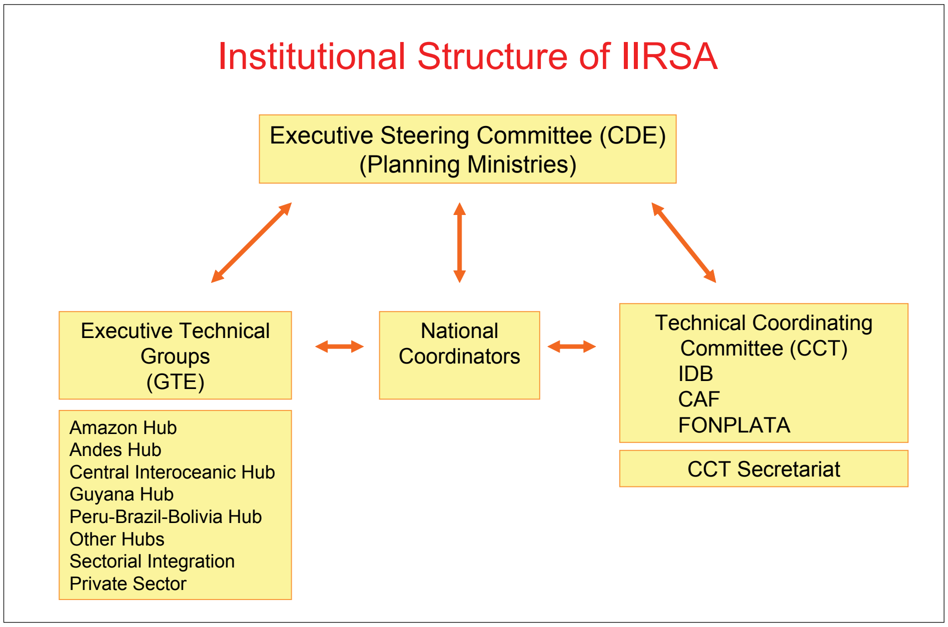

Figure 1.3. IIRSA structure. The Executive Steering Committee of IIRSA includes representatives from each South American government. Projects are administered by three multilateral lending agencies: the Inter-American Development Bank (IDB), the Andean Development Corporation (CAF), and the Financial Fund for the Development of the Río Plata (FONPLATA).

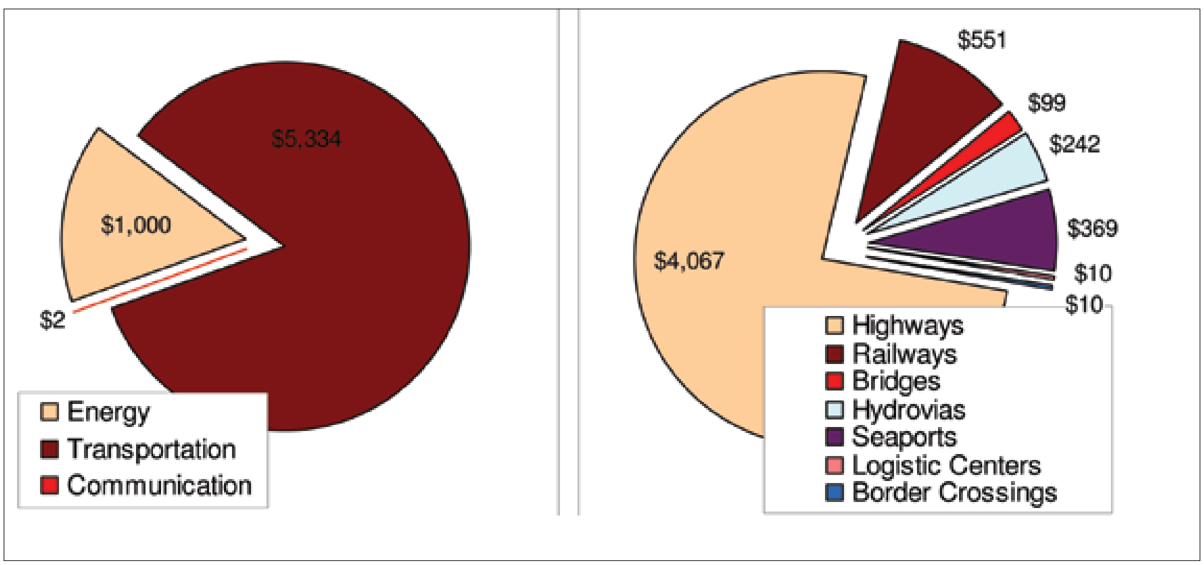

Figure 1.4. IIRSA investments are largely concentrated in highway infrastructure, but they also include other strategic transportation systems, as well as energy grids and communication systems (IDB 2006).

Figure 1.5. In a Utilitarian Scenario, an infusion of private capital would convert the Amazon into an agro-industrial powerhouse that provides the planet with food, fiber, and biofuels, while allowing for sustainable economic growth and social equity. Amazonian countries would develop technological solutions to overcome agricultural challenges such as soil infertility and weed control (© Hermes Justiniano/Bolivianature.com).

Because of the adverse impacts associated with similar investments in the past, IIRSA investments in infrastructure are viewed by many observers as a threat to the natural ecosystems of the Amazon and surrounding regions. Fortunately, most of the financial organizations involved with IIRSA have relatively high standards for environmental and social evaluation and usually condition loans on the implementation of environmental and social action plans.[5] Nonetheless, because infrastructure projects are being evaluated individually,[6] they fail to consider how the combination of projects and external forces such as global markets, transfrontier migration, or climate change might act synergistically to cause unforeseen effects.[7] The academic community has provided valuable insight into the potential future impacts and ample justification that a comprehensive evaluation procedure should be required for both IIRSA and PPA (Laurance *et al.* 2001, 2004, Nepstad *et al.* 2001, da Silva *et al.* 2005, Fearnside 2006b).

THE FUTURE OF THE AMAZON: THREE SCENARIOS

Virtually all South American societies support the conservation of the Amazon forest and — simultaneously — call for increased development that will provide residents of the Amazon a dignified life free of poverty. There are enormous differences among people as to what this vision actually entails, particularly regarding the preservation of wilderness areas, forest management, agricultural production, and land tenure. Most conservationists view IIRSA as a traditional type of development that will lead to widespread deforestation; at the same time, many economists and business people view the goals of the conservation movement as an impediment to economic growth. Regardless of these contrasting viewpoints, it will be the economic markets and the decisions of democratic societies that will ultimately decide the fate of the Amazon. It is impossible to predict this future, but it is possible, based on historical events and scientific research, to envision various scenarios that would likely follow different policy implementations. This section provides three scenarios of what the Amazon might look like after a century of human-induced change. Two are decidedly optimistic in outlook, but diametrically opposed in their philosophical underpinnings, whereas the third scenario is a more realistic view of what is most likely to occur without a radical change in current public policies.

The Amazon as Bread Basket (the Utilitarian Scenario)

In this scenario, climate change and land use change interact to create an Amazon that becomes progressively drier and warmer, and where the natural forest ecosystems are largely replaced by tree plantations and mechanized agriculture (Figure 1.5). This scenario is largely based on two assumptions: 1) the climate in the Amazon will become drier and warmer, as predicted by climate-change models, leading to a collapse of the humid forest ecosystem; and 2) there will be massive deforestation in the Amazon as a result of decisions made by national governments and local people. The remainder of the assumptions underpinning this scenario, specifically regarding agricultural systems and economic growth, reflect modern society's resilience and technological capacity to adapt to change.

5 Multilateral banks have been more progressive on environmental and social issues than commercial banks. For example, IDB and CAF have developed and adopted environmental guidelines and Strategic Environmental Assessments, although these have yet to be fully implemented. In contrast, FONPLATA requires only that projects meet the environmental norms of its member countries, and BNDES recently received poor ratings by an independent evaluation that focused on commercial banks (WWF/BankTrack 2006).

6 At the time of press, Strategic Environmental Assessments have been contracted or are underway for the corridor Puerto Suarez–Santa Cruz (IDB Project No. TC-9904003-BO0), the Corridor del Norte in Bolivia (IDB project BO-0200), and the InterOceanic Corridor in Madre de Dios, Peru (INRENA-CAF Project).

7 Only one region-wide study was commissioned before 2006, which consisted of an $81,000 consultancy contracted by IDB with funds provided by the Netherlands; the contract was made to a private consulting group, Golder Associates, of Boulder, Colorado.

Global warming is the primary driver of change. Increasing temperatures and dryness cause rainforest soils to respire at rates greater than trees photosynthesize; this shifts the Amazon ecosystem into a net source of carbon, further exacerbating global warming. The tree species of the humid forest ecosystem cannot adapt to the new climate conditions and are eventually eliminated from the forest due to increased adult mortality and lower levels of reproductive success. IIRSA's transcontinental highways increase the density of secondary roads, so that within a century eventually 70 percent of the original forest cover is replaced with pastures, crops, or tree plantations. Once it becomes clear that tree species are under physiological threat from climate change, governments adopt policies to monetize timber reserves rather than lose them to natural processes of mortality and decay. The forest ecosystem essentially collapses and is replaced by an agricultural production system that consolidates Brazil as the most important producer of agricultural foodstuffs and biofuels in the world.

Technology will allow the agricultural sector to adapt to climatic change. Archeological reconstructions in the central Amazon have revealed how Amerindian civilizations improved soil resources and sustained fertility over the long term using ceramics and charcoal to ameliorate soil acidity and increase organic matter Modern agricultural science has rediscovered these management techniques and adopted them for both perennial and annual production systems. Agriculture will become more diversified with annual crops predominating on the best soils, whereas cattle ranches and tree farms will prevail on rolling topography. The production of biofuels will become increasingly important, with plantations of sugar cane producing alcohol and oil palm for biodiesel fuel. Research will improve pest control using genetically modified organisms in combination with an ever-increasing arsenal of pesticides. Farms that specialize in highly productive perennial species will make the Amazon the most productive agricultural region in the world on a per hectare annual basis.

Although precipitation will decline, the Amazon basin will still be the world's largest freshwater hydrological system, containing the world's largest underground aquifer.[8] Irrigation technology, powered from the western Amazon's abundant natural gas reserves and from locally produced biofuels, will mitigate seasonal fluctuations in precipitation. Dams and reservoirs will contribute surface water to the irrigation system and provide affordable hydroelectric power for urban centers with an industrial economy focused on metallurgy, forest products, and food processing. There will be continued migration from rural to urban areas, particularly in cities such as Iquitos, Peru, and Leticia, Colombia, which will follow the example of Manaus, Brazil, to develop economies based on manufacturing, financial services, and technological innovation.

These radical changes to the Amazon basin will cause environmental impacts at the global, regional, and local levels. At the global level, the collapse of the forest ecosystem will exacerbate global warming. Carbon reserves of the Amazon will be released into the atmosphere; the carbon emitted from the Amazon during this century will be equivalent to about 13 years of industrial emissions.

Precipitation regimes in the Amazon and surrounding areas will be affected by both global and regional manifestations of climate change. However, moderate levels of rainfall over the central Amazon will be guaranteed by the trade winds that transport water vapor from the Atlantic Ocean. Deforestation will negatively impact the convective systems that recycle about 50 percent of the precipitation that falls on the Amazon; this will cause dry seasons to become longer and more severe. The low-level jet stream system that modulates the seasonal monsoon and transports water vapor from the Amazon to the Río Plata basin will increase in intensity but will transport less water due to the drier conditions that predominate in the western Amazon. Nonetheless, the agricultural productivity of the lower Río Plata basin will not be severely affected because other weather systems will increase the precipitation that originates over the South Atlantic.

Biodiversity conservation will be managed by a reserve system of protected areas that was established in the last decade of the twentieth century and will continue into the first two decades of the twenty-first century. Like protected areas in North America and Europe, these are island-like preserves containing a representative sample of the biodiversity that existed in the Amazon prior to the industrialization of agriculture. As predicted by conservation biologists, this level of isolation will cause the widespread extinction of many endemic species and the homogenization of many of the biota within protected areas. Ecosystem fragmentation will limit the ability of many species to migrate in response to global warming, therefore causing even more extinctions.

The economic growth from agriculture, cattle ranching, and plantation forestry will create a favorable business environment and increase employment opportunities. Prosperity will increase tax revenues and allow greater investment in education and health services. The skilled professionals needed to manage the financial, industrial, and commercial institutions will migrate into the Amazon from urban centers of South America (e.g., São Paolo, Bogotá, and Lima). Indigenous peoples will adapt to change by relying on their internal social organizations as a bulwark against the homogenization of their cultures and to protect the economic interests of their communities. However, the most important element in their success is the advantage of being granted clear title to large expanses of land. As the group with the largest land area in the Amazon, they will use this asset to engage in economic growth through agricultural production and plantation forestry.

In this Utilitarian Scenario, the Amazonian nations have successfully integrated their economies, and Brazil has evolved into one of the most prosperous and dynamic nations on the planet. Its large population and stable economy act as the economic motor for the region and provide much of the technological innovation behind the sustainable, productive systems that now characterize the Amazon. The Andean countries have close commercial ties with Brazil, and the economic growth in the Amazon is linked

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8 The dimensions of the southern part of this aquifer were recently mapped in Santa Cruz, Bolivia (Cochrane *et al.* 2007). The geology of the basin, known as the Andean foredeep, is composed of loosely consolidated sediments that have been charged with water over several million years. Because this is a nonconfined aquifer, it is recharged continuously from surface sources and has the potential for a truly sustainable irrigation system.

to Asian markets that are accessed via Pacific Ocean coastal ports. The predictions of biodiversity loss have been shown to be real, but ecological collapse has been avoided by using technology to develop sustainable production systems that provide strategically important commodities to global markets.

The Amazon as Forest Wilderness (the Utopian Scenario)

In this scenario, the dramatic decrease in precipitation predicted by some climate models does not materialize and wide-scale deforestation is avoided because the countries that share the Amazon basin make a commitment to conserve the Amazon forest as a natural ecosystem (Figure 1.6). The avoidance of deforestation depends on the creation of a system in which payments for ecosystem services subsidize the conservation of the Amazon. For example, developed nations allow payment for carbon storage in natural ecosystems and are willing to transfer significant sums of money from their domestic economies to Amazonian countries. The stability in current precipitation levels assumes that the world will avoid the worst-case global warming scenario by limiting carbon emissions and that forest conservation will maintain the convective systems that recycle water over the Amazon. The basis of this scenario is a belief that human societies have the capacity to manage growth and development in the Amazon and that Latin American societies reform their governments and establish the rule of law in frontier areas, particularly regulatory systems that govern land tenure.

National governments that agree to reduce deforestation will adopt mechanisms for using payments for ecosystem services to conserve forests in exchange for investments in health and education; a portion of these payments will be used to subsidize value-added industries that transform the region's abundant natural resources into globally competitive goods and services. Annual satellite surveys monitor land-use change, and failure to meet commitments will be reflected in the annual social service budget. This explicit link will create strong local support to comply with deforestation reduction targets, and the emphasis on social services will have immediate short-term benefits due to a surge in the construction of new schools and clinics, while longer-term impacts will result from job growth in the education and health sectors.

In line with one of IIRSA's main goals—to facilitate the export of agricultural commodities from central Brazil to the Pacific coast—intensive production will increase exports, but deforestation will be contained by adopting mixed land-use models that maintain 80 percent of the land as forest and limit land-use change to 20 percent of total cover.[9] Implementation of this model will be promoted by guaranteeing clear title and providing subsidized credit to land tenants who adopt the 80:20 land-use rules. This credit will be linked to intensive production systems that maximize the use of deforested land. Satellite imagery will monitor land use and identify farms that fail to meet the criteria; noncompliance will result in loss of credit and reversion of land tenure.

Instead of highway corridors, the Amazonian countries will adopt the transportation model "people by air and cargo by water." Low-cost barge traffic will make commodities and minerals competitive in world markets. Subsidized air transportation will facilitate a more effective health care system, allowing the sick access to health care during emergencies and allowing health care professionals to make regular visits to remote communities. Inexpensive air service across the Amazon will stimulate development of the tourist industry in remote areas. Subsidized credit will be used to foster partnerships between the private sector and local communities, ensuring the participation of local residents while improving the tourist experience.

9 This land-use regulation is already enshrined in Brazilian law but is poorly enforced in almost all frontier areas.

Figure 1.6. A Utopian Scenario would require an international agreement that compensates Amazonian countries for reducing carbon emissions caused by deforestation. Payments for ecosystem services would be used to fund health and education, and to subsidize production that avoids deforestation and forest degradation (©Greenpeace).

Intensive production systems will include some traditional options, such as mechanized agriculture, livestock, tree plantations, and biofuels. However, because water is the most abundant and most valuable resource in the Amazon, it will also logically be the most important basis of production. Fish farming is the most efficient way to convert agricultural commodities to animal protein, especially in the warm ponds of the Amazon where herbivorous native species are fed agricultural commodities imported from nearby grain-producing regions. Aquaculture requires a small surface area and is ideally suited to the family farm; more importantly, it creates a value-added production chain that increases income for rural populations. The production model with the largest footprint, however, will continue to be timber exploitation. The forest products sector will adopt harvest guidelines that mimic natural forest processes with harvest cycles greater than 100 years. This low-intensity timber harvest model will depend upon transportation subsidies, tax abatements, and direct payments for ecological services. Instead of collecting royalties for the exploitation of timber, states will provide compensation to landholders for adopting management criteria that ensure forest conservation.[10]

Maintaining the integrity of the forest ecosystem will lead to benefits for biodiversity conservation in this optimistic utopian scenario. Farms and plantations will be dispersed over a broader geographic landscape due to the dependence on river transport; however, adherence to the 80:20 land-use rule will help avoid forest fragmentation and keep the forest matrix intact. Connectivity among protected areas will be maintained across the landscape to ensure the survival of regional endemics and rare species. Unfortunately, the dependence on river transport will lead to a degradation of aquatic systems, especially where locks and dams are installed to circumvent rapids or where dredges and dynamite are used to facilitate transit of barge convoys on smaller rivers.

[10] This will end the current perverse incentives in which forest concessionaires pay royalties on harvested timber, while cattle ranchers and farmers pay none on the timber they harvest during land clearing.

Figure 1.7. A Business as Usual Scenario assumes that existing patterns of natural resource exploitation would continue, leading to landscapes dominated by low intensity agriculture and degraded forests. Poor governance and unregulated markets would lead to boom and bust cycles that inhibit long-term investment in social services, and the region would be characterized by entrenched poverty (© Olivier Langrand/CI).

Similarly, the widespread adoption of fish farming degrades some hydrological resources due to the release of effluents from production ponds.

The Utopian Scenario provides for improved human welfare in Amazonian societies. Large cash flows from the payment for ecosystem services improve incomes and subsidize key social services. The mixed land-use model combines low-intensity timber management with high-intensity agricultural production. Indigenous groups with large land assets benefit by forming joint ventures with urban investors who provide technical expertise and access to capital. Most importantly, the use of subsidies, tax abatements, and low-interest loans for sustainable production creates new business opportunities that increase the quantity and quality of employment in both rural and urban communities. The Utopian Scenario allows the Amazonian nations to integrate their economies. Brazil's sovereign decision to conserve the Amazon ecosystem as a national heritage leads to the development of a system to compensate communities for the ecosystem services provided by the forest. The Andean countries follow suit and make special efforts to preserve the ethnic diversity that characterizes the lowlands in the western Amazon. Asian markets continue to dominate Amazonian exports but are characterized by value-added production chains that generate employment and contribute to stable economies.

The Amazon as a Degraded Forest (the Business as Usual Scenario)

Unfortunately, the most likely future scenario is "more of the same." The assumptions underlying this scenario are that individuals continue to be motivated by short-term financial gain, while national governments are unable to enforce regulations for controlling development in the Amazon, and international organizations are unsuccessful in creating market mechanisms to pay for ecosystem services. As a result, world markets and national demographic pressures continue to motivate individuals to acquire land in the Amazon and engage in agricultural and development practices that deforest landscapes, degrade soils, and interrupt hydrological systems (Figure 1.7).

The motivation for this pessimistic scenario is not unlike that underlying the optimistic utilitarian scenario; however, in this scenario, the sophisticated production systems that require capital investment and technological innovation do not materialize due to instability in land tenure and the high cost of financial capital. Nonetheless, the determination to integrate the transportation infrastructure of the continent accelerates demand for land and induces governments to open up more areas for settlement. Small farmers and peasants compete for land with industrialized agriculture, but poor soil management practices eventually lead to the predominance of low-intensity cattle ranching combined with tree plantations, a low-risk business model that provides a moderate return for affluent investors.

Deforestation has dramatic impacts on the regional hydrological cycle by decreasing precipitation and increasing the intensity of the annual dry season. Agriculture is also negatively affected in extra-Amazonian areas such as Argentina, Paraguay, and Santa Cruz and Mato Grosso do Sul, Brazil, which are the most important granaries of the continent. Landscapes are radically altered, and the once extensive forest has been reduced to degraded patches that vary in size and composition depending on their distance from major highways. Large blocks of forest exist only in protected areas, indigenous lands, and extractive reserves, although the latter two categories will be highly degraded due to overly aggressive logging practices. Connectivity among forest patches will be minimal or nonexistent, except in areas where topography and soils inhibit the development of agriculture. Rivers and streams will suffer increased sedimentation and runoff from the use of pesticides and nitrogenous fertilizers, changing both their physical and chemical attributes. Upstream landowners will construct containment structures to provide water for livestock, while government initiatives to build dams and reservoirs for water management and hydropower will degrade connectivity in aquatic systems and impoverish them.

Biodiversity will suffer in both terrestrial and aquatic ecosystems, with massive levels of species extinction occurring at global, regional, and local scales. This millennial extinction will take place in slow motion, with many species, such as long-lived woody plants, surviving as lone nonreproducing individuals in many forest patches. The extermination of large mammals and the overexploitation of large migratory fish populations will cause dramatic changes in both the structure and composition of biological communities. The rapid rate of climate change and the fragmented landscape will inhibit the ability of many species to adapt or migrate to regions where the climatic conditions are adequate for their survival. All of these processes will lead to the extinction of many regional endemics in the Amazon lowlands and to local endemics in the Andean foothills.

The lack of investment and policy innovations will lead to the stagnation of human communities. Indigenous societies that acquired title to vast tracts of forest will have overexploited those resources and become even more dependent on subsistence agriculture due to the scarcity of fish and game. The social group most susceptible to the negative effects of poorly planned economic growth and environmental change will be the rural poor with no clear ethnic affiliation. Poverty and the scarcity of game will increase the pressure on protected areas, leading to illegal logging and hunting in the more remote and lawless regions of the Amazon. Squatters will continue to encroach on protected areas, which remain a low priority for governments that must deal with widespread poverty. Unskilled workers, both native and immigrant, will congregate in urban ghettos and compete for work in a stagnant job market. Social inequality becomes more accentuated because commercial cattle ranchers and mechanized farmers prosper by producing commodities for export markets with little value-added transformation. The lack of investment in education will result in individuals having few marketable skills, while the absence of research budgets at universities will stifle innovation in developing new production systems.

In this scenario, the Amazonian nations will not have succeeded in integrating their economies despite the massive investments in infrastructure. In the Brazilian Amazon, large-scale industrialized production predominates because of a societal decision to embrace a free market capitalist economy. In contrast, the Andean nations will have opted for a development model in which the state assumes a predominant role in economic planning. Subsequent economic stagnation causes poor people from the rural highlands to migrate to the western Amazon where, lacking capital resources, they adopt inefficient production systems. Asian markets continue to dominate Amazonian exports but are characterized by raw commodities rather than value-added manufactured goods derived from those commodities. Consequently, producers in the Amazon are subject to large fluctuations in international markets, perpetuating the boom-and-bust mentality that has characterized the region for more than two centuries.

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CHAPTER 2

The Drivers of Change

Prize winning Nelore cattle at the Estancia el Carmen in Santa Cruz, Bolivia (© Luiz Fernando Saavedra Bruno).

IIRSA will unleash economic and social forces that will radically alter the Amazon. Many of these are well known and have been responsible for the ongoing process of deforestation and forest degradation over the past half century. The rapidly evolving dynamic of a global economy makes it essential to visualize the economic and social phenomena that are just beyond our cognizant horizon. In this chapter we describe the major drivers of change and their interrelationship with economic growth and infrastructure investments. Only by understanding the nature and dimensions of these forces can we understand the potential impact of IIRSA investments and develop an effective mitigation strategy to manage growth and development.

ADVANCE OF THE AGRICULTURAL FRONTIER

The greatest threat to the conservation of the Amazon Wilderness Area, the Cerrado Hotspot, and the Tropical Andes Hotspot is land use change caused by the expansion of the agricultural frontier. Despite profound reforms to national economies and massive domestic and direct foreign investments over the last two decades, tens of thousands of peasant farmers continue to migrate ever deeper into the Amazon wilderness, a result of demographic pressure and the entrenched poverty that characterizes the region's nations. At the same time, mechanized farms and cattle ranches are expanding production in frontier areas, taking advantage of low land prices and modern technology to obtain economies of scale and an attractive return on investment. IIRSA-financed highway projects (although they largely involve improvements to existing road networks) will accelerate this process by increasing access to tens of thousands of square kilometers of unclaimed lands. Indeed, modern highways are the most important driver of deforestation in the Amazon. New and improved roads will also change the economics of transportation models: although the primitive, unimproved roads created by timber companies do not offer a viable transportation system, when these are upgraded with raised beds, bridges, and pavement, transportation costs will drop, making remote agricultural producers in the Amazon competitive in national and international markets (Kaimowitz & Angelsen 1998, Lambin *et al.* 2003, Hecht 2005).

The dynamic of land use change varies among the region's nations and has changed over time. In the 1970s and 1980s, governments throughout the region adopted economic and development policies to promote the migration of small farmers into frontier areas and provided a variety of subsidies to cattle ranchers (Hecht & Cockburn 1989, Thiele 1995, Pacheco 1998). The impact of these policies is still visible in the landscape of many parts of the Amazon (Figure 2.1).

In the 1990s, concern about tropical deforestation led governments to revise their policies and end many of the subsidies that supported the agricultural production systems responsible for deforestation. Simultaneously, governments and international agencies invested in protected areas and encouraged the growth of ecotourism (Mittermeier *et al.* 2005). The search for economically viable alternatives to agriculture led to initiatives to improve the management of both timber and nontimber products (Putz *et al.* 2004, Ruiz-Perez *et al.* 2005). However, deforestation has shown no signs of abatement: After a brief respite in the late

Figure 2.1. Migration stimulated by highway construction has left its imprint on Amazonian landscapes; the social and agricultural systems can often be seen in the deforestation pattern: a) Deforestation in Roraima is characteristic of subsistence farmers in remote regions of Brazil who have no market for their agricultural production; many are also gareimpero gold miners. b) Scattered deforestation on the Caguan River in the Caquetá Department of Colombia is believed to be largely dedicated to coca cultivation. c) Large blocks of deforested land are characteristic of the corporate cattle farms of northeast Mato Grosso in Brazil. d) Colonization along a grid of primary and secondary roads in Rondônia, Brazil, has led to a fishbone pattern of deforestation. e) On the Andean piedmont near Pucallpa, Peru, colonists have settled along highways that connect Amazonian tributaries to urban markets in the Andean highlands. f) Complex land-use patterns in Santa Cruz, Bolivia, are the result of colonists from the Andes, Mennonite communities, and corporate farms (Google Earth ™ Mapping Services).

1990s and perhaps again in the past two years,[11] annual deforestation rates have been steadily increasing in both Brazil and Bolivia (Figure 2.2).

Although governments no longer actively promote migration and land use change through organized colonization projects,[12] they continue to support agricultural development, both directly and indirectly. Most obvious is their support for infrastructure investments such as those exemplified by IIRSA (Laurance *et al.* 2004, Hecht 2005). However, other policies have subtle effects as well. For example, state-supported research in tropical agriculture and animal husbandry contributes to the economic profitability of agricultural systems that drive land use change. Similarly, providing titles to individuals and companies that occupy state-owned land confers indisputable economic benefits to the actors that are directly responsible for deforestation (Andersen 1997, Pacheco 1998, Margulis 2004). However, the most important development contributing to deforestation is the linking of global markets to the agricultural sector, which is now firmly ensconced in a free market model based on supply and demand. Thus, the small farmer or large cattle rancher in the Amazon works to maximize the return on his personal investments (Margulis 2004). Market forces are now the single most important factor driving tropical deforestation.

One of tropical ecology's most resilient doctrines is that tropical soils are infertile; many conservation biologists are convinced that deforested landscapes will eventually be abandoned or require long fallow periods to restore fertility. If this were true, agricultural expansion and deforestation would have no economic logic, except in those cases where peasants migrate, practice slash-and-burn agriculture, and then move on in a futile effort to escape poverty (Fujisaka *et al.* 1996).[13] However, modern technology and markets are rapidly enabling agricultural development and making large-scale mechanized agriculture economically feasible (see Text Box 1). Investments in genetically improved cattle breeds and pasture cultivars, combined with efficient meat processing factories and currency devaluations have augmented production to make Brazil the world's largest beef exporter. Eighty percent of the growth in the national livestock herd in the last decade has occurred in Amazonian states. Meanwhile, investments in local transportation and electricity grids have lowered operating costs for producers. IIRSA's investments will accelerate this process by increasing access to tens of thousands of square kilometers of unclaimed lands, thus further improving the competitiveness of Brazilian livestock producers. Similar processes are underway in Bolivia and Colombia, and the Brazilian production model will probably expand to other Andean countries as a consequence of IIRSA projects (Figure 2.3).

In addition, the rediscovery of unique farming methods practiced by pre-Columbian cultures may also provide technolo-

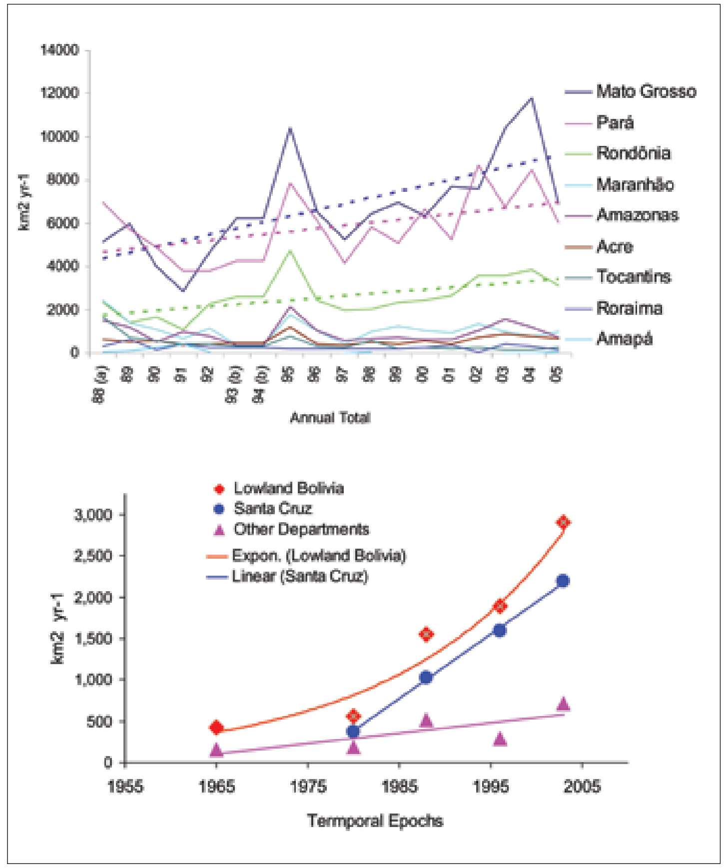

Figure 2.2. Deforestation data fluctuate from year to year, but increase over the mid term, at least in Brazil and Bolivia. IIRSA will open vast areas of previously remote forest, increasing the rate of deforestation over the short term unless measures to counter this trend are taken (modified from PRODES 2007 and Killeen *et al.* 2007).

gies for modern agricultural development in the Amazon basin. Archeologists have shown that the Amazon has supported intensive agriculture and that the main branch of the Amazon River sustained populations in excess of several million inhabitants (Roosevelt *et al.* 1996).[14] The agricultural production systems of these populations were tightly linked to major rivers, but they also included extensive tree gardens where the soil chemistry was modified by additions of charcoal and ceramics, an agricultural practice that provides an intriguing alternative for development around a revitalized river transport system (Lehmann *et al.* 2003, Glaser & Woods 2004).

Key social actors play an important role in introducing agricultural technology and capital into frontier regions. Mennonite and other expatriate farmers have often been the first to bring mechanized agriculture into an area and have been adept at experimenting with different crops. Mennonites have a cultural tradition of migrating to lands where they had no previous presence and that are often hundreds of kilometers distant from

11 The Environmental Ministry in Brazil has reported a decrease of 31 percent in the 2004 annual deforestation rate in the Brazilian Amazon; more information is available at http://www.socioambiental.org/nsa/detalhe?id=2161.

12 This policy may be changing yet again in Bolivia, where the government of President Evo Morales has announced a land distribution plan aimed at small farmers and landless peasants.

13 The consequences of this model and the predicted poverty are evident in areas settled by peasant farmers with little access to capital or technology, such as the Andean piedmont, Rondônia, and along the Transamazonian Highway in Pará.

14 The current Cabloco culture retains many attributes of this production system, including farming, fishing, and fruit harvesting from tree and palm species in the flooded river valley forests. Pre-Columbian populations also inhabited the uplands to the north and south of the floodplain where they practiced an intensive agriculture using anthropogenic "black earth" soils that were created using a combination of technologies such as charcoal and clay. There is also circumstantial evidence that they created extensive orchards of native trees that served both as a source of fruit, and as an attraction for game (see Mann 2005 for a popular account and review of the pertinent literature).

Text Box 1

How Feasible Is Mechanized Agriculture in the Amazon?

Tropical ecologists have long held that tropical soils are infertile and not economically viable for agricultural development. However, modern technology is disproving this belief and well-capitalized farmers and cattle ranchers are overcoming the limitations of tropical soils (Mertens *et al.* 2002). By using new varieties of cultivated forage grasses, rotational grazing to control weeds, and vitamins to compensate for the lack of micronutrients, ranchers have increased profitability and obtained sustainability. Other factors have also made Amazonian beef competitive in global markets: innovations in animal husbandry, the elimination of foot and mouth disease, and the absence of bovine spongiform encephalitis (mad cow disease), which has hurt European and U.S. competitors. Pasture in the Brazilian Amazon now covers some 33 million hectares and houses around 57 million head of cattle (Kaimowitz 2005).

Farming is also becoming more feasible, thanks to modern technology and cost-effective solutions. In the Cerrado Hotspot, soy farmers apply chemical lime ($CaCO_3$), which changes the pH of soils, resolves aluminum toxicity, and mobilizes plant nutrients that were previously tightly bound to clay particles. In Bolivia, farmers rotate soy with corn or sorghum to manage fungal pathogens. Similar solutions are likely to be discovered and implemented in the Amazon to manage soil fertility and improve pest management. A report for the National Academy of Sciences contends that continuous food crop production is feasible on most Oxisols and Ultisols in the humid tropics and is economically viable when market conditions ensure access to fertilizers and a market for produce (BOA 1993).

their original homesteads. Likewise, second or third generation Andean migrants with experience cultivating tropical crops often spearhead colonization into new areas. Currently, all three groups are actively involved in land speculation on the periphery of Madidi National Park in northern Bolivia.

In Brazil, market forces govern the actions of small and medium-sized resident farmers, as well as the urban investors who own most industrial farms and ranches. Small farmers are often directly responsible for deforestation. Even though their farms are not particularly lucrative, they realize a large capital gain when they sell their land to cattle ranchers and soy farmers who consolidate these small holdings into large agribusiness operations (Fearnside 2001a, Margulis 2004). In the Andean countries, deforestation is largely the result of peasants practicing subsistence agriculture, which is supplemented by cash crops that are commercialized in urban areas on the coast or in the highlands (Gomez-Romero & Tamariz-Ortiz 1998, Kalliola & Flores-Paitan 1998). In some localized areas the cash crop is coca, which is used to produce illicit drugs (Figure 2.1b). By integrating Brazilian and Andean economies, IIRSA will accelerate the trend for Andean farmers to adopt Brazil's more efficient production systems and radically increase the rate of land use change in the western Amazon, as happened previously in both eastern Paraguay in the 1980s and Bolivia in the 1990s (Steininger *et al.* 2001, Pacheco & Mertens 2004). There are, for example, recent reports of farmers adopting mechanized rice production near Pucallpa, Peru (Figure 2.1e).

In Bolivia, peasant and industrialized agriculture have coexisted over several decades, but in the last few years mechanized agriculture and intensive cattle farming have expanded dramatically as the region has become linked to global markets (Pacheco 1998, Kaimowitz *et al.* 1999, Pacheco & Mertens 2004). With this expansion of market-driven agriculture, land speculation has become an increasingly important driver of land use change (Pacheco 2006), and the area under cultivation has been growing at annual rates that approach 20 percent over the past decade (Figure 2.2b). Technological transfer is occurring not just from

Figure 2.3. Cattle farming in Brazil is based on a successful business model that uses improved genetic stock, cultivated grasses, rotational grazing, and supplemental vitamins fine-tuned to essential soil minerals. Brazilian technology is exported to this ranch in Santa Cruz, Bolivia, where livestock productivity is closely monitored by computer (© Luiz Fernando Saavedra Bruno).

Brazilian investors to Bolivian agribusiness, but also from the agribusiness sector to peasant agriculture.[15]

A reform of world trade could also dramatically increase the pressure on tropical forest ecosystems. Agricultural production is more profitable in Latin America than in North America, Europe, or Japan thanks to fuel subsidies, low labor costs, land values, and tax exemption or avoidance.[16] Regional farmers already successfully compete in international markets, particularly China,[17] and increased access to markets in developed countries would dramatically increase pressure on natural habitats. The new interest in biofuels will also bring pressures on tropical forest ecosystems, especially if these fuels are derived from species adapted to tropical climates and soils (see section on biofuels below).

IIRSA's integration corridors will open up vast areas in the interior of the continent to migration, land speculation, and deforestation (Figure 2.4). The dimensions of agricultural expansion that will accompany these changes have not been adequately evaluated by the studies commissioned by IIRSA; in some cases, agricultural expansion may be a desired outcome and a legitimate motivation for investments. However, in remote areas where natural ecosystems still predominate, the potential environmental impacts related to agriculture must be foreseen and described so that appropriate mitigation measures can be incorporated into IIRSA investments (see Chapter 6).

15 A recent flight over a peasant colonization zone (San Julian) near Santa Cruz, Bolivia, revealed that approximately 25 percent of the fields were planted in row crops, including soy, sunflower, and maize. Agribusinesses enterprises are proactively engaging small farmers by providing credit during the planting season that is payable in grain after harvest (pers. comm. D. Onks, General manager ADM/São, Santa Cruz, Bolivia).

16 Land values range from $20–$300 ha−1 (Santa Cruz, Bolivia) to $200–$1,000 ha−1 (Matto Grosso do Sul, Brazil), compared with $2,000–$7,000 ha−1 (Iowa, USA). See http://www.extension.iastate.edu/agdm/articles/leibold/LeibDec01.htm.

17 Large-scale soy farmers in Bolivia experienced returns as high 100 percent on capital in 2005, with yields of 2 metric tonnes (Mt) ha−1 and prices at $240 per Mt, while breaking even at $140 Mt.

FORESTRY AND LOGGING

Improved access to markets will also bring profound changes to the forest products industry, which is based on the extraction and exploitation of both timber and nontimber forest products. The most environmentally sustainable sector in this industry is also one of the most economically profitable activities in the southwestern Amazon: the collection, processing, and transportation of Brazil nut. The southwestern Amazon has some of the highest densities of Brazil nut in the Amazon (Peres *et al.* 2003), with northern Bolivia alone annually exporting about $70 million worth of nuts, representing about 50 percent of the global production of this important Amazonian commodity (Bolivia Forestal 2007). Ironically, IIRSA highways will improve the profitability of this sector over the short term by decreasing transportation costs, but over the medium term, exports will decline as deforestation and forest fragmentation devastates Brazil nut populations. Even if trees are left standing on deforested landscapes, studies have shown that individual trees in pastures fail to produce fruit and suffer high rates of mortality (Ortiz 2005).

IIRSA will have an equally profound effect on the timber industry. Amazonian hydrovias and modern highway corridors will connect the remote regions of the western Amazon basin with the Pacific coast (see Figure A.1). Currently, timber extraction in these areas is highly selective; only a few species are well known in international markets and have wood characteristics that make them particularly attractive.[18] Although this type of logging has been criticized by both the timber industry and conservationists as inefficient and leading to the commercial extinction of these high unit–value species (Uhl & Viera 1989, Blundell & Gullsion 2003, Kometter *et al.* 2004), the overall structure, function, and biodiversity of the forest remain essentially intact, even though the pressure on these few species might be great (Gullison & Hardner 1993). However, improved transport systems in the western Amazon would change the business model of the regional timber sector (Figure 2.5), making it more like the exploitation model that has prevailed in the eastern and southern Amazon. This type of semi-intensive logging, sometimes erroneously referred to as selective logging, has been shown to be very damag-

18 Mahogany (Sweitenia macrophylla), spanish cedar (Cedrela odorata), cerajiera or roble (Amburana cearensis).

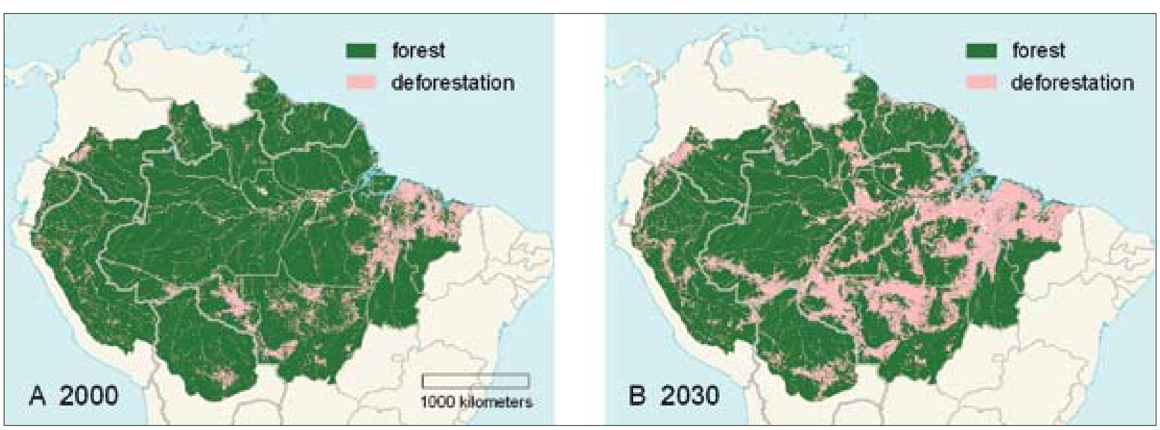

Figure 2.4. Statistical models based on past trends (map a) can provide insight into the distribution of future deforestation (map b). This model probably underestimates deforestation on the Andean piedmont because it did not factor in impacts from IIRSA investments (Britaldo Soares, Universidade Federal de Minas Gerais).

ing to the forest structure (Uhl *et al.* 1997, Asner *et al.* 2005) and will eventually lead to forest degradation, the loss of economic value in the forest, and eventual conversion of the forest to pasture, crops, or plantation forestry—despite ongoing attempts to make the industry sustainable (see Text Box 2).

Given the current scenario, IIRSA investments will have both positive and negative impacts on the forest products sector. Improved transport systems will increase profits for both timber and nontimber producers. However, increased deforestation caused by the IIRSA highways will lead to a progressive erosion of the resource base that supports the forest products sector. Likewise, better access to remote regions will lead to increased logging intensity by both the formal and informal sectors; this logging, whether it is certified or not, will most likely not be truly sustainable in maintaining natural forest ecosystems (Figure 2.6). Under the best of circumstances, the deforested landscapes adjacent to the IIRSA highway corridors will be converted to plantation forestry that produce wood, conserve soil resources, and contribute to the hydrological processes that support regional weather systems. However, these forest plantations will fail to conserve the biodiversity of natural forest ecosystems. Environmental evaluations and the subsequent action plans need to address the issue of long-term forest degradation, particularly the impact of opening the western regions of the Amazon to commercial exploitation of timber.

GLOBAL AND REGIONAL CLIMATE CHANGE

Climatologists estimate the consequences of global warming using global circulation models (GCMs), which integrate geophysical processes and energy flows in the atmosphere, oceans, and on the land. Although model projections are uncertain, they help indicate the potential consequences of climate change on continental and global scales (IPCC 2007). One GCM (HadCM3LC) incorporates principles of plant physiology into its land surface component, showing how the increasing temperatures and dryness in the Amazon may lead to dieback of the humid tropical forests (Cox *et al.* 2000). Eventually, plants will absorb less carbon through photosynthesis than is released by soil respiration, turning the Amazon ecosystem into a net source of carbon and further exacerbating global warming. This model assumes that tropical plant species will not adapt to high temperatures and drought. This assumption is supported by the response of the Amazon ecosystem to dry phases of El Niño–Southern Oscillation (ENSO), a climatic phenomenon characterized by wet/dry and warm/cool phases in different parts of the southern hemisphere (Potter *et al.* 2004, NOAA 2007). During dry phases of ENSO, the Amazon becomes a net source of carbon due to increased respiration and wildfire (Giannini *et al.* 2001, Coelho *et al.* 2002, Foley *et al.* 2002).

Figure 2.5. Bolivia and Peru have granted commercial logging concessions (hatched areas) in permanent production forests and are implementing forest certification processes in the hopes of attaining sustainability (Modified from *Superintendente Forestal*, Bolivia and INRENA, Peru).

Text Box 2

Sustainable Forestry: Fact, Fiction, or Just Wishful Thinking?

Forest ecologists have proposed a series of management recommendations to ensure sustainability; these have become very popular in the past decade and are upheld by programs that certify sustainable logging. They include the adoption of rotational harvests of 20 to 30 years, reduced impact logging methods, fire control, and the conservation of key wildlife species (Putz *et al.* 2004). However, studies have shown that individual trees require decades to grow into the canopy and attain reproductive maturity (Gullison *et al.* 1996, Brienen & Zuidema 2006), while the proposed harvest quotas are often well above the combined annual growth rates of the species with economic potential (Dauber 2003).

Foresters argue that target species will shift between harvest cycles and that remnant populations exploited in the first cycle will grow and regenerate to maintain populations. Although this might be the case in a well-regulated industry, the current regulatory environment in the Amazon ranges between lax and chaotic (Powers 2002). A more likely scenario given current certification guidelines will be a sequential extinction of species and the loss of the forest's residual economic value. At this point, concessionaires will either abandon their concessions or adopt plantation forestry, growing short rotation species to produce pulp, biofuel, and timber. This scenario may be acceptable to the forest products sector (Lugo 2002, Hecht *et al.* 2006), but will not ensure the conservation of the biodiversity in the Amazon Wilderness Area or the Tropical Andes Biodiversity Hotspot (Rice *et al.* 2001).

The HadCM3LC model predicts that global climate change will essentially tip the eastern and central Amazon into conditions very similar to the dry phase of the ENSO phenomenon (Figure 2.7), initiating a feedback cycle that shifts the Amazon from an evergreen to a savanna ecosystem within the next century (Betts *et al.* 2004, Cox *et al.* 2000). These authors stress the uncertainty of their models and, in a recent evaluation of the HadCM3LC model outcome, Li *et al.* (2006) applied eleven GCM models developed for the Intergovernmental Panel on Climate Change (IPCC 2007) and found that although overall precipitation levels did not change in most models, seasonality was enhanced with increased precipitation in the wet season and decreased precipitation in dry seasons, thus enhancing water stress. Corraboration that the Amazon has been warming was recently provided by Malhi and Wright (2005) who showed a temperature increase of 0.25°C per decade since the 1970s.

In addition to these ecosystem changes caused by global climate change, deforestation could also alter the regional climate of the Amazon. Global deforestation contributes about 20 percent of the total annual anthropogenic emissions of greenhouse gases and, consequently, is a major contributor to global climate change (IPCC 2007). However, deforestation also affects local and regional hydrological cycles that drive the formation of thunderstorms in the Amazon (Werth & Avissar 2002, Avissar & Werth 2005, Feddema *et al.* 2005). The importance of forest cover in maintaining high levels of precipitation in the Amazon has been a basic tenet of ecosystem ecology for decades (Chen *et al.* 2001). In summary, the tropical rainforest ecosystem of the Amazon depends on the humid trade winds that bring water from the Atlantic Ocean; however, about 25–50 percent of the rain that falls on the Amazon comes from evapotranspiration and precipitation through convective systems that form thunderstorms (Salati & Nobre 1991, Eltahir & Bras 1994, Garreaud & Wallace 1997). When the landscape is nearly completely deforested, the amount of water cycled through convective systems decreases by about 10–25 percent (Shukla *et al.* 1990, Nobre *et al.* 1991, Henderson-Sellers *et al.* 1993, Laurance 2004). Deforested landscapes are warmer than forest landscapes. Combined with smoke produced by forest fires to clear land, deforestation can delay the onset of the rainy season (Koren *et al.* 2004, Li & Fu 2004).

Figure 2.6. Logging on the Amazonian frontier typically targets old-growth trees between 100 and 300 years old, like these shown on this logging truck in Brazil. However, certification programs are based on harvest cycles of 20 to 30 years, which are insufficient to ensure regeneration of native timber species (© John Martin/CI).

Incongruously, some studies show that partially deforested landscapes experience an increase in precipitation as greater evaporation over forests leads to increased precipitation over pastures (Avissar & Liu 1996, Negri *et al.* 2004). However, rainfall is dramatically reduced with increasing deforestation, and precipitation levels decrease when more than 50 percent of the landscape has been deforested (Kabat *et al.* 2004). Like all climate change phenomena, long-term trends are often masked by short-term cycles or simply random fluctuations. For instance, recent above-average precipitation in the southern Amazon basin has been attributed to decadal-scale phenomena that have masked the impact of deforestation at the regional scale (Marengo 2006).

Although the rate and scale of future change remains a subject of conjecture, there is ample evidence of past climate change in lakebed deposits and in the current distribution of plant species. During the last glacial maximum, about 20,000–25,000

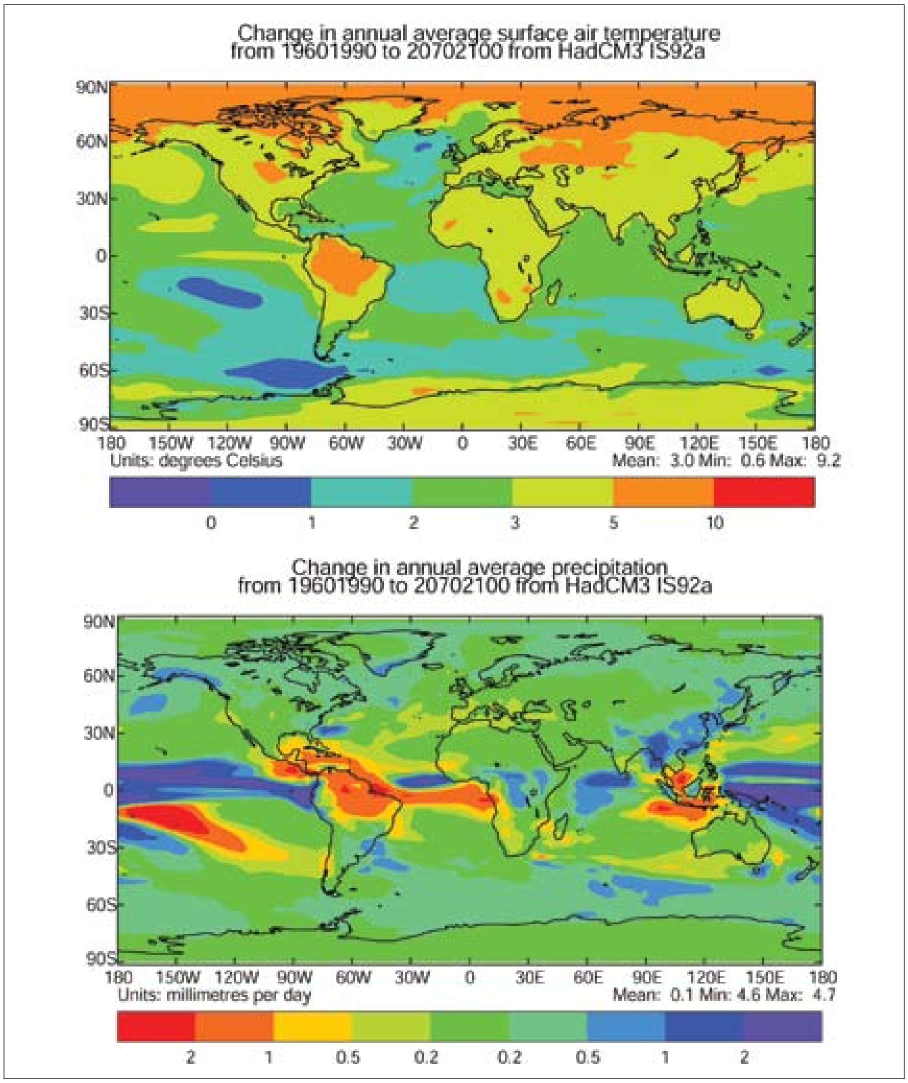

Figure 2.7. Temperature and precipitation changes. Some global circulation models predict that the Amazon will become warmer and drier, leading to a die-back of the Amazon forest; a more likely outcome would be a shift from a humid evergreen to a seasonally dry forest (Betts *et al.* 2004, see http://www.metoffice.com/research/hadleycentre/models/HadCM3.html).

years ago,[19] the distribution of humid forest species shrank to a much smaller region in the western equatorial Amazon; correspondingly, much of the geographic area currently considered to be "Amazonian forest" has been occupied by species previously restricted to seasonally dry deciduous forests and savannas that now predominate on the periphery of the Amazon (Mayle *et al.* 2004, Pennington *et al.* 2005). Subsequently, species responded to climate change by shifting their distributions as the Amazon became a warmer and wetter environment. There is ample evidence that humid forest species have expanded their distribution over the past few hundred years (Grogan *et al.* 2002, Mayle *et al.* 2004). The future climate in the Amazon may be warmer and drier, causing a forest dieback, or—if we are lucky—warmer and wetter, so that species continue to expand their distribution. In either case, species distributions will adjust to changing environmental conditions, but only if climate change is sufficiently slow and migratory corridors remain intact on Amazonian landscapes. If climate change is too rapid and corridors of natural habitat are not maintained, then many species will face extinction.

Unfortunately, no attempt has been made by member governments or multilateral agencies to evaluate the impacts of IIRSA transportation corridors on regional and global climate change. This oversight is particularly unfortunate given the ongoing research that the National Aeronautics and Space Administration (NASA), in collaboration with the Brazilian (INPE) and European (ESA) space agencies, has performed as part of the Large Scale Biosphere–Atmosphere Experiment in the Amazon (Gash *et al.* 2004). Their results show that increased deforestation along IIRSA highways will affect the regional climate by modifying local hydrological systems. Carbon emissions from deforestation will further exacerbate global warming, while changes in regional weather patterns may lead to further forest degradation; worse yet, highway corridors composed of anthropogenic landscapes will impede the ability of species to adapt to climate change.

[19] During the Pleistocene era, continental glaciers expanded and contracted periodically over tens of thousands to hundreds of thousands of years. The last glacial maximum occurred approximately 25,000 to 20,000 years ago.

WILDFIRE

Each year, millions of hectares of Amazon forest suffer from fire (Figure 2.8) (Cochrane & Laurance 2002, Cochrane 2003). Most fire is related to land clearing; however, fire also spreads into the standing forest causing degradation (Cochrane *et al.* 1999). Fires have occurred throughout history in the seasonal forests situated on the margins of the Amazon (Barbosa & Fearnside 1999), as well as in the central Amazon where they are associated with mega-Niño[20] events (Meggars 1994). However, the frequency and extent of fires have been increasing in the past few decades due to two phenomena, both related to improvements in the road infrastructure (Cochrane 2003). First, as roads are extended into remote areas and more land is cleared, the forest becomes fragmented, creating a greater ratio of forest edge to interior; thus a larger area of forest is exposed to pasture fires. Second, as increased logging opens up the forest canopy, it degrades the forest, allowing greater penetration of light that causes the forest floor to become drier, creating the conditions for forest fires (Cochrane *et al.* 1999, Nepstad *et al.* 1999). If climate change leads to increased drought, there will be an even greater incidence of forest fire (Nepstad *et al.* 2004).

Although fires in humid tropical forests are usually low-intensity ground fires that leave most of the mature trees standing, trees do suffer extensive damage to their cambium, with up to 50 percent mortality over the next few years (Barlow *et al.* 2002); in seasonal deciduous forests where trees have evolved bark that is somewhat resistant to fire, adult mortality can be as high as 27 percent (Pinard & Huffman 1997, Pinard *et al.* 1999). Greater adult mortality creates canopy gaps that allow greater penetration of light, increasing grass cover, creating the conditions for recurrent fires (Barlow *et al.* 2002). Wildfire also affects vertebrate populations. Large mammals, particularly ungulates, are absent from recently burned forest, an absence that is exacerbated by hunting in populated areas. Over the medium term, the increased mortality of adult fruit-bearing trees leads to a decline in frugivore species of monkeys and birds, whereas a reduction in forest floor detritus negatively affects ant-birds and other forest floor species that feed on invertebrate detritivores (Barlow *et al.* 2002).

IIRSA investments will increase the incidence and severity of wildfire. Currently, wildfire is most severe during El Niño years when drought conditions predominate; if the more pessimistic models regarding climate change are true, wildfire will become even more prevalent, particularly in the degraded forests that will occupy the landscapes surrounding IIRSA corridors. The environmental action plans that accompany the IIRSA investments should prioritize fire control and fire management programs as part of an environmental mitigation package. Without adequate steps to limit fire, other measures to conserve and protect forest fragments will be undermined.

HYDROCARBON EXPLORATION AND PRODUCTION

The western Amazon is the world's largest unexplored region of hydrocarbon potential outside Antarctica (Figure 2.9). The Andean piedmont and front ranges have long been identified as areas with potentially large reserves. Existing production in Argentina, Bolivia, Ecuador, and Peru is estimated on the basis of reserves situated in the Mesozoic and Paleozoic sedimentary formations on the eastern slope of the Andes and adjacent piedmont (Figure 2.10). Exploitation of these reserves has been slow because the inaccessibility of the region makes costs of exploration, production, and transportation high. Discoveries in the central Andes have tended to be rich in natural gas, a hydrocarbon that, until recently, was difficult to commercialize. Advances in natural gas liquefaction technology and a growing demand for fuels that emit

20 A mega-Niño event occurs when the phenomenon is both longer and more severe in intensity than the norm.

Figure 2.8. Wildfires in tropical forests are completely different than those in temperate ecosystems; often they are low-intensity ground fires that leave the tree canopy intact. Nonetheless, fires increase tree mortality, allowing for greater light penetration and lowering humidity levels in the understory. This sets the stage for recurrent wildfire and forest degradation (© Greenpeace).

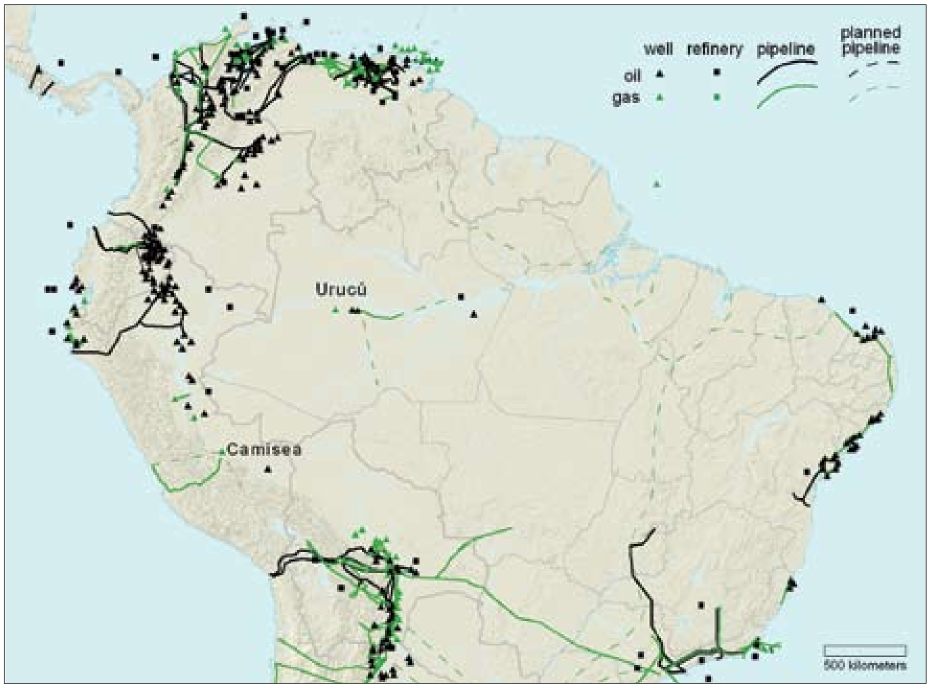

Figure 2.9. The western Amazon and Andean piedmont contain some of the world's last unexplored regions with significant potential for oil and gas. The discovery of gas in the Urucú basin in Amazon State has greatly increased the potential for discovering new reserves in the western Amazon (Modified from the World Energy Atlas).

less carbon have increased interest in the natural gas reserves of the western Amazon and central Andes.

The recent climb in oil prices is stimulating investment and exploration in areas that were previously not economically attractive. This new dynamic is most conspicuous in Peru, which has issued fifteen new exploration blocks in the last 12 months, many of them contiguous with the Brazilian border. A similar process is underway in Ecuador as it expands production to fill the recently completed heavy crude oil pipeline (OCP according to its Spanish acronym). All three major pipelines completed in the last decade have spurred further exploration and production, because once the transport problem is resolved, additional upstream investments are necessary to fill the pipelines.[21]

The development of *Urucú* gas fields in the Brazilian state of Amazonas has changed the way petroleum geologists view the Amazon. Most hydrocarbon exploration in the western Amazon has been concentrated near the Andes Mountains, where the process of mountain building has created anticlines that trap hydrocarbons.[22] However, the alluvial plain situated between the *Urucu* concession and the Andes lies over deep sedimentary rocks that were deposited prior to the breakup of Gondwanaland, dating from the geological eras (50 to 150 million years ago) that typically have the greatest hydrocarbon potential. Consequently, the entire western Amazon must now be viewed as an area with relatively high hydrocarbon potential. A gas pipeline is under construction and will have the capacity to provide Manaus with 10 million cubic meters per day, enough to make Manaus self-sufficient in energy generation and to provide feedstock for the petrochemical industry. A spur pipeline to Porto Velho in Rondônia is in the advanced planning stage (Figure 2.9).

In the last three decades, the petroleum industry has adopted standards to minimize environmental impacts. Seismic exploration, which typically covers tens of thousands of hectares, now uses helicopters, and the mid-term impact associated with transects is negligible. Exploratory wells are usually restricted to a relatively small area, and the use of directional drilling allows multiple production wells on a single platform (Rosenfeld *et al.* 1997). Current design standards, construction, and pipeline maintenance have reduced the impact of right-of-ways, while geographic models and improved materials have lessened the probabilities of catastrophic failures in pipelines.[23]

21 Construction of the Bolivia–Brazil pipeline was initiated prior to the discovery of Bolivia's vast (~54 trillion cubic feet) gas reserves. The Oleoducto de Crudo Pesado (OCP) oil pipeline in Ecuador is currently using only half of its capacity, and exploration and new production is underway in Yasuní National Park and other areas (pers. comm. R. Troya, TNC-Ecuador). The Camisea pipeline, which was constructed with a 32-inch-diameter pipe up to approximately the continental divide, and then reduced to a 24-inch-diameter pipe, was designed for more capacity than its present configuration and without the proven reserves to fill it. A second pipeline is being constructed that will originate at the continental divide and take gas to a separate port facility where it will be liquefied and exported. Gas to fill the first pipeline comes from Block 88, the original discovery made by Shell in 1993, whereas the gas to fill the second pipeline will come from the adjacent concession, Block 56 (http://www.camisea.com).

22 The geological structure of these submontane hydrocarbon reservoirs makes them very profitable because the gas is ejected from the reserves under high pressure and very few wells can produce enough gas to fill a pipeline. However, wells must perforate the reservoir at the highest point of the geological stratum (typically an anticline); consequently, they are situated on ridge tops, which maximizes the environmental impact because of the construction of roads and drilling platforms on steep inclines. Directional drilling from the base of the mountain is considered to be too risky because it increases the possibility of "missing" the top of the formation and damaging the reserve (pers. Comm. S. Smythe, BG-Bolivia).

23 Several of the largest multinational energy companies have formed a partnership with conservation organizations to develop practical guidelines, tools, and models to improve environmental management, particularly to reduce the threats to biodiversity via The Energy & Biodiversity Initiative (EBI 2003).

Figure 2.10. Oil and gas exploration has increased in remote wilderness areas of the Andean foothills, as shown by this oil well in eastern Bolivia (© Hermes Justinian/Bolivianature.com).

Regardless of these advances, industrial accidents still happen, and oil spills that cause severe environmental impacts occur, especially in the eastern Andes where very high rainfall and unstable topography have contributed to several recent oil spills in both Bolivia and Peru. In addition, and more importantly, drilling platforms and pipelines require roads that can support heavy machinery,[24] and the construction of roads usually leads to colonization and deforestation. Peru has managed to develop a petroleum infrastructure with limited deforestation: the extreme remoteness of production fields and the decision to use river transport for heavy equipment has kept the oil fields in northern Peru relatively free of secondary deforestation associated with colonization (Figure 2.11).

The presence of foreign oil companies can exacerbate deforestation, as local land speculators use the foreign companies' presence as a pretext to expand their own claims. In Amboró National Park in Bolivia, peasant leaders argue that if a region is to be open to foreign oil companies, then it must also be opened up for national citizens who are both landless and poor. Even the most positive aspects of hydrocarbon production will negatively affect the environment. In Peru, 50 percent of the royalty revenues from the Camisea concession will be channeled back to the Cuzco regional government. Like local governments everywhere, the government will use this income to invest in schools and hospitals, which is laudable; however, they will also invest in roads and bridges that will lead to increased forest degradation.

It is unrealistic to expect the Andean nations to forgo the opportunity to exploit their hydrocarbon reserves; demands for economic growth are too great, and the expansion of the hydrocarbon sector is enshrined as state policy. In Bolivia and Ecuador, hydrocarbon exploitation has been defined as a national strategic priority and is allowed within protected areas, including national parks. Peru currently does not allow the exploration of hydrocarbons within national parks, but the rest of the eastern lowlands are rapidly being put out to bid for oil and gas exploration.

Nonetheless, despite national policies to promote the exploration of hydrocarbons, it has become one of the most conflictive issues in Andean society. Large sectors of the impoverished population have not benefited from the wealth generated by the hydrocarbon sector, whereas export earnings for multinational corporations have surged. Some civil groups have opposed oil exploration and production in remote areas on environmental and social grounds, and opposition to multinational oil companies has contributed to the success of recent political candidates in Ecuador and Bolivia.[25] However, once this debate over the role of multinational firms has been resolved, increased exploration and production is a foregone conclusion.

Part of IIRSA's policy and investment agenda is to integrate energy grids (oil and gas pipelines, as well as high-tension electric lines); however, unlike highways and hydrovias, energy transport systems are largely owned and operated by private entities or state-owned corporations. As such, the IIRSA executive and technical committees exercise a less influential role in planning and constructing oil and gas pipelines. However, the same multilateral institutions involved in IIRSA finance these investments, and the same government ministries actively promote hydrocarbon expansion programs.[26]

Large multinationals have come to recognize their responsibility in mitigating secondary impacts as part of a comprehensive environmental and social management plan (EBI 2003). However, many Amazonian hydrocarbon concessions are being developed by second-tier companies, which are smaller, regional in focus, or come from a nontraditional global market.[27] These companies often place less emphasis on environmental management, which holds less weight with their shareholders and

24 The AGIP pipeline in Amazonian Ecuador is an exception and was constructed without deforesting the right-of-way. It is supported on stilts like the Alaska pipeline and was built using a specially designed machine that moved forward on rails as the pipeline was extended. However, most companies prefer to bury pipelines for safety reasons, particularly in populated areas. The right-of-way is usually maintained free of woody vegetation, because roots can invade the coating of a pipeline and shorten its lifespan.

25 In Ecuador, a legal ruling allowed the government to rescind a contract with Occidental Petroleum. In Bolivia, existing contracts were modified to change the royalty and tax structure associated with concessions, as well as the role of the state in joint ventures.

26 The IDB made a loan of $135 million, and CAF made one of $75 million to Transportadores de Gas de Peru (TGP) to construct a gas pipeline connecting Camisea to the Pacific coast. IDB assumed a leadership role in organizing the environmental evaluation and the subsequent management plan (http://www.iadb.org/exr/pic/camisea/status.cfm).

27 These include smaller companies from the developed world as well as energy companies from Latin America, Russia, and East Asia (see http://www.peru-petro.com.pe/ for a list of companies that have recently acquired exploration concessions).

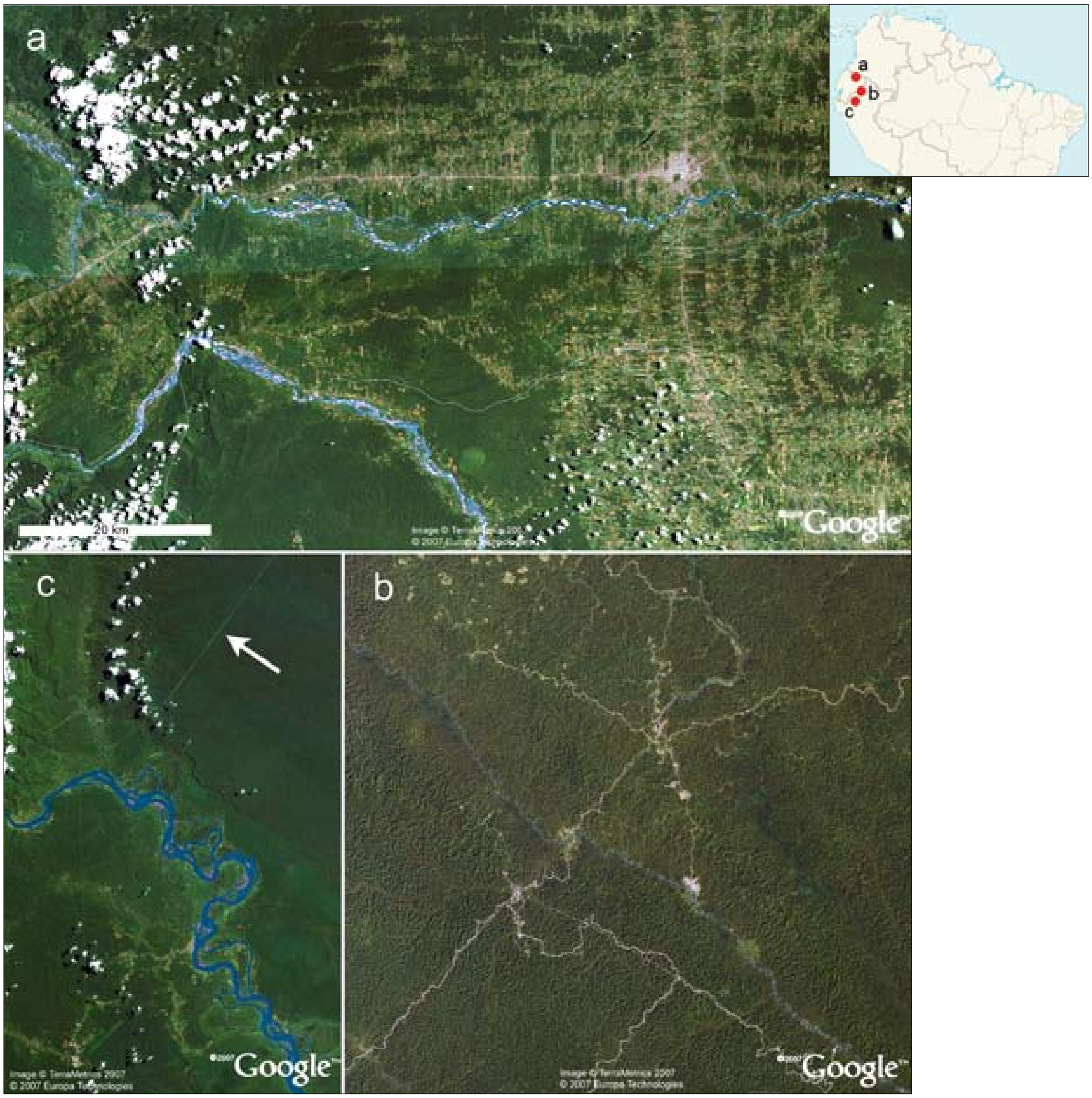

Figure 2.11. (a) In Ecuador, pipelines and roads were built concurrently during the 1960s, leading to colonization and deforestation. (b) In contrast, the remote producing fields in northern Peru were treated like offshore oil platforms; workers were transported by air, and equipment by river barge. (c) As a result, pipeline right-of-ways in Peru (arrow) were not converted into highways, and large scale deforestation has been avoided (Google Earth ™ Mapping Services).

home markets. When oil field development is shared by multiple operators, these smaller companies avoid responsibility for secondary impacts and are able to pass on the responsibility to the government or financing agency. Many commercial banks that finance these operations also lack solid environmental and social review processes.[28] Similarly, the need to improve the capacity of national regulatory agencies to monitor hydrocarbon exploration and production is essential given the more diverse corporate partners that characterize current energy development in the Amazon basin.

[28] A group of commercial banks recently adopted a set of guidelines known as the Equator Principles to improve their environmental and social evaluation process (see http://www.equator-principles.com/principles.shtml).

The four major energy transport projects in Bolivia, Ecuador, and Peru all predate IIRSA, but the economic benefits associated with those projects are a perfect manifestation of the goals of IIRSA.[29] Similarly, Petrobras, with the support of BNDES, has devised a strategic plan to create a national grid of gas pipelines to link domestic supplies to urban markets. Any discussion of development in the western Amazon and Andes should address the implications of increased hydrocarbon exploration and production, and the relationships between energy exploration and infrastructure, regional development, human migrations, and agricultural expansion.

[29] Bolivia: Gas Trans Bolivia (GTB), Gas Oriente Bolivia (GOB); Peru: Transportadores de Gas de Perú (TGP); Ecuador: Oleoducto de Crudo Pesado (OCP).

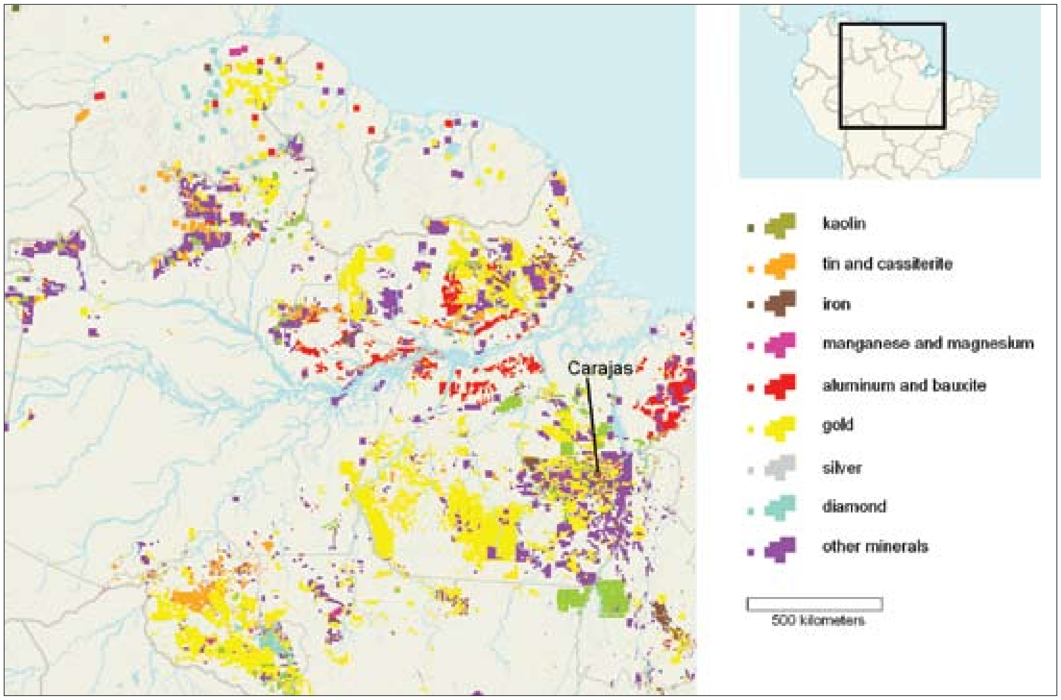

Figure 2.12. The Precambrian rocks of the Brazilian and Guayana Shields hold strategic reserves of many industrial minerals, such as gold, silver, and diamonds (Modified from Departamento Nacional de Produção Mineral (DNPM) and Global InfoMine. See http://www.infomine.com/).

Figure 2.13. (a) Small-scale placer gold miners on the Huaypetuhe River in southern Peru produce between $100 and $200 million annually—almost five times the income earned from ecotourism. (b) The strip mines west of the Trombetas River in northern Pará State, Brazil, are among the world's largest producer of bauxite ore for aluminum (Google Earth ™ Mapping Services).

MINING

Mining is an important economic activity in the eastern Amazon where Precambrian rocks hold strategically important reserves of industrial minerals, including bauxite, iron ore, manganese, zinc, tin, copper, kaolin, and nickel, as well as less well known minerals such as zirconium, tantalum, titanium, beryllium, and niobium, which have become essential for modern technology (Figure 2.12). Bauxite is essentially old alluvium with concentrated levels of aluminum due to millions of years of weathering in tropical climates. The Amazon has huge bauxite reserves, particularly on ancient tertiary landscapes situated adjacent to the main course of the Amazon River and on the coastal plain of northern South America (Figure 2.12 and 2.13b). The ongoing growth of the aluminum sector and the development of a similar value-added production chain for transforming copper ore from mines in Pará State are securely entrenched in Brazil's development plans.[30]

Similarly, the Andean countries have a long tradition of mining with gold, silver, tin, and copper being the foundation of the mining industry in the high Andes. State-controlled enter-

30 The Sossego, Salobo, and Alemão mines are all within 100 km of Carajás, and the existing infrastructure in rail and port facilities makes them some of the most competitive copper mines in the world. See http://www.cvrd.com.br.

prises predominate in Venezuela,[31] with multinational corporations operating in the coastal nations of Guayana and Suriname, as well as in Bolivia,[32] Brazil,[33] and Peru. Large industrial mines are strategically important to the economies of Latin America because they produce export commodities that generate royalty income for governments and contribute to the national balance of payments. Large mines are notorious for having direct, local impacts on the environment, but they do not typically cause regional-scale alterations comparable to the deforestation brought about by agriculture and ranching. However, industrial mines often lead to other investments that bring about secondary impacts several orders of magnitude greater than the mines themselves. For example, mines produce large volumes of bulk cargo that require modern transportation systems, leading to increased migration. Governments usually seek to add value to natural resources and produce jobs, whereas corporations seek to reduce transportation costs by transforming bulk minerals into industrial commodities such as steel and aluminum ingots (Kinch 2006). These metallurgical industries are energy intensive, which can affect terrestrial and aquatic ecosystems alike.

A case in point is the Greater Carajás Project in southeast Pará, Brazil, which has been the subject of an extensive and prolonged debate (Fearnside 1986). The operator of the concession, the Companhia Vale do Rio Doce (CVRD) and the Brazilian state took early action to manage the environmental and social impacts associated with what is now the world's largest iron ore mine, including the creation of 800,000 hectares of protected areas and indigenous reserves. Nonetheless, the construction phase of the project and the parallel improvement of the regional highway network stimulated migration into the region. The landscape surrounding the mining concession and its complex of protected areas and reserves is now largely deforested. CRVD's construction of an 800-kilometer rail line to service the Carajás mine has come under particular criticism because it contributed to the development of pig iron and cement factories that rely on vegetable charcoal. The demand for charcoal over the 30-year life of the rail line has been estimated at 1.5 million hectares of lost forest, surpassing the amount of forest habitat set aside as protected area by approximately 50 percent (pers. comm. CI-Brasil 2007).

Because the use of native wood species to produce charcoal is illegal under Brazilian law, pig iron producers are obligated to use charcoal made from eucalyptus plantations. Nonetheless, charcoal is an anonymous commodity, and there is a robust contraband trade. This stems naturally from the synergy between the industry's energy needs and the economic interests of cattle ranchers, who produce charcoal as a byproduct of land clearing (Fearnside 1989b) and who see it as a logical way to cash in on a capital asset and finance the establishment of their farms.[34,35] Realistically, this market will end only when native forests have been completely exterminated. Unfortunately, charcoal production is also often associated with exploitive labor practices characterized by many outside observers as a form of slave labor (Treece 1988).

Bauxite mines and aluminum smelters also have long-term secondary impacts on aquatic systems. Aluminum smelters require massive amounts of electrical energy; the decisive factor in developing an aluminum processing facility is not the availability or quality of bauxite ore but access to inexpensive energy. In Brazil, Venezuela, and the Guayanas, hydroelectric power is the preferred energy option due to high rainfall and topography. These reservoirs have, however, several key environmental impacts: they interrupt seasonal high and low water flows in rivers, reduce sediment loads, and interrupt the migratory behavior of fish species (see below).

Large industrial-scale gold mines exist or are under development in the three coastal states of Guyana, Suriname, French Guiana, and Venezuela, as well as in parts of Amapá and Pará states in Brazil in the eastern Amazon and in the high Andes of Peru and in the Condor region of Ecuador. Industrial-scale gold mines are usually associated with hard rock deposits where the concentration of mineral gold is extremely low. Cyanide is used to leach the mineral gold from the bulk ore, a process that releases heavy metals previously immobilized in the rock. Consequently, industrial gold mines produce tailings and effluents that remain environmental hazards for centuries.[36] Containment dams and synthetic membranes isolate water treatment ponds where the cyanide is removed and heavy metals are precipitated out of the water column. However, these ponds are susceptible to catastrophic failure with devastating consequences for the downstream watershed. The environmental standards of the world's mining corporations have been widely criticized and the economic consequences of poor environmental management are now so large that international mining companies enthusiastically embrace the environmental standards promoted by the World Bank (Warhurst 1998).

Although the greatest volume of gold ore is produced by industrial mines, the most common form of gold mining in the Amazon and Andes is conducted by small-scale cooperatives that extract mineral gold from alluvial sediments using rudimentary placer mining technology and mercury to concentrate the gold (Hanai 1998). The environmental impact of placer mining can be devastating, as giant dredges plow through the landscape, overturning the top layer of soils to get at the gold concentrated in sediments from ancient riverbeds. Placer mining leaves behind a lunar landscape that is devoid of vegetation and wildlife (Figure 2.13b). The use of mercury, with its well-documented impacts on neurological function and birth defects, poses an even more insidious environmental threat. Studies have shown that it has been accumulating in the Amazon over several decades and, like

[31] The Corporación Venezolana de Guayana (CVG) mines iron ore, bauxite, gold, zinc, and other minerals, while managing steel and aluminum plants and electrical generating facilities (http://www.embavenez-us.org/kids_spanish/mining.energy.htm).

[32] The Bolivian state mining company, COMIBOL, which dominated the industry from 1952 to 1984 and was dismantled in the 1980s, is once again taking a leading role in organizing joint ventures under the current government.

[33] The Companhia Vale do Rio Doce was privatized by the Brazilian government in the 1990s and is now one of the world's largest mining companies with its headquarters in Rio de Janeiro.

[34] O LIBERAL (Brazil) 21-11-05, reported fines by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) of R$598 for the use of illegally logged vegetable charcoal that originated in southern Pará State.

[35] There are an estimated 20,000 charcoal factories in Pará and Maranhão (http://www.ipsenespanol.org/interna.asp?idnews=31041).

[36] Typically 30 tons of ore are needed to produce 1 ounce of pure gold; in contrast, iron ore is between 70 percent and 90 percent mineral.

many toxic substances, is concentrating in the higher tiers of the ecological food chain (Maurice-Borguin *et al.* 2000).

In Brazil, cooperative miners known as *garimpeiros* have a history of creating "gold rushes" to remote localities, where populations can boom overnight into temporary communities numbering in the tens or even hundreds of thousands. *Garimpeiros* are a disruptive presence in remote areas traditionally populated by indigenous groups; they often introduce infectious diseases and resort to violence to establish their presence (Hanai 1998). Cooperative mining may also help advance the agricultural frontier because many *garimpeiros* are peasant farmers and invest the capital they acquire from prospecting into rural property. The intensity of *garimpeiro* mining oscillates with the international price of gold: during the 1980s, hundreds of thousands of *garimpeiros* worked the alluvial sediments in Tapajos, Pará, Roraima, and Rondônia, while similar groups in Bolivia and Peru were active in both montane and lowland regions of those countries. Compared with corporate mines, cooperative miners cause much greater cumulative environmental damage; however, cooperative mining creates many more jobs than super-efficient corporate mines. Regulation of cooperative mining is largely ineffective because governmental agencies do not have the resources to impose effective control nor the political will to confront large populations of impoverished people. Programs aimed at decreasing the environmental damage of cooperative mines also have the very important added benefit of increasing social welfare for an economically deprived sector of the population.

Although IIRSA does not include mining projects in its portfolio of investments, its investments in highways, hydrovia, railroads, and energy grids directly benefit the mining sector in that mines and their related processing and smelting industries are heavily dependent on energy and transportation costs. The agencies that coordinate IIRSA are fully aware of the synergistic nature of their investments.[37] Many, if not most, of the protected areas in the region also contain significant mineral reserves, and mining is allowed within most sustainable use areas; some countries explicitly allow mineral exploitation within a broader category of protected area. In Bolivia, mining is legally allowed within even the highest category of national park (Ricardo & Rolla 2006). The synergies between IIRSA and mining have positive aspects, particularly the generation of wealth and jobs; however, the negative aspects of mining are that it will increase deforestation and degrade aquatic systems. The potential long-term conflict between mining and protected area management is an issue that should be resolved, so that the mining sector does not oppose the creation of protected areas and recognizes that some protected areas should be exempt from any sort of mining activity.

HYDROELECTRIC POWER AND ELECTRICITY GRIDS

Bauxite mining is one of the most obvious examples of a secondary impact — in which investments in one sector (mining) lead to investments in another sector (hydroelectric power). Part of the incentive for investing in new hydroelectric facilities in the Amazon stems from government policies to process mineral

37 A recent example is the approved IDB loan of $750 million to Venezuela for the expansion of the hydropower facility on the Caroni River. This facility supports the mining and processing activities of the Corporación Venezeloana de Guayana.

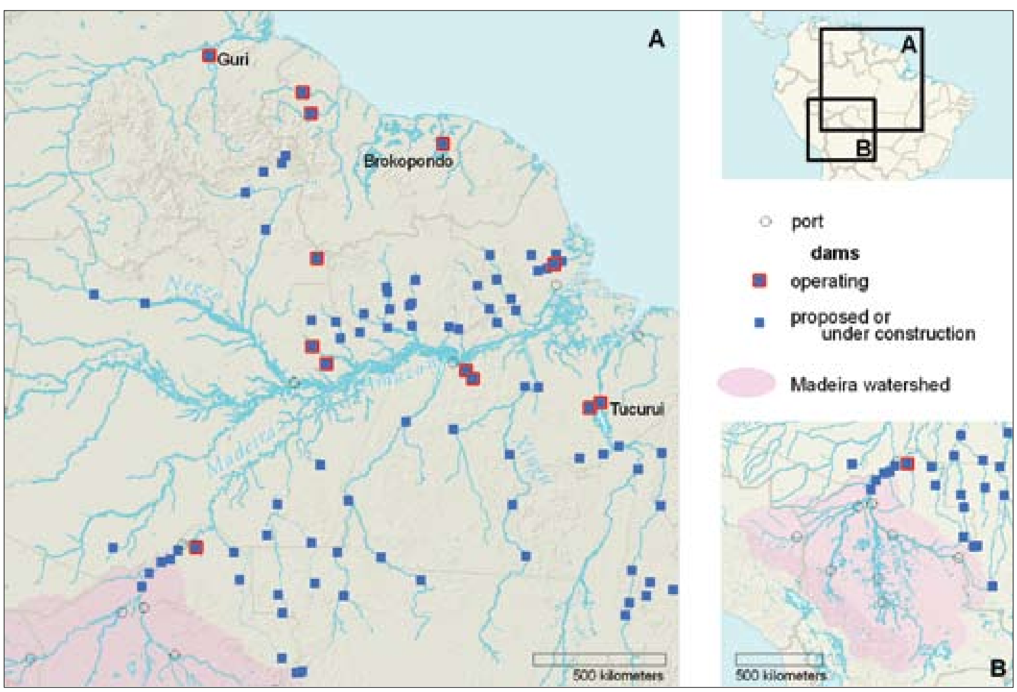

Figure 2.14. a) Guri, Brokopondo, and Tucuruí are the three largest hydroelectric facilities in the greater Amazon. The Amazon and Tocantins watershed represent 6% of the world's potential hydropower, with 68% of its undeveloped hydropower potential in Brazil. b) Controversy about the environmental impacts of river dams surrounds projects planned for the Xingu and Madeira rivers (Agência Nacional de Energia Eléctirca and Amazonian Scenarios Database, Woods Hole Research Center).

resources rather than merely exporting ore to overseas markets; in the terminology of governmental planning ministries, this is "adding value." Aluminum smelting is the most energy-intensive industrial process in the world, using about 2 percent of the world's energy and about 8 percent of total energy production in Brazil (Cadman 2000). In northern Brazil, the metallurgical sector consumes about 50 percent of the installed energy capacity, representing an annual subsidy between $200 and $400 million (LaRovere & Mendes 2000). The hydrological resources of the greater Amazon[38] are massive, and at least three of the world's largest hydroelectric facilities have been built with the express purpose of subsidizing the development of aluminum smelters: 1) the Gurí complex on the Caroni River in Venezuela; 2) the Brokpondo Reservoir in Suriname; and 3) the Tucuruí Reservoir on the Tocantins River in Pará State (Figure 2.14). The environmental impacts of these hydroelectric facilities are far greater than those created by the mine or the industrial smelters that process the bauxite ore (Fearnside 1999, 2001a). As Amazonian urban centers consume more electricity, the energy needed to support the aluminum industry must be provided by new facilities.

To review the social and environmental impacts of dams, The World Commission on Dams chose Tucuruí as one of seven case studies over its 30-year lifespan (LaRovere & Mendes 2000). Some impacts were expected, such as changes in inundation regimes that altered sedimentation rates and fertility levels on the floodplains below the dam. In addition, the reservoir experienced greater than expected eutrophication due to the decay of massive amounts of submerged biomass. The nutrient-rich waters caused an explosion of aquatic plants, which at their maximum extent in the 1980s covered 25 percent of the surface area of the lake before falling to current levels of approximately 10 percent. The abundance of floating plants fostered an increase in mosquito populations and impeded navigation and fishing. The submerged vegetation produced anoxic benthic environments that led to increased emission of greenhouse gases, particularly methane and carbon dioxide (Fearnside 1995, 2002, LaRovere & Mendes 2000). These direct impacts are common to all reservoirs in the tropics.

Each of these three mega-hydroelectric facilities on the Amazon River is situated at the lower part of a river basin (Figure 2.15). This location is advantageous for the production of energy, which depends on the volume of water that can be channeled through a turbine. However, placing a dam near the mouth of a river also maximizes its potential environmental impact because all upstream portions of the basin will essentially be isolated from other aquatic populations (see Chapter 4). Like all reservoirs, these three massive reservoirs will fill with sediment over time; consequently, engineers have proposed constructing dams upstream to prolong the life of these keystone facilities on the mouths of the river. This engineering logic is currently being carried out in the Tocantins-Araguaia River basin where twenty-five major dams and generating stations are being built on the two

38 Here the term "greater Amazon" refers to the whole of the Amazon and Orinoco basins, as well as the multiple independent basins of the northeast coast of South America.

Figure 2.15. Large hydroelectric projects like the Raul Leoni Dam at Gurí on the Caroni River in Venezuela provide subsidized energy for aluminum smelters. Like many dams, it is situated near the mouth of a large river to maximize electrical energy production, which depends on water volume and vertical drop. However, placing the dam at the mouth of the river also isolates fish populations of the entire watershed from the rest of the Orinoco basin (© Daniela Vizcaino/CI).

major rivers, with another seventy smaller hydropower stations on upstream tributaries (Figure 2.14).

It is precisely this logical process of maximizing and protecting a strategic investment that has mobilized opposition to the Belo Monte Hydroelectric Complex on the Xingu River; a proposed facility that would generate approximately 11,000 megawatts and cost approximately $7 billion.[39] Belo Monte was first proposed two decades ago and was shelved because of public opposition to its perceived environmental and economic costs (Junk & de Mello 1987). However, the current government has attempted to resurrect the program as part of its development agenda for northern Brazil. Belo Monte is seen as being efficient in terms of energy per dollar invested and area flooded, and it would provide energy for the expansion of planned bauxite and copper smelting facilities.[40] However, the construction of the Belo Monte facilities would lead to economic, environmental, and social outcomes similar to Araguaia-Tocantins, including the construction of other dams upstream on the Xingu,[41] which is home to thirty-seven different ethnic groups that represent four distinct major linguistic families. The inevitable environmental impacts would be magnified by the social impact on these communities (Fearnside 2006a).

Other large dams in the region are the Balbina Dam near Manaus and the Samuel Reservoir near Porto Velho in Rondônia, which were constructed to generate power for urban markets. Both reservoirs illustrate the challenges that faced the civil engineers who designed and built these facilities in the Amazon wilderness. Insufficient information about local topography led to errors in mapping the inundation zone and underestimating the potential impact. In the case of Balbina, the reservoir turned out to be much larger than originally anticipated, resulting in one of the worst ratios in the world between the size of the reservoir and the energy generated by the hydroelectric facility (Fearnside 1989a). Engineers who designed the Samuel Reservoir were forced to build an elongate 15-kilometer dike along a lateral ridge to raise the level of the lake so as to meet the energy demands of Porto Velho (Fearnside 1995, 2005a).

Hydroelectric energy is an important component of the IIRSA investment portfolio. Twelve dams are planned for the headwater regions of Andean Ecuador where their environmental impacts would be minimized because they mimic the abundant natural barriers that characterize rivers and streams.[42] The most expensive project in the entire IIRSA portfolio is the Madeira River Hydroelectric Power Project near the cities of Porto Velho and Abunã on the border between Pando, Bolivia, and Rondônia, Brazil (Figure 2.14b). This project includes a series of dams and turbines that will produce 7,500 megawatts[43] at an estimated cost of $4.5 billion (Wanderley *et al.* 2007). The motivation for this project is largely to increase domestic energy production in Brazil; however, dams would flood the rapids that have obstructed river traffic, and a series of locks would create a river transport system connecting the Upper Madeira watershed with the main branch of the Amazon River. Known as the Madeira-Mamoré Hydrovia, this waterway would provide a low-cost alternative for exporting commodities from Rondônia and Acre,[44] as well as the incipient agricultural zones of northern Bolivia and southern Peru (see Figure A.2).

The Madeira hydroelectric complex will have a variety of environmental impacts. Proponents argue that flooding will be minimized because the dams will be only a few meters in height, an engineering decision dictated by the relatively flat local topography. Nonetheless, approximately 100,000 to 200,000 hectares of seasonally inundated forest will be permanently flooded, causing a radical change in a keystone habitat that provides ecosystem services such as nesting and feeding for fish populations. Dams will also act as barriers to migratory fish species that are important food resources for local populations and the foundation of the commercial fish industry (see Chapter 4). The proponents of the Madeira project have suggested that mitigation programs will alleviate negative impacts on migratory species, but previous experiments with fish ladders have not been successful in other regions of the world. Although the construction company of the Madeira projects contracted an environmental impact study, which was approved by the Brazilian Institute for the Environment and Renewable Resources (IBAMA) in October 2006,[45] civil groups in Brazil and Bolivia, particularly the local communities that will be directly affected by the reservoirs, question the impartiality of the study and continue to oppose the construction of the project.[46]

Large, complex hydroelectric energy projects are a sign of development and are largely welcomed by rural residents because they bring affordable energy to areas that have long been dependent on expensive hydrocarbon energy. In addition, the development the Araguaia-Tocantins, Madeira, and Paraná-Paraguay hydrovias will lower the cost of grain export for producers from the agricultural heartland of central Brazil in increasingly competitive international commodity markets. Politicians of all persuasions are enamored with dams because they are massive construction projects that provide employment opportunities for thousands of individuals with low skill levels and stimulate local economies. These synergies are exactly what entice the promoters of IIRSA.

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39 This is 30 percent more than the capacity of the Tucuruí hydroelectric facilities; feasibility studies are part of the current PPA investment agenda. However, critics agree that due to fluctuating water levels, the facility will rarely produce at the installed capacity.

40 In 2002, CRVD expressed its willingness to participate in a construction consortium; CVRD has investment interests in aluminum smelters located in Pará State (http://www.isa.org.br).

41 There will be another separate dam, the Altamira, better known by its former name of Babaquara.

42 The recently elected President of Peru, Alan Garcia, has offered to provide the western regions of the Brazilian Amazon with electricity produced in Andean hydropower stations, and the IIRSA Amazon hub includes a high-tension line to connect Pucallpa with Cruzeiro do Sul in western Acre State.

43 Itaipu, the large hydroelectric facility on the Paraná River in southern Brazil, generates 14,000 megawatts of energy. A nuclear power plant on average produces about 8 megawatts of energy, and the new thermoelectric facility in Cuiabá generates 400 megawatts of energy.

44 See http://www.riomadeiravivo.org/debate/docapresentados/PortoVelho-Maio2006-Alcides.pdf.

45 In December 2006, IBAMA initiated a series of public consultations with local communities, and the decision to proceed with the project is expected in 2007. For more information, see http://www.ibama.gov.br/novo_ibama/paginas/materia.php?id_arq=4535, and http://www.riosvivos.org.br/canal.php?canal=318&mat_id=9898.

46 The consortium contracted to conduct the environmental impact analysis for the hydroelectric facilities (Furnas/Oderbrecht) are also likely to participate in the bidding for its construction (Oderbrecht) and operation (Furnas).

Nonetheless, dams and reservoirs have multiple direct and indirect environmental impacts that are well documented and that cannot be easily mitigated (see Chapter 3). Mega-hydroelectric projects in particular should be avoided on primary rivers that integrate major watersheds because they negatively impact huge upstream areas. In contrast, multiple small hydropower stations situated upstream on tertiary tributaries have a relatively small footprint in spatial terms and limit the degree of aquatic ecosystem fragmentation. The economic, social, and environmental tradeoffs among development options are precisely what strategic environmental evaluations are designed to elucidate (see Chapter 6) and should be conducted for all hydropower projects at the basin scale as part of early-stage feasibility studies before the modification of infrastructure investments becomes politically difficult, if not impossible.

BIOFUELS

The growing demand for biofuels could stimulate another investment boom that would dwarf all previous commodity-based exploitation in the Amazon. This demand is driven by governments seeking alternatives to fossil fuels, which are becoming less appealing due to political instability, climate change, and a perceived impending scarcity of oil. The projected market for biofuels is so large that it could stimulate deforestation far beyond the most pessimistic scenarios envisioned by conservationists (see Text Box 3) (Laurance *et al.* 2001, 2004, Câmara *et al.* 2005, Soares-Filho *et al.* 2006). Brazil, which has the most advanced biofuel technology in the world, has led the way in using sugar cane alcohol as an alternative to traditional fossil fuels. It is now also promoting the production of biodiesel as part of its national strategy for energy independence and, since 2006, has required that 2 percent biofuel be mixed with traditional fossil fuel diesel (Kaltner *et al.* 2005). Brazil has also made a commitment to replace 5 percent of diesel consumption with biodiesel by 2013.

This early shift to biodiesel will be made possible with soy, which is receiving a lot of attention as a biofuel source due to existing production and processing capacity in Brazil. However, African oil palm (*Elaeis guineensis* Jacq.) will dominate the biodiesel market over the mid term due to its chemical properties, energy content, and oil yield on a per hectare basis, producing approximately eight times more oil than soy (Figure 2.16).[47] Brazil has already increased research and development efforts for the African oil palm, which has a long history of cultivation in northeast Brazil. Oil palms are cultivated in the Huallaga Valley of Peru, Amazonian Ecuador, and the Colombian Chocó region. The African oil palm is the most successful tropical crop in the world in gross productivity and market value, which explains why it has been a leading driver of deforestation in Indonesia and Malaysia (Kaimowitz & Angelsen 1998).

Ethanol derived from grains and sugar cane is also being promoted by producer groups as an alternative biofuel in Brazil and the United States. Brazil has a long and successful history of adapting its domestic fleet of motor vehicles to gasoline-ethanol combinations, and of improving the productivity and adaptability of sugar cane. However, an emerging technology may soon revolutionize the production of ethanol throughout the world. The current basis of ethanol production is the conversion of starch and sugar, compounds found in the tissues of plant storage organs; these offer an easily mobilized form of chemical energy. However, a much more abundant carbohydrate is cellulose, the principal constituent of plant structural tissues; cellulose can only be metabolized by specialized micro-organisms that have evolved the necessary enzymes for breaking down cellulose into its constituent sugar molecules. Modern biotechnology has now harnessed these enzymes into an industrial process that converts cellulose to ethanol. The implications of this second-generation alcohol technology have yet to be fully understood by the popular press, but essentially, any plant biomass can now be converted into en-

[47] Soy produces between 2 and 4 metric tons per hectare and in the tropics can produce two harvests per year; approximately 20 percent of the total soy yield is vegetable oil. In contrast, oil palm produces between 5 and 6 tons of vegetable oil per hectare on an annual basis. Palm oil also has higher energy ratio per unit volume.

Text Box 3

Biofuels: The Next Deforestation Threat

Biofuels are being heavily promoted as a climate-friendly energy source and are the object of venture capital investors around the globe. However, demand will most likely spread the cultivation of biofuel crops farther into the Amazonian frontier where land values are lower and production costs promise to make them competitive in future markets. The current emphasis on sugar cane and soy to produce ethanol and biodiesel will eventually shift to other crops adapted to conditions of the humid tropics.

The biggest threat comes from palm oil (Figure 2.16), perhaps the most productive tropical crop in the world and one that is well adapted to areas with mean annual precipitation rates over 2,000 mm and dry seasons shorter than 3 months (Kaltner *et al.* 2005)—climatic conditions characteristic of the wilderness areas in the central and western Amazon. The entire region, including the relatively steep slopes of the Andes and the marginal lands of the Cerrado that have escaped the plow, also has potential for elephant grass plantations or some other high biomass yield species that will be a feedstock for the rapidly developing second-generation technology of cellulosic alcohol.

Unless effective regulatory measures are implemented, these market forces will lead to a boom in deforestation that will surpass all previous deforestation cycles. Biofuels represent the greatest latent threat to the conservation of the Amazon Wilderness Area, as well as to the Tropical Andes and Cerrado Biodiversity Hotspots.

Figure 2.16. African oil palm is a potential biofuel crop that produces up to six times more vegetable oil per hectare than soy and could improve the livelihood of tens of thousand of tropical farmers. It also threatens the Amazon forest as a new—and powerful—driver of land use change if its cultivation is not restricted to previously deforested and degraded lands (© John Buchanan /CI).

ergy—greatly increasing the efficiency of biofuel production.[48]

Many scientists argue that biofuels are a false panacea due to the energy required for their production. Recent studies have demonstrated that the cost-benefit ratio varies depending on the production system and, in many cases, biofuel crops are net energy producers (Hill *et al.* 2006). A more important constraint to converting the global economy to biofuels will be the competition with food crops for arable land, especially as the planet's population doubles over the next century. Major energy corporations have questioned whether it is ethical to promote biofuels, arguing that they will lead to the conversion of arable land in developing countries where human populations are undernourished. However, the promoters of cellulosic ethanol technology point out that this production system is well suited for marginal lands where traditional crops cannot be competitively cultivated. In the United States, biofuel production could lead to the conservation or even the restoration of millions of hectares of native prairie, where the leaves and stems of the native switch grass (*Panicum virgatum*) can be harvested to produce approximately 12 metric tons per hectare of biomass annually (Radiotis *et al.* 1999). The productive capacity of tropical grasses is far superior to switch grass; one of the most productive tropical forage species, elephant grass (*Pennistem purpureum*), can be harvested three times per year to produce between 35 and 50 metric tons per hectare of biomass under ideal conditions of water and nutrient availability (Espinoza *et al.* 2001).

[48] Biomass refers to live plant tissue and is composed largely of cellulose, although it may also contain lignin and chemicals characteristic of wood; biomass is approximately 50 percent carbon and 50 percent oxygen, hydrogen, and other trace elements.

This new biofuel market will, hopefully, lead to plantations on the approximately 60 million hectares of Amazon landscape that have already been deforested, including the secondary forest that predominates in the colonized zones on the Andean piedmont and the degraded pastures in cattle ranching regions of Brazil. However, the fear is that market forces will eventually prevail, and the demand for food will require the full productivity of the world's best arable land, with biofuels relegated to marginal land where food crops do not provide adequate yields.[49] Unfortunately, most of the Amazon and Andes Mountains fit into that latter category. African oil palm and elephant grass are ideally suited to the tropics, being perennial species adapted to high precipitation regimes and acidic soils; most importantly, they are incredibly productive on a per hectare basis.

GLOBAL MARKETS AND GEOPOLITICS

Peasant farmers, cattle ranchers, agribusiness companies, and land speculators are the most conspicuous agents of change in the Amazon and in the adjacent regions of the Andes and Cerrado, but these local actors are influenced directly or indirectly by international markets and policy decisions made in New York, Lima, Rio de Janeiro, Beijing, and other major urban centers. Iron ore, petroleum, soy, rice, timber, cinchona bark, rubber, and Brazil nuts are all commodities whose price is set by international markets. Commodity markets have historically fluctuated widely, stimulating investments and bankrupting businesses that did not understand the inherent risk of boom and bust markets. Nations and corporations attempt to limit their risk by creating vertical business models that protect their economies from shortages and high prices. In the Amazon, however, the reaction has often been to adopt an extractive mentality that maximizes profits over the short term while prices are high; even renewable resources are treated as if they were minerals and are exploited until they are nearly an exhausted resource.[50]

The most conspicuous market phenomenon of the last decade has been the rapid growth of the oilseed industry, particularly soy but also sunflowers and rape seed. The international market for soy has been driven by demand from East Asia, particularly China, and has been partially responsible for the rapid growth in mechanized agriculture in central Brazil and for the conversion of almost 50 percent of the Cerrado ecosystem. Competition in international markets is one of the major reasons for IIRSA and PPA investments, because transportation is a major component in establishing the cost of soy exports. For example, the principal market for Bolivian soy has been Andean countries, where tariff preferences under the Andean Community of Nations Treaty (CAN) have provided Bolivian exporters a price advantage over producers from other countries. This trade advantage is now

[49] A study recently published by the National Academy of Sciences found that neither ethanol nor biodiesel can replace petroleum without having an impact on the food supply. If all American corn and soybean production were dedicated to biofuels, that fuel would replace only 12 percent of gasoline demand and 6 percent of diesel demand. The study concludes that the future of replacing oil and gasoline lies with cellulosic ethanol produced from low-cost materials such as switch grass or wheat straw, grown on agriculturally marginal land or from waste plant material (Hill *et al.* 2006).

[50] Two famous examples are quinine in the nineteenth century and mahogany in the twentieth century.

scheduled to terminate because Colombia and Peru have reached free trade agreements with the United States, whereas Venezuela purchases grains from Argentina and Brazil, whose prices are more competitive than Bolivia's. Thus, because Bolivia's future ability to compete in international soy markets depends to a large extent on transportation costs, the country is, not surprisingly, anxious to improve its infrastructure. IIRSA investments in highways, railroads, and hydrovias address these concerns.

The Amazon basin also has enormous potential as a source of high-quality hardwood timber. Currently, most exports from Bolivia and Peru are destined for the United States, with growth in the U.S. market occurring at a 25 percent annual rate since 2003 (PROMPEX 2006). Currently, there is no appreciable trade in timber between the Pacific coast of South America and China; however, this may change, especially as IIRSA investments in hyrdovias and highway corridors reduce transport costs. China has more than tripled its imports of timber in the last decade (Sun *et al.* 2004), and traditional sources of tropical hardwood are rapidly being depleted in Southeast Asia (Curran *et al.* 2004). Plantation forestry in both China and Southeast Asia will play an important role in meeting future demand. However, Amazonian timber could find a niche in the Chinese market for high-quality hardwood for the manufacture of flooring and furniture. Chinese furniture manufacture is an important part of the forest products industry; fully 50 percent of all imported wood in China is re-exported as finished products, with furniture making up approximately 32 percent of those exports (Sun *et al.* 2004). In 2005, Peru reported its first sale of hardwood flooring to the Chinese market (PROMPEX 2006). No systematic economic analysis has been conducted on this potential new market and its environmental and social impact on the Amazon Wilderness Area.

The most important international commodity is oil, and one of the most obvious links between global markets and geopolitics is the simultaneous impact of political unrest in the Middle East and the increased demand for oil in China. The current high price of oil has stimulated exploration and production throughout the world, including in the western Amazon and Andean piedmont. Although increased production worldwide will eventually lead to a decrease in oil prices, some analysts think the mid- to long-term price will remain well above historically low levels (Hickerson 1995). In search of stable energy supplies, state-owned corporations such as the China National Petroleum Company (CNPC) have acquired overseas oil reserves free from the control of foreign multinational corporations. Chinese-owned subsidiaries are exploring for oil in Peru (PetroPeru 2006) and Ecuador (ChinaView 2006), and the CNPC has also acquired a 36 percent stake in the OCP pipeline in Ecuador, which ensures control not only of petroleum reserves, but also of the transport system needed to bring those reserves to their domestic market.

Brazil is likewise expanding its sphere of economic influence. Petrobras holds 14 percent of Bolivia's natural gas reserves and is a shareholder in the pipelines that connect those reserves with Brazil's domestic markets. Petrobras is also actively involved in exploring gas and oil reserves in Ecuador and Peru, including within Yasuní National Park and in concessions adjacent to Camisea. Future growth of the Peruvian reserves near Camisea may resurrect part of Shell Oil's original business plan from the early 1990s for a pipeline to connect Camisea with Brazil. Brazil's growing influence is reflected in its recent commitment to support the executive offices of the Organization of the Amazon Cooperation Treaty (OTCA). The mission of the OTCA is to promote economic growth and conserve the natural ecosystems of the Amazon basin. IIRSA is mentioned in the OTCA strategic plan as an explicit priority and is fully justified by the original OTCA treaty. Brazil has played an active role in rejuvenating the role of the OTCA and is helping finance individual IIRSA projects via loans to Brazilian construction companies through BNDES and other Brazilian financial institutions.

Brazil is not the only Amazonian state that is attempting to expand its influence in the region. The President of Venezuela, Hugo Chavez, has been particularly energetic in promoting a "Bolivarian" vision of regional integration that is both independent of the United States and based on state intervention in national economies (Figure 2.17). As part of that vision, he has announced that the state energy company (PDVSA) is willing to invest in a *Gasoducto del Sur* to connect Venezuela to Argentina and Uruguay via Brazil.[51] According to projected prices for natural gas in international markets, this pipeline is only marginally viable on an economic basis; however, the Southern Cone countries may be willing to subsidize its construction to diversify energy sources, while Venezuela seeks to open new markets for its huge gas reserves.[52] The *Gasoducto del Sur* meets all the development criteria in the vision and mission statements of IIRSA and offers intriguing possibilities to create a continental energy transport system.

In the Amazon, the economic impact of a continental-scale energy grid would be enormous. If natural gas prices within the region remain subsidized, it would spur investments in other industries linked to natural resources—the foundation of the Amazonian economy. For example, in order to establish the country's first steel mill, the Bolivian government recently agreed to provide gas at below-market prices to attract foreign investments in an iron ore mine and processing facility. Gas pipelines would also mean a proliferation of electrical generation facilities and the extension of rural electrical grids. Modern highways combined with abundant energy resources would lead to explosive growth; deforestation would increase at near exponential rates, and the Amazon would be radically and permanently altered.

The future development of the Amazon will be driven in part by political factors and will be influenced by the electoral processes in South America. Voters have been rejecting the traditional elites and the political parties that have dominated over the last few decades, instead supporting new political groups called "social movements." Governments in Bolivia, Ecuador, and Venezuela and opposing political parties in Colombia and Peru

51 Although it may sound farfetched, it was included as a goal in a recently signed agreement between PDVSA and ENARSA (http://www.abn.info.ve/go_news5.php?articulo=27174&lee=3); in addition, the Russian gas giant Gazprom and Petrobras have initiated discussions to jointly develop this pipeline (Reuters 2006).

52 Venezuela has an estimated 147 trillion cubic feet of natural gas reserves, approximately triple those of Bolivia and ten times those discovered at Camisea, Peru (http://www.dinero.com.ve/196/portada/energia.html).

Figure 2.17. IIRSA is a manifestation of the political determination of South America countries to integrate their economies, a goal that is broadly supported by all sectors of society and which will transcend the periodic changes of the electoral process (© Getty Images).

advocate a larger role for the state in managing the national economy. Some criticize multinational corporations that exploit the mineral and energy resources of the region, and civil groups often use environmental issues to obstruct hydrocarbon exploration, particularly in protected areas and indigenous reserves. However, once elected, politicians—and the voters they represent—usually energetically support natural resource exploitation as a means to generate economic growth.

In Bolivia, opposition to hydrocarbon exploitation was based not on a concern for conservation, but on a perception that the business arrangement with multinational companies was unfair to the country and indigenous peoples. A new relationship between the state and the multinationals was recently negotiated, and the new government has promised a portion of the oil royalties to indigenous groups. Consequently, opposition to exploration has essentially dissipated; exploration and production are now viewed as strategic priorities. Importantly, the lead institution is no longer a distrusted foreign multinational, but a state-owned company with broad public support. Historically, state-owned companies have not adopted the most rigorous environmental and social policies, although some companies such as Petrobras have successfully changed corporate cultures, adopting environmental standards common to the industry.

In Latin America, governments and opposition movements speak of the need to establish "policies of the state" versus "policies of the government." The former refers to strategic objectives and decisions that are broadly supported by all sectors of society and that transcend the periodic swings of the electoral process. Important examples are Bolivia's demand for access to the Pacific Ocean, Venezuela's decision to maintain managerial control over the exploitation of its mineral and hydrocarbon resources, and Brazil's fierce defense of its sovereign right to manage the conservation of Amazon biodiversity. IIRSA is another such "policy of the state" and as such, it transcends current governments and the wills of individual leaders. However, IIRSA also represents an opportunity to conserve the biodiversity of the Andes Mountains and the Amazon because it provides a forum to address the multiple threats of development directly and to provide integrated alternatives that respond to the legitimate needs of Amazonian society for economic growth and development. Key to the reform of IIRSA is the recognition that the nations of the Amazon have sovereignty over their natural resources. Each nation must thus be convinced that its own national strategic interest is best served by conservation. The recent resurrection of the Organization of the Amazon Cooperation Treaty (OTCA), with its recognition of the centrality of biodiversity conservation, provides an appropriate and timely mechanism for perfecting the collective state policies represented by IIRSA.

CHAPTER 3

Biodiversity

The Amazon, Andes and Cerrado are among the richest and most diverse regions of the planet. (Top: ©Haroldo Castro/CI; Bottom: ©John Martin/CI)

Collectively and individually, IIRSA projects represent an enormous threat to the conservation of the biodiversity of the South American continent. All but one of the ten IIRSA corridors intersects with a Biodiversity Hotspot (Andes, Cerrado, Atlantic Coastal Rainforest) or Wilderness Area (Amazon, Pantanal, Gran Chaco, Caatinga). The IIRSA highway corridors planned for Bolivia, Ecuador, and Peru, the Arco Norte in the Guayana Shield region, and the PPA investments in the Brazilian Amazon are particularly worrisome because they will radically increase access to wilderness areas with very high levels of biological endemism. IIRSA will expose the western Amazon and the Andean foothills to potent global and regional economic forces, and the region's interconnected ecosystems will be inalterably changed. Climate change and geological history have left their mark on today's ecosystems and their species. The distribution of biodiversity is radically different in each of the region's major biomes due to the distinct physical attributes of mountains versus lowlands, and terrestrial versus aquatic ecosystems. Consequently, IIRSA and other development phenomena will have variable impacts across the Amazon, Andes, and the Cerrado biomes. Designing mitigation programs and conservation strategies must be predicated on a thorough understanding of the regional nature of biodiversity.

MONTANE FOREST

Montane forests are the most biologically diverse habitats within the Andes Mountains, occupying the terrain between the grasslands of the Andean highlands and the humid forests of the Amazonian lowlands. Landscapes include broad valleys, narrow canyons, slopes of varying steepness, cliff faces, and ridge tops situated between 500 and 3,500 m in elevation. Tropical montane forests are characterized by strong gradients related to topography and manifest as differences in elevation, precipitation, humidity, soil type, slope, aspect, and radiation. Species adapt to these gradients in often contrasting ways, and their distribution depends on the characteristics that define their reproduction and survival (Kessler *et al.* 2001, Young *et al.* 2002). For example, the diversity of epiphytic bromeliads is correlated with elevation, as this functional group is adapted to cool and humid cloud forest habitats, whereas aroids are more abundant in warm and humid forest communities. Terrestrial bromeliads and cacti are most abundant in dry valleys where high levels of incident radiation reach the forest floor; fern richness is correlated with moss cover, because the fern gametophytes depend on the water captured and held by moss (Kessler 2000, 2001, 2002). Trees, the most important functional group in the ecosystem, are most diverse at lower elevations, but species composition changes over multiple gradients. Birds and bats decrease in species richness with elevation, but the diversity of rodents is unrelated to elevation (Patterson *et al.* 1998). Forest communities are subject to periodic disturbances from landslides due to high precipitation and mountainous terrain (Veblen *et al.* 1981). Because of disturbances and multiple gradients, montane forests are extraordinarily complex spatially; thus, habitat diversity and species turnover are prominent attributes of this ecosystem.

Figure 3.1. Cloud forests are unique habitats that vary according to local topography and wind flow; consequently, they are inherently fragmented and spatially complex as shown by this composite image of the Andean foothills in Bolivia. This image is derived from MODIS images taken at approximately 10:30 and 13:30 local time from the NASA Terra and Aqua satellites. White areas are those with frequent cloud cover (© Michael Douglass).

Lower montane forest communities are similar to lowland rain forests; however, with increasing altitude, montane species become more abundant and lowland species more rare (Gentry 1988, 1992a, 1992b). At the top of the montane forest sequence are "cloud forests," where ridge tops in the foothills and the flanks of the eastern cordillera intersect with the cloud layer that forms over the adjacent lowlands. Cloud forests have unique environmental conditions characterized by mist, low temperatures, and limited solar radiation. Because they are surrounded by forest types that are radically different in structure, function, and composition, patches of cloud forest are effectively geographically isolated (Killeen *et al.* 2005). One of the central tenets of conservation biology is that island-like habitats are important in establishing the reproductive isolation that drives allopatric speciation (Stebbins 1950, MacArthur & Wilson 1967). The effective isolation of cloud forests is manifest in the negative relationship between mean range size and mean elevation; essentially, species with the smallest range sizes occur at higher altitudes (Kessler 2002).

Environmental differences among patches of cloud forest are caused by elevation gradients and the frequency of cloud formation (Figure 3.1). The Andean foothills are composed of a series of parallel ridges of increasing altitude situated between the lowland plain and the eastern cordillera. Evaporation over the valleys leads to cloud formation over the adjacent ridges in a diurnal cycle that exaggerates both the humidity on ridges and the evapotranspiration in the valleys (Troll 1968, Kessler *et al.* 2001, Killeen *et al.* 2007a); consequently, cloud-impacted communities occur at elevations as low as 1,000 m and as high as 3,500m. High levels of endemism are particularly pronounced for higher taxa and functional groups such as amphibians (Köhler 2000, Kattan *et al.* 2004) epiphytic orchids (Vasquez *et al.* 2003), aroids (Vargas *et al.* 2004), and mosses (Churchill *et al.* 1995). Taxa that are well represented in other biomes also have experienced a radiation of species in montane forests: Ericaceae (Luteyn 2002), *Inga* (Pennington 1997), Solanaceae (Knapp 2002), and the Podocarpaceae (Killeen *et al.* 1993). Animal species such as hummingbirds have coevolved with plant taxa (Ericaceae and Bromeliaceae) that are both abundant and speciose in montane forests (Stotz *et al.* 1996). Many species are known to exist at a single locality, making them extremely vulnerable to extinction (Figure 3.2).

Mid-level and lower montane forest communities provide additional complexity. Some of the valleys of the eastern Andes experience annual precipitation greater than 6,000 mm (Hijmans *et al.* 2004), but rain shadow and the diurnal cycles in deep canyons create semiarid habitats with precipitation less than 1,000 mm (Troll 1968, Killeen *et al.* 2007a). Montane dry forests occur as isolated habitats from Argentina to Venezuela. Although they share a common biogeographic history, they have experienced thousands of years of divergent evolution. Andean dry forests contain numerous endemic species or infraspecific regional variants (Pennington *et al.* 2005); many have been heavily affected by human populations.

The magnitude of IIRSA-related impacts on montane forests is impossible to map with any level of precision because the environmental gradients and the resulting habitat mosaic of these forests is complex. Nonetheless, the consequences of road improvement and expansion in the humid montane regions of Bolivia, Ecuador, and Peru are very predictable. Due to the extremely high levels of endemism associated with cloud forests, there is a high probability that any highway construction will directly lead to species extinction (Ricketts *et al.* 2005). Deforestation on the adjacent piedmont may reduce cloud cover and raise the height of the cloud base during the dry season (Lawton *et al.* 2001, Nair *et al.* In press), possibly altering the environmental conditions of the cloud forest during a critical time of the year. If such a trend develops, then cloud forest species will have to shift their distribution upward or be exposed to environmental conditions different than those to which they are adapted. Many will not be able to migrate upward in response to a rapidly changing altitudinal gradient or adapt to the changing conditions at their current elevation distribution. If so, these species will become extinct.

In lower montane forests the largest impacts will be indirect because they are associated with increased deforestation and forest fragmentation (see discussion on lowland tropical rainforests below). Fortunately, montane forests of the central Andes Mountains are still largely intact; a dozen highway corridors connect the Andean highlands and the Amazon lowlands, but large forest blocks remain unsettled and wild. IIRSA threatens to change this rare wilderness area, permanently degrading a global biodiversity hotspot. Several of the planned transportation corridors will transect areas that have been inhabited for decades (Yungas and Chapare in Bolivia, Huallaga Valley in Peru, Napo in Ecuador), but road improvement will accelerate the expansion of secondary roads into the intact forest blocks, degrading forest remnants. The construction of the Interoceanic Corridor in southern Peru[53] will produce even greater impacts because it will improve a road that is closed during several months of the year and that is sparsely settled where it transects montane forests. The situation is even more critical in Colombia, Ecuador, and Venezuela, where montane forest ecosystems have been occupied by human civilizations for centuries. The montane forests of the northern Andes are already highly fragmented, and the cloud forest habitats have been encroached upon from above and below the cloud zone.[54] The potential impact from IIRSA investments in the northern Amazon basin will take place on landscapes that have already been substantially altered by human activities. Consequently, special care needs to be taken so that the few remaining patches of native habitat are identified and provided maximum protection.

53 The Interoceanic Corridor is a project in the Peru–Brazil–Bolivia Hub rather than a component of the Central Interocenic Hub that spans Bolivia and Brazil to the south (see Figure 1.1 and Figure A.2).

54 In Colombia, potatoes are cultivated near the ecotone between cloud forest and high altitude paramo grasslands.

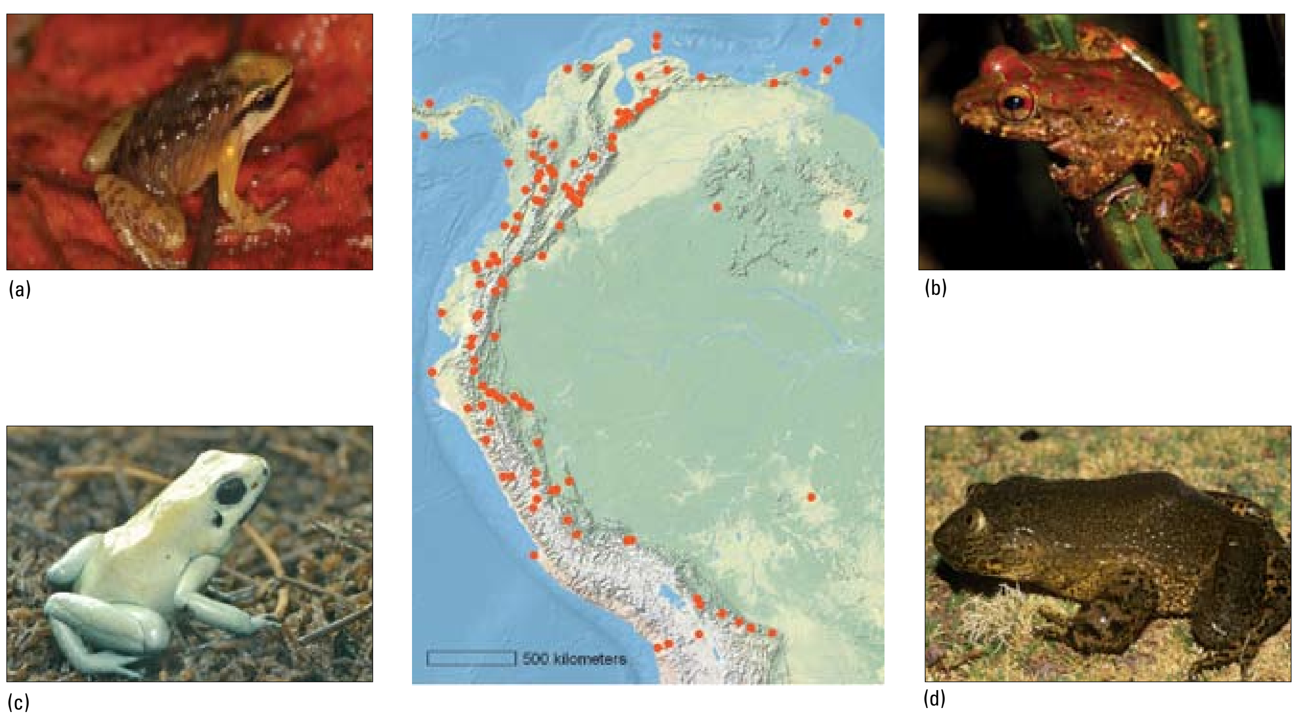

Figure 3.2 The Alliance for Zero Extinction (AZE) identified locations that contain the only known populations of one or more endangered species. Amphibians top the list and include these South American species: (a) *Colostethus ruthveni* and (b) *Cryptobatrachus boulengeri,* both from Sierra Nevada de Santa Marta National Park in Colombia (© ProAves), (c) *Phyllobates terribilis* from Río Saija in Colombia (© John White), and (d) *Telmatobius gigas* from Bolivia (© Ignacio de la Riva).

LOWLAND TROPICAL RAINFOREST

The Amazon region is sometimes described as a monotonous expanse of tall forest that covers more than half of the continent; however, this apparent uniformity is deceiving: the variability in species composition is manifest at the basin, the regional, and the local scale. Botanical research has shown that the floras have strong regional differentiation (Prance 1972, 1989, Mori & Prance 1990, Baker *et al.* 2004) and that plant communities vary over latitudinal and longitudinal gradients (ter Steege *et al.* 2000). The distribution of vertebrates is constrained by rivers, leading to many endemic species and subspecies (Wallace 1852, Emmons 1997, Patton & da Silva 1998, da Silva *et al.* 2005). Scientists with different taxonomic and disciplinary perspectives have fiercely debated the origin and evolution of biodiversity in the Amazon (Haffer 1969, Colinvaux 1993, Nelson *et al.* 1993, Irion *et al.* 1995, Marriog & Cerqueira 1997, Lovejoy *et al.* 1998, Burnham & Graham 1999, Maslin 2005, Mayle & Bush 2005). There is no argument, however, over the distinctiveness of the regional biota and that IIRSA projects will impact some regions more than others.

Studies of vertebrate taxa have identified eight subregions of the Amazon separated by rivers and differentiated according to the distribution of endemic frog, lizard, bird, and primate species (see review in da Silva *et al.* 2005). The most commonly accepted hypothesis is that the largest Amazonia tributaries and the main trunk of the Amazon River are situated in very old valleys that have acted as barriers to the distribution of forest species over millions of years. Given this geographic isolation, a characteristic suite of endemic species or subspecies has emerged within each subregion. Each one of these biogeographic subregions (Figure 3.3) represents a basic unit of conservation planning because the species in it cannot be affected by conservation measures in the other subregions. One of the central tenets of conservation planning is the need to protect large blocks of forest (Tarabelli & Gascon 2005); however, if a large block is composed of two or more separate subregions that are differentiated by endemism, then the effective size of that forest block is proportionally reduced. Consequently, the large forest remnants in the southern and eastern Amazon are not as effective conservation units as they may seem. Regional endemism should be the primary consideration in designing conservation corridors (da Silva *et al.* 2005). Unfortunately, IIRSA corridors have been designed without consideration of their potential impact on regional endemics. Regional endemism is less important in defining geographic stratification on the Andean piedmont, where landscapes are younger and there is little evidence that rivers have acted as barriers to the distribution of species (Aleixo 2004); nonetheless, there are still regions of high endemism that must be considered in development planning. Botanical studies show a gradual change in forest composition between Bolivia and Ecuador (Smith &

(a) (b) (c) (d)

Figure 3.3. The Amazon has different biogeographic regions, each characterized by endemic vertebrates: (a) Equatorial saki (*Pithecia aequatorialis*) is endemic to the Napo region in Ecuador and northern Peru; (b) White-faced saki (*Pithecia pithecia*) is endemic to the Guiana region; (c) Emperor tamarin (*Saguinus imperator*), is endemic to the Inambari region and (d) Prince Bernhard's titi monkey (*Callicebus bernhardi*) is endemic to a restricted area in the Rondônia region. Deforestation has already severely affected the eastern and southern regions, while IIRSA investments will impact the Inambari and Napo regions.

Killeen 1998, Terborgh & Andresen 1998, Pitman *et al.* 2001). However, the latitudinal gradient does not correspond simply with the precipitation gradient that is responsible for a concomitant reduction in biodiversity. There are three regions that experience anomalously high rainfall at some distance from the equator (Hijmans *at al.* 2004); each of these regions is floristically distinct and contains high levels of species richness and endemism (Killeen *et al.* 2007a). They have been hypothesized to be climatically stable and probably remained wet during the Pleistocene, when the distribution of humid forest species was reduced.[55] Habitat conversion in these regions is particularly unfortunate, especially because these areas are prime candidates for biological reserves that are resistant to future climate change (Killeen *et al.* 2007a).

The structure and composition of Amazon forest communities make them particularly susceptible to deforestation and fragmentation because they are characterized by a small number of oligodominant tree species (usually ten to twenty) that are more or less abundant, constituting up to 50 percent of all stems (Pitman *et al.* 2001, 2002). Oligodominants tend to have very wide distributions and can be viewed as successful species in terms of their ability to reproduce, disperse seeds, and recruit adult individuals into the forest canopy. However, the rest of the tree community is composed of hundreds of species that are represented by only one to a few individuals per hectare. Rare species represent the bulk of tree diversity in tropical forest communities (Pitman *et al.* 2001, 2002, Condit *et al.* 2002). Detailed studies on the range distribution of rare species have not been undertaken, but it is reasonable to hypothesize that most are regional endemics. Because of their low population densities, they are particularly susceptible to forest fragmentation and deforestation, which will tend to homogenize the Amazon forest as these rare regional endemics are eliminated, leaving the widespread oligodominants.

The deleterious effects of forest fragmentation are well documented (Laurance *et al.* 2002, Tabarelli & Gascon 2005). Most deforested landscapes retain patches of natural forest surrounded by a matrix of human modified landscapes that include crops, pastures, and secondary forest. Forest fragments are relatively small and have a large edge-to-interior ratio that exposes the fragment to further degradation. Edge effects include greater penetration of light and wind, which leads to drier conditions in the understory, impedes the regeneration of native species, and exposes adult trees to increased mortality from wind sheer (Laurance & Wiliamson 2001). In addition, fire is an increased threat because forest fragments are often surrounded by pasture that is periodically burned for weed control; fire invades forest remnants, increasing adult mortality and further degrading the forest structure (Cochrane & Laurance 2002). Because forest remnants are located in areas with relatively high population density and reduced regional fores cover, logging is also more intensive to meet the local population's ongoing need for timber and firewood. Similarly, intensive hunting quickly leads to the local extinction of the vertebrate fauna, which limits the dispersal of seeds and genetically degrades tree populations. Edge effect has been shown to penetrate up to 300 m into forests, and because remnants are often quite small, there is often no place free from some sort of edge effect (Laurance *et al.* 2002). Disturbance from adult mortality, logging, and fire promote the regeneration of pioneer species that are both invasive and widely distributed; all of these processes lead to further homogenization of the forest flora (Tabarelli & Gascon 2005).

Lowland forests will be degraded over an extensive area due largely to the economic and social forces unleashed by the IIRSA projects (Fearnside & Graça 2006). Highway construction in remote areas stimulates human migration, which leads to accelerated land use change and increased habitat fragmentation. Because the land on the piedmont and adjacent plains is essentially flat, secondary roads will proliferate, bringing extensive deforestation, forest fragmentation, and forest degradation (Laurance *et al.* 2001). It is not unreasonable to predict that at least 250,000 km^2 will be deforested in the Amazon over the next decade, with a total of at least 50,000 km^2 in Bolivia, Colombia, Ecuador, and Peru combined.[56] If the proposed highways are constructed, forest habitats on the eastern slope of the Andes and the adjacent piedmont will be fragmented into at least eight distinct blocks with several highways transecting proposed biodiversity conservation corridors. Even larger areas will be subject to forest degradation caused by logging and fire.

GRASSLANDS, CERRADOS, AND DRY FORESTS

The regions adjacent to the Amazon support a variety of ecosystems adapted to the seasonal climates of the dry tropics (Daly & Mitchell 2000). The largest and the most biologically diverse of them is the Cerrado Biodiversity Hotspot, a complex of savannas and shrublands that stretches across the southern Amazon from Maranhão to eastern Bolivia (Machado *et al.* 2007). Structurally similar but floristically distinct are the grasslands in Colombia and Venezuela (*Llanos de Orinoco*); Bolivia (*Llanos del Moxos*); and on the border of Bolivia, Brazil, and Paraguay (*Gran Pantanal*), which are recognized as wilderness areas because the greatest part of their surface area remains essentially intact. Natural grasslands also occur in the Guayana Shield region of Venezuela (*Gran Sabana*), Guayana (*Rupinini*), and Brazil (*Roraima*), as well as on isolated patches associated with poor soils or seasonally inundated landscapes in the Brazilian Amazon, such as the Araguaia River (*Ilha do Bananal*) and white sand *caatingas* of the central Amazon. Savannas and scrublands predominate on these landscapes due to environmental factors such as seasonal drought, poor soils, and impeded drainage, with fire almost always playing an important role in modulating the density of the woody cover. Savannas almost always occur within a landscape mosaic with a seasonal forest habitat

55 The presence of humid forest refugia in the Pleistocene does not imply that Amazonian speciation occurred during that period (e.g., Refugium Hypothesis), which is generally believed to be a Tertiary phenomenon (see Maslin 2005), but only that several disjunctive or loosely connected areas on the Andean piedmont would have provided appropriate conditions for humid forest species (Killeen *et al.* 2007a).

56 Annual land use change in the Brazilian Amazon is approximately 20,000 km^2 yr−1 (Laurence *et al.* 2004); in Bolivia it is 2,400 km2 yr−1 (Killeen *et al.* 2007b). Studies are underway in Colombia, Ecuador, Peru, Venezuela, and the Guayanas, with a sum of 3,000 km2 yr−1 being a conservative estimate for these countries (see Table A.2).

where the edaphic constraints that limit forest formation are less severe. Dry or seasonal forest formations exist on landscapes with relatively fertile soils, such as in eastern Bolivia (*Chiquitano, Gran Chaco*), northeastern Brazil (*Caatinga*), and Venezuela (Pennington *et al*. 2005).

The Cerrado biome is renowned for its high levels of diversity and endemism, with an estimated 40 percent of its woody plants and 38 percent of its reptiles occurring only in this biogeographic region (Colli 2005, Ratter *et al*. 2006). One of the key ecological attributes of the Cerrado ecosystem is its habitat diversity, which ranges from open grasslands to dense scrubland and gallery forests along water courses; specialized species are often most abundant or even restricted to a specific habitat type (Figure 3.4). Habitat diversity leads to complex landscape mosaics with multiple ecotones. Gallery forests are particularly important for providing cover for wildlife, and most savanna fauna depend on this habitat type within the savanna ecosystem. The biodiversity of the Cerrado Hotspot has not been adequately mapped, but the distribution of woody plant species reveals that there is strong regional differentiation (Ratter *et al*. 2006), and a gap analysis performed for 244 threatened and endemic amphibians, reptiles, birds, mammals, and plants demonstrated that almost 30 percent of the Cerrado biodiversity is not represented in the existing protected areas (Machado *et al*. 2007).

Modern development in the Cerrado region began in the 1950s and 1960s with the expansion of cattle ranching on the Planalto de Mato Grosso. However, because most native grasses are coarse and unpalatable, landowners cleared them to plant cultivated grasses that allowed them to increase their livestock herds and improve animal management. Beginning in the late 1980s, agronomists learned that the application of lime ($CaCO_2$) to Cerrado soils could dramatically improve soil fertility. Landhold-

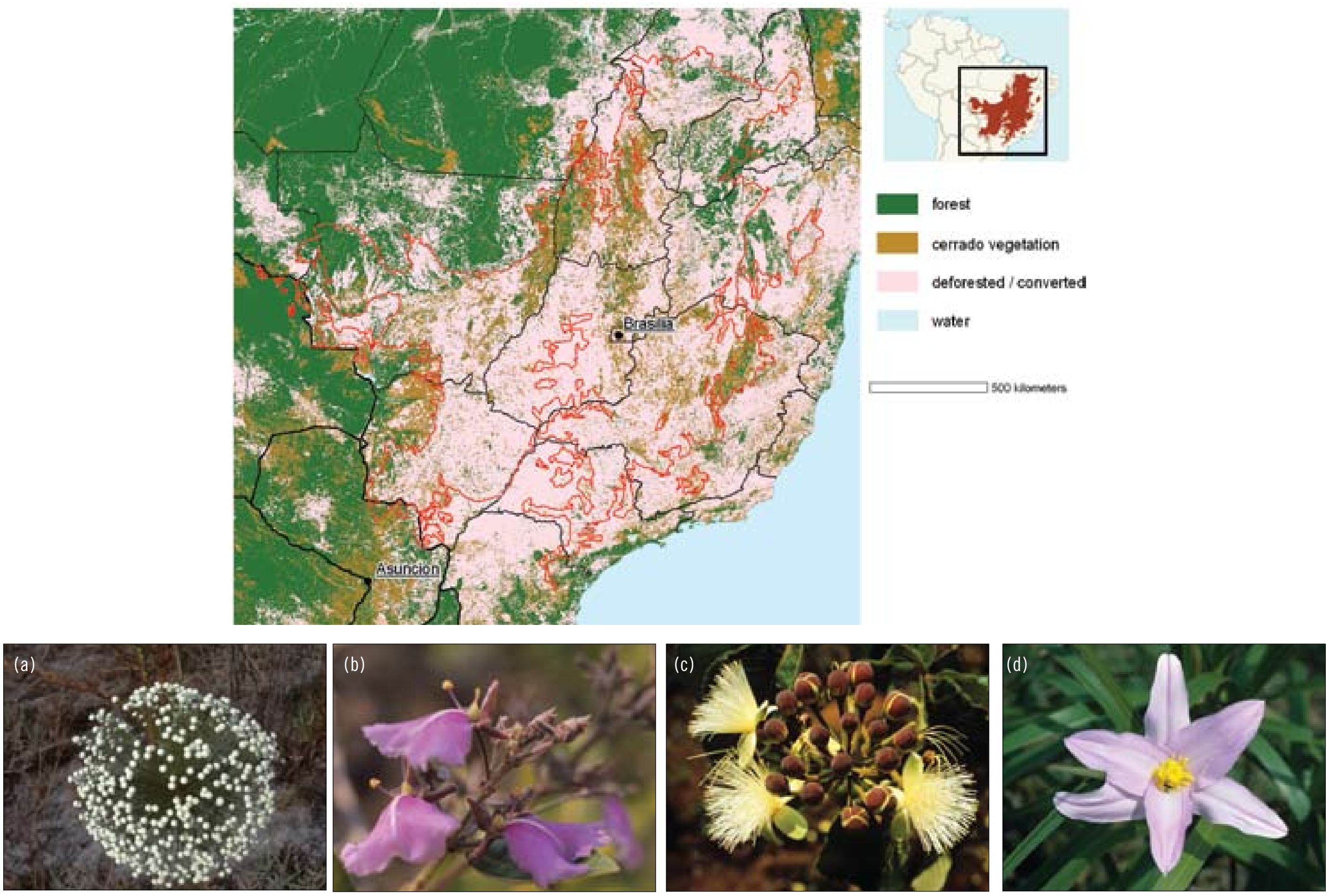

Figure 3.4. The Cerrado Biodiversity Hotspot is well known for its endemic plant species: (a) *Actinocephalus bongardii* (A. St. Hil.) Sano (© Haroldo Castro/CI); (b) *Quarea parviflora* Mart.; (c) *Caryocar brasilensis* Camb., and (d) *Vellozia squamata* Mart. ex Schult. (© Dr. Jimmy Ratter, Royal Botanical Garden of Edinburgh). The Cerrado has already lost much of its natural habitat to agricultural production; an improved transportation infrastructure will increase the competitiveness of Cerrado agriculture, leading to an intensification of land use.

ers then began to convert ranches into cropland, and the Cerrado has since become the largest soybean producing region, making Brazil the largest exporter of soy in the world. The original extent of the Cerrado habitat has been estimated at 2.2 million km^2, but approximately 55 percent has been converted to either pasture or cropland. The rate of habitat conversion was estimated at 1.36 to 2.2 million ha per year between 1985 and 2002, and some models predict that what remains of the Cerrado will disappear by 2030 (Machado *et al.* 2004, 2007). Unfortunately, only 2.2 percent of the original Cerrado area has been set aside as protected areas (Klink & Machado 2005, Rylands *et al.* 2005).

Rapid land use change and habitat degradation are similarly occurring in seasonally dry forest formations, where climates and soils have long favored human settlement and agriculture (Olson & Dinerstein 1998). These geographically separate forests share a common biogeographic history (Prado & Gibbs 1993, Pennington *et al.* 2005). Apparently, they coalesced near the equator during the last glacial maximum surrounding a much reduced rainforest ecosystem in the central and western Amazon (Mayle *et al.* 2004); nonetheless, today, each subregion of seasonally dry forest has its own group of endemic species or subspecies (Pennington *et al.* 2005). Nonsustainable logging practices are particularly damaging in these ecosystems because of the inherently slow growth rates of species adapted to these climatic regimes (Dauber 2003). The Caatinga region is the most degraded of the seasonal forest regions due to the long history of human settlement and colonization in northeastern Brazil. Recent deforestation has impacted dry forest regions in Bolivia, Venezuela, and southern Brazil.

Fortunately, the savannas of the Llanos de Orinoco, Moxos, and the Gran Pantanal are still relatively intact due largely to the seasonally inundated landscapes, which inherently limit cultivation. Nonetheless, cattle ranchers do graze livestock on the native grasses of these regions, which are more palatable than the native grasses on the upland savannas, and some areas are locally impacted by overgrazing. In addition, there are recent experiments to convert seasonally inundated habitats to paddy rice cultivation in Bolivia, and there is clearing of woody plants in the Gran Pantanal.

IIRSA and PPA investments will accelerate habitat degradation in most, if not all, of the extra-Amazonian ecosystems. The Cerrado Biodiversity Hotspot is the most endangered due largely to its suitability for mechanized agriculture. Although the Federal Government of Brazil makes repeated commitments to conserve the Amazon, similar actions to conserve in the Cerrado region are weighed against national priorities to expand agricultural production (Figure 3.5). Thus, although the Amazon ecosystem faces extensive degradation and fragmentation due to IIRSA investments over the medium term, the Cerrado faces virtual annihilation over the next half century (Machado *et al.* 2007). Considering the advanced state of the destruction of this biome, protected area creation should be part of any strategy that seeks to mitigate the effects of the PPA's investments in modern highways. The Brazilian forest code requires that 20 percent of private properties be left as native habitat within the Cerrado biome. These efforts to conserve gallery forests within private lands could significantly

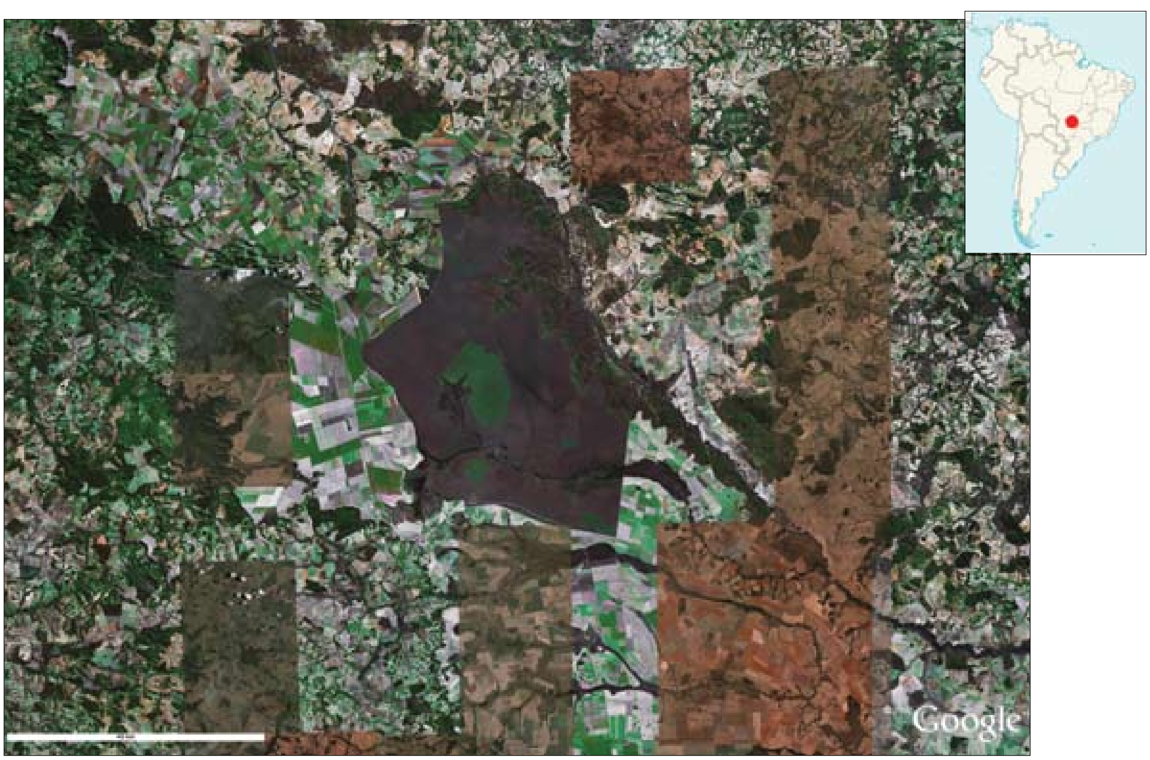

Figure 3.5. Emas National Park is an island of native habitat surrounded by farmland in the Cerrado. Gallery forests along rivers and scattered remnants of native habitat provide opportunities for a regional conservation strategy (Google Earth ™ Mapping Services).

reduce the effect of habitat conversion within savanna ecosystems.[57]

AQUATIC ECOSYSTEMS

The Amazon River system is the world's largest freshwater ecosystem, with nearly 20 percent of the Earth's freshwater discharge (Goulding 1980). The aquatic biodiversity of the Amazon is the consequence of geological history, the sheer size of the basin, the contrasting nature of the constituent sub-basins, and the extraordinary habitat heterogeneity of each individual floodplain. The Amazon's sub-basins have been traditionally classed into three broad categories on the basis of turbidity, color, and pH of the water: 1) white water rivers originating in the Andes are characterized by high sediment loads and approximately neutral pH; 2) black water rivers drain lowland landscapes with white sand soils dominated by plants with very high tannin[58] levels, so their runoff is very dark and acidic; 3) clear water rivers arise in moderate terrain, particularly the Brazilian and Guayana Shield, and have relatively clear water of nearly neutral pH (Sioli 1968, Junk 1983). Recent studies have emphasized the diversity of aquatic habitats associated with the morphological variability of channels, lakes, and wetlands, as well as distinct hydrological regimes in upstream, midstream, and downstream sections of the river (Mertes *et al.* 1996, Goulding *et al.* 2003). Like their terrestrial counterparts, aquatic ecosystems are characterized by high levels of biodiversity and species endemism (Figure 3.6). Estimates of the number of Amazonian fish species vary between 1,300 and 3,000, but the true number may be much higher as systematists revise the status of headwater populations of widespread but poorly studied taxonomic groups (Ruffino 2001).

Migration is a behavioral trait characteristic of many Amazonian fish. Some of the most economically important commercial species such as the piramutaba (*Brachyplatystoma vaillantii*) and the dourada (*B. flavicans*) migrate long distances between the estuary and upstream sections of the basin. Other species are less pelagic in their migration, moving within certain sectors of the basin, such as the tambaqui (*Colossoma macropomum)*, pacú (*Mylossoma* spp.), jaraqui (*Semaprochilodus* spp.), and curimatã (*Prochilodus nigricans),* among others (Barthem & Goulding 1997, Ruffino 2001). One of the most salient features of the Amazon River system is the importance of the floodplain in providing multiple niches for aquatic organisms, and many fish species migrate locally between the channel and flood plain habitats in accord with annual fluctuations in river levels (Goulding 1980, Goulding & Ferreira 1996). Along white water rivers, floodplain forests known as *varzea* are particularly productive because the sediments washed down from the Andes bring essential chemical nutrients. Frugivorous fish migrate into *varzea* during periods of high water to spawn and feed on a rich assortment of fruits, then return to the river channels during low-water periods (Barthem & Goulding 1997).

Modifications to the Amazon's aquatic systems through the construction of dams and reservoirs will bring obvious direct impacts in the immediate area of each project. The most serious are those relating to fish populations. At the Tucuruí dam on the Tocantins River in Brazil, a program to monitor fish populations before and after the flooding of the reservoir showed declines in species diversity upstream (25 percent) and downstream (19 percent); in addition, species diversity was down 27 percent compared with the preexisting riverine habitat (LaRovere & Mendes,

57 Conservation International–Brazil is working with farmers and ranchers to restore areas cleared beyond the legally allowed amount; voluntary certification schemes are being promoted to reward farmers in compliance by providing secured access to European markets.

58 Tannins are chemical compounds that plants have evolved as defense mechanisms against herbivores. They are particularly common in plants from areas with very sterile soils where the leaf nutrients are difficult to replace.

Figure 3.6. The inundated forests of the Amazon are strategically important for biodiversity conservation: (a) Igapo forest near Manaus is home to plant and animal species adapted to the acidic conditions of black water rivers; (b) Varzea forests have muddy, nutrient-laden waters and are among the most productive wetlands in the world (©CI and Tim Killeen/CI).

2000). Another recent study of mercury contamination in the Caroni River in Venezuela revealed that mercury levels in fish populations were several-fold higher within the reservoir than in populations below the reservoir. Apparently the high organic content of lake bed sediments (the result of flooding tens of thousands of kilometers of forest vegetation) creates anoxic conditions that enable mercury-methylate to form, a type of mercury that is rapidly absorbed by biological organisms (Veiga 1997, Fearnside 2001a, 2005a).

Aquatic systems are particularly susceptible to secondary long-term impacts: upstream effluents and sediments are conveyed downstream, while downstream obstacles impede the migration of species to headwater regions. Consequently, the impacts of IIRSA investments on aquatic systems will be apparent both locally and regionally. Deforestation of upland forest in lowland landscape will bring about a pulse of nutrients associated with ash and increased sedimentation, as well as long-term changes in temperature and chemistry (Bojsen & Barrigo 2002). Muddy streams that meander through cattle pasture bear little resemblance to the cool, shaded, clear water habitats that existed prior to deforestation. Paddy rice cultivation is not common in the Amazon, but recent experiments in Bolivia are encouraging new migrants to adopt this production system in the accessible areas of the Llanos de Moxos of the Beni. The conversion of savanna wetlands for paddy rice cultivation will also have important, if poorly understood, impacts on fish populations. Savanna fishes are known to be diverse, although they represent the most poorly studied segment of freshwater fishes in tropical America (Schaefer 2000). Deforestation of inundated forests is particularly devastating because it directly affects the prime feeding and spawning ground of the most economically important fish species. Road-building in mountainous regions will have severe short-term impacts. Because roads typically are built on slopes above rivers, earth-moving equipment can dump tens of thousands of tons of soil and rock into watercourses during construction. Highways and rivers usually run parallel for dozens of kilometers; thus, the riparian environment will be permanently altered.

A major emphasis of IIRSA is the renovation and improvement of hydrovias. This promotion of river transport will have fewer negative impacts than highway construction, and the creation of river ports will pose moderate impacts. Nonetheless, a revitalized Amazonian hydrovia will potentially lead to increased population density along major and minor rivers. This would almost certainly lead to increased fishing pressure, and may also foster increased deforestation in both upland and flooded forests. IIRSA investments to construct dams for energy production would constitute a long-term, permanent impact on dozens if not hundreds of migratory fish species. Damming the major tributaries of the Amazon River may have catastrophic effects on fish migration and fish populations and bring about huge economic consequences.

CHAPTER 4

Ecosystem Services

The collection and processing of Brazil nuts is considered by many to be the quintessential sustainable forest enterprise and is the mainstay of many traditional communities (©Andre Baertschi).

The Amazon Wilderness Area and the Tropical Andes and Cerrado hotspots provide ecosystem services to the world via their biodiversity, their carbon stocks, and their water resources. It is difficult to estimate the economic value of these resources due to their intangible nature and the tendency of traditional economists to discount goods and services that cannot be monetized in a traditional market (Costanza *et al.* 1997). One method of valuating ecosystem services is to estimate their replacement costs; simply put, how much would it cost human society to replace those good and services or, if they are irreplaceable, how much wealth has been lost? (Balmford *et al.* 2002). Regardless of how difficult it is to measure precisely, there is overwhelming agreement that ecosystem services are extremely valuable to society at global and continental scales alike, although market mechanisms and human nature tend to discount or even disregard that value when individual decisions are made at the local scale (Andersen 1997). The growing concern over global climate change and biodiversity extinction has stimulated efforts to estimate the value of ecosystem services and to create mechanisms whereby communities that choose to conserve natural habitats are compensated by other communities that enjoy the benefits of those services (Turner *et al.* 2003).

THE VALUE OF BIODIVERSITY CONSERVATION

Biodiversity conservation is the most problematic ecosystem service to valuate, even though biodiversity has been the foundation for the world's economy since the origin of human civilization. All food staples are domesticated varieties of wild plants and animals, and most modern pharmaceuticals are also derived from natural products. Thus, one of the most compelling arguments for conserving biodiversity is the potential for new food sources (Heiser 1990), as well as new medicines and pesticides (Reid *et al.* 1993, Ortholand & Gane 2004). Even in today's global economy, species from natural ecosystems provide subsistence income to a large segment of the earth's human inhabitants; fish, wildlife, fruit, and fibers contribute enormous value to the world's economy (Gowdy 1997, Pimentel *et al.* 1997).

Unfortunately, it is difficult to harness markets that would pay for the potential benefit of biodiversity conservation (Pearce 1994). There are three principal constraints to levying fees for biodiversity conservation:

1) Users are incapable of paying for the goods and services because they have no economic resources and/or the goods and services are part of the "public commons" in which traditional use makes it difficult to collect fees.
2) It is impossible to place a value on an undiscovered benefit (i.e., a potential new crop or drug). Stated simply, we don't know who owns the resource, how much it might be worth, or who might be interested in acquiring that resource.
3) It is not plausible to extract fees for knowledge that was acquired in the past and is now in the public domain (i.e., the historical legacy of biodiversity). Past discoveries and domestications illustrate the value of biodiversity, but commercial users are unwilling to pay for something that has been available at no cost for centuries.

Constraint One: Lack of Financial Resources

Fish and wildlife resources illustrate the first constraint. Fishing is the most important and stable component of the Amazonian economy, providing employment and sustenance to an overwhelming majority of its residents, either directly by subsistence fishing or indirectly by commercial and sport fishing (Figure 4.1). The commercial fishing industry in the Brazilian Amazon produces at least $100 million in annual revenues while providing more than 200,000 direct jobs; these statistics do not include related sectors such as boat building, tourism, mechanical shops, and other services (Almeida *et al.* 2001, Ruffino 2001). There is much concern about the sustainability of current fishing practices, particularly on the main trunk of the Amazon River where human population is relatively dense (Goulding & Ferreira 1996, Ruffino 2001, Jesús & Kohler 2004). Remote regions with fewer human residents still have relatively robust fish populations (Chernoff *et al.* 2000, Silvano *et al.* 2000, Reinert & Winter 2002). IIRSA investments in hydrovias will probably lead to higher population densities along rivers and to an increase in overfishing if appropriate management procedures are not implemented. Unfortunately, most Amazonian fishermen are impoverished and would probably never be convinced to pay for the right to fish even though most of them have an innate understanding of the link between forest and wetland conservation. Over the long term, fish farming may offer a more sustainable—and lucrative—alternative to the commercial exploitation of native fisheries (see Text Box 4).

Figure 4.1. Fisherman with migratory Jau Catfish (*Zungaro zungaro*) which, like most Amazonian catfish, is vulnerable to watershed fragmentation from dams and reservoirs. Fishing is the most important economic activity in the Amazon that is wholly dependant on biodiversity. It provides financial opportunity to fishermen, as well as to boat builders, mechanics, and fishmongers (© Russell Mittermeier/CI).

Calculating the economic value for terrestrial wildlife populations is much more difficult. Large mammals are subject to overharvesting in areas with moderately dense human populations and are usually the first species to be exterminated in settlement zones, a process that will be exacerbated when IIRSA investments increase human populations along roads. This is a classic management issue. Only when a resource becomes severely limited will users agree to restrictions or pay for management to ensure the survival of the resource (i.e., hunting/fishing licenses). Studies that have assessed the economic value of mammal populations have primarily considered what it would cost to replace wildlife harvests if a management plan were to be implemented to reduce harvests (Bodmer *et al.* 1994). A few international donor agencies and private individuals are willing to subsidize the conservation of wildlife resources to promote their sustainable use as a food source and to protect biodiversity particularly within indigenous reserves (Noss & Cuellar 2001). However, this type of international assistance is typically limited to a few million dollars per year and would not generate the revenues necessary to counter the very strong economic forces driving the expansion of the agricultural frontier.

Constraint Two: Unknown Benefits

The second constraint that makes it difficult to monetize the value of biodiversity is that many of its benefits are still unknown to science and society. Such is the case with chemical compounds derived from natural products. Pharmaceuticals have been viewed as an important potential income source for biodiversity conservation (Reid *et al.* 1993, Rosenthal 1997); this expectation stems from the historical use of plants for many modern medicines

Text Box 4

Aquaculture: A Solution to Poverty

Aquaculture, also known as fish farming, is an economically viable option for the sustainable use of the Amazon's most abundant natural resource—water—and would provide multiple social benefits as well. The cultivation of native herbivorous fish such as the giant pacú or tambaquí is one of the most efficient ways to produce protein, yielding an average of 4,500 kg/ha per year in tropical regions under ideal conditions (Peralta & Teichert-Coddington 1989). In the past, aquaculture had to compete locally with commercial fishing of wild stocks, and nationally with efficient marine fisheries (Jesús & Kohler 2004). Also, development projects tended to stress self-sufficiency and encouraged peasant farmers to grow food for the fish, thus limiting fish production to the poor yields of shifting agriculture. However, IIRSA investments can change this failed paradigm by linking the high rainfall areas of the Andean piedmont with the soy and maize granaries of central Brazil and the port facilities of the Pacific coast or the main trunk of the Amazon in Brazil. The new transportation links could create a value-added production chain worth hundreds of millions of dollars in export income for Bolivia, Brazil, and Peru. Even more important, aquaculture can easily be undertaken on small family farms and is economically competitive with the cultivation of illicit drug crops. The global demand for fish will likely continue, and the ongoing degradation of marine fisheries makes aquaculture one of the most robust growth industries on the planet. Amazonian fish farming could become a truly sustainable economic activity that is compatible with conservation and provides the long-sought solution for rural poverty.

and the large revenues that some of these drugs have generated. Given this background, all Amazonian nations now impose strict controls on biodiversity research in an effort to guarantee the intellectual property rights of nations and individual peoples. The term "biopiracy" is routinely (and usually erroneously) applied to efforts by pharmaceutical companies to screen natural products for chemical or biological potential.

Legal, scientific, and economic factors, however, have brought about a dramatic reduction in the research and collection of natural products by pharmaceutical companies over the past 15 years (see Text Box 5). Most biodiversity-based pharmaceutical research is now restricted to countries with an Anglo-Saxon legal tradition, where protection of intellectual property rights favor the researcher, or where research is supported by government agencies and academic research institutions that renounce any claim to the discovery (Rosenthal 1997). In addition, major corporations outsource research to universities or rely on public domain information from government-supported entities (Ortholand & Gane 2004). As an example of industrial and academic priorities, a March 2004 issue of *Science* magazine dedicated to drug discovery made no mention of biodiversity-related pharmaceutical research.

Simultaneously, the advent of molecular biology and mass screening protocols (combinational chemistry) changed the way chemicals were developed. Some researchers have compared combinational chemistry to a shotgun approach, as opposed to a rifle approach: natural compounds have passed through millennia of natural selection and provide a direct ecological benefit (i.e., resource competition, protection from predation) to the organism that produced them. Thus, the chance that they will yield a compound with biological activity is much greater than the chance offered by thousands of compounds produced via random non-biological processes. Many academics now view combinational chemistry as a mistake, and a review of new pharmaceutical compounds revealed that between 60 percent and 70 percent are still derived from natural compounds (Newman *et al.* 2003).

Pharmaceutical researchers have since modified their research protocols; the current trend is to use natural product libraries combined with synthetic methods. However, the new methodology has not revitalized the collection of natural products in tropical forests. Research is more focused, and biodiversity assays concentrate on blank spots in the taxonomic database. Patent protection for natural products will not necessarily benefit conservation or indigenous groups, because new compounds will most likely be based on synthetic modifications of natural compounds (Figure 4.2).

Thus, even though the importance of natural products and the intrinsic value of biodiversity have been reaffirmed as an economic asset, the cost associated with research, drug development, and the mechanics of the marketplace make it unlikely that civil society will be able to require pharmaceutical companies to monetize that value in any meaningful way. Even if the countries of the Andes and Amazon were willing to open their forests for unlimited pharmaceutical prospecting, it is unlikely that the major pharmaceuticals would make any significant investments, and certainly not on the scale necessary to create an economic incentive to conserve the Amazon.

Figure 4.2. The tree datura [*Brugmansia arborea* (L.) Lagerh.] is used by Andean shamans for its curative and hallucinogenic properties; the active ingredients are tropamine alkaloids, mainly scopaline, which has multiple pharmaceutical uses, including pupil dilation and as a treatment for motion sickness. Like many pharmaceuticals, the intellectual property rights of these compounds are in the public domain because they come from centuries of prior use and knowledge (© Carmen Ulloa/Missouri Botanical Garden).

Text Box 5

The False Promise of Bioprospecting

Bioprospecting by the pharmaceutical industry has fallen off dramatically in recent years, in part due to new technology and in part due to the controls that developing countries have placed on natural product research. Access to biological resources in the Andes, for example, is regulated by a common strategy adopted by the Community of Andean Nations. These regulations are meant to foster pharmaceutical exploration by guaranteeing the intellectual property rights of member countries and indigenous communities. However, no Andean government has been willing to grant exploration rights since the early 1990s due to the political controversy such a permit would generate.

Simultaneously, advances in molecular biology and computer modeling have allowed pharmaceutical researchers to replace natural product screening with a method known as "combinational chemistry," which generates huge numbers of new synthetic compounds that are assessed by mass screening systems. Pharmaceutical companies still use extensive natural product libraries that have been compiled over decades, or even centuries, of scientific research, but they now do so in combination with the new synthetic methods. Thus, patent protection for these products will not benefit developing countries or indigenous groups, because new compounds will most likely be based on a synthetic modification of documented natural compounds.

Constraint Three: Historical Legacies

Agriculture and forestry illustrate the third constraint in monetizing the value of biodiversity conservation. Plants and animals make an indisputable economic contribution to the agricultural and timber industries, and academic research has provided ample evidence that biodiversity has great value as a genetic resource for crops and domestic animals.[59] But the crops that form the foundation of modern agricultural systems are an historical legacy. The high Andes are home to many wild relatives of domesticated plant and animal species, including potato, squash, and beans, as well as the New World camelids (llamas and alpacas). Today's technologically advanced farmers have no incentive to pay for the conservation of the biodiversity that they have been using for centuries. Agronomists and geneticists continue to conduct research on wild plant relatives, but this research depends on public subsidies, and discoveries are usually placed in the public domain.[60] Any attempt to garner economic support from the agronomic research sector would most likely stifle research—similar to the way efforts to gain support from the pharmaceutical industry restricted natural products research—and would constitute a net economic loss to the world's economy.

Ecotourism

An economic sector that clearly and unequivocally depends on biodiversity in the Amazon is ecotourism.[61] The revenues from ecotourism are difficult to estimate because most countries have multiple tourist options and do not separate out the portion related to the Amazon, or even ecotourism, but a conservative estimate would put this number near $100 million annually.[62] Tourism is particularly beneficial because it generates direct benefits at both the national and local levels, creating business opportunities for small and medium-sized enterprises that provide employment for both skilled and unskilled labor. There are several geographic centers of the tourist industry in the Amazon situated near or within protected areas.[63] However, due to its decentralized nature and small profit margins, the tourist sector is most likely not able (or willing) to pay for the ecological services that are necessary to conserve the Amazon. User fees for national parks are currently quite low and should be increased to provide more direct funding to the national park services. Similarly, some sort of local tax could be developed so that tourist revenues contribute to local government.[64] The most important contribution that tourism can make to conservation is job creation at the local level, which generates a vested interest to conserve the forest ecosystem (Figure 4.3).

The greatest negative impact from IIRSA investments is likely to be the loss of biodiversity. Unfortunately, biodiversity's real value will remain intangible, so assigning it economic value is not likely to convince economists and politicians—much less individual landholders acting in their own economic interest. Efforts to assign economic value on the basis of erroneous assump-

59 Few major food crops have their origin in the Amazon tropical forest, with the notable exception of manihot; the peanut and pineapple come from peripheral areas. Rubber is an important industrial commodity from the Amazon, and its tree resources have yet to be fully appreciated.

60 This is distinct from the multibillion dollar research industry related to modern cultivars that uses the existing gene pool to increase production and ward off pests; similarly, the use of molecular biology to create genetically modified organisms does not depend on bioprospecting.

61 Ecotourism is defined in a broad sense here, including all tourist activities that incorporate some sort of visit to a natural habitat as a major attraction.

62 Peru has an approximately $1 billion annual tourist industry that is dominated by Cuzco; about 47 percent of tourists also visit national parks. Venezuela's approximately $200 million industry is largely based on the Caribbean. Ecuador's $435 million tourist industry is dominated by the Galapagos, and about 1 percent of Brazil's $2 billion tourist revenues are generated from the Amazon. See the ecotourism statistical fact sheet at http://www.ecotourism.org.

63 These areas are Yasuní and Loja in Ecuador; hotels and villages situated on the Amazonian tributaries near Iquitos and Puerto Maldonado in Peru; adjacent to national parks in the villages of Rurrenebaque, Villa Tunari, and Buenavista in Bolivia; and to a lesser extent the city of Leticia in Colombia; as well as the thriving tourist sector in Manaus and the Pantanal in Brazil.

64 Current park entry fees in Bolivia are only $20 per tourist per visit; there are no local taxes, and most local enterprises avoid paying any of the national value-added sales tax (VAT). Similar situations occur in Peru and Ecuador, although it is more difficult for the larger, well-organized companies with links to international partners and with administrative offices in the urban centers to avoid paying at least some of the VAT.

tions or hopeful scenarios may raise expectations that cannot be met and diminish the validity of other, more convincing arguments that are presented on their own merits. It may be more convincing to frame the conservation of biodiversity as a moral obligation—to preserve a heritage bequeathed either by a deity or as the end result of millions of years of evolution. In this context, the two most accurate words that describe the value of biodiversity are "priceless" and "irreplaceable."

CARBON STOCKS AND CARBON CREDITS

The Amazon is a vast reservoir of carbon with approximately 76 gigatonnes (Gt) [65] stored in its above-ground biomass. If released into the atmosphere, these carbon emissions would equal approximately 20 years of fossil fuel consumption. At current valuation in international markets ($5–10 per tonne of CO_2), the Amazon's carbon store has a value between $1.5 and $3 trillion in potential carbon credits (see Appendix Table A.1).[66] This calculation is the most straightforward assessment of the ecosystem service value that the Amazon Wilderness Area provides through carbon storage. It is not a realistic calculation, however, because the Clean Development Mechanism (CDM) of the Kyoto Protocol to the United Nations Framework Convention of Climate Change (UNFCCC)[67] does not recognize the conservation of standing natural forest as a carbon offset. However, at the latest Conference of the Parties in Nairobi, Kenya (COP-12), signatories to the UNFCCC made a commitment to explore financial incentives and policy frameworks to reduce emissions from deforestation (RED) after 2013 or, in other words, to compensate countries for conserving natural forest ecosystems.

A variety of proposals are being discussed; most are predicated on reducing deforestation rates to levels below some historical benchmark, an option that has been endorsed by a coalition of

65 Gt = 10^9 t, which is equivalent to a Petagram (Pg) = 10^{15} grams (g); in plain English this would be 76 billion tonnes (the term tonne [1000 kg] is used to distinguish the metric unit from "ton" of the U.S. and Imperial systems). The value of 76 Gt is a conservative estimate; Saatchi *et al.* (2005) estimated the carbon reserves of the Amazon basin at 86 Gt, and Malhi *et al.* (2006) at 92 Gt. If carbon stocks from below-ground biomass and soils were included, this value would be 20–50 percent greater.

66 Carbon credits are units in a market-based mechanism for reducing greenhouse gas emissions. They allow companies (and countries) to trade emissions and emission reductions. Carbon credits are calculated in tonnes of CO_2 equivalents and can be traded in U.S. and European markets.

67 The Kyoto Protocol is an agreement adopted in 1997 as an amendment to the UNFCCC. See http://unfccc.int/essential_background/convention/items/2627.php.

Figure 4.3. Ecotourism has enjoyed steady growth over the last two decades, providing economic opportunities for both the private sector and traditional communities: (a) Chalalan Ecolodge in Madidi National Park, Bolivia, (b) Kapawi Ecolodge and Reserve on the Pastasa River in Ecuador, and (c) Laguna Canaima in Cainama National Park, Venezuela (© Stephan Edwards/CI).

tropical countries and environmental organizations.[68] The exact nature of this proposed benchmark—usually referred to as a reference period—is the subject of considerable debate because countries have different deforestation histories. For example, deforestation peaked in the 1970s and 1980s in Ecuador and Peru, while reaching maximum levels in the 1980s in Brazil. In Bolivia and Colombia, the annual rate has been increasing over the past decade, whereas Guayana and Suriname have historically low levels of deforestation and would not benefit from any compensation scheme based on a historical reference period. This important debate will ultimately determine the dimension of future revenues from deforestation avoidance, as well as the social feasibility of programs to reduce deforestation.

Brazil is supporting RED and has proposed a compensation fund for developing countries that commit to reducing deforestation below historical levels. The fund would be administered as official development assistance, and deforestation commitments would be voluntary. However, other countries and most conservation organizations support market-based mechanisms that would directly reward countries that materially reduce carbon emissions from deforestation and forest degradation (Figure 4.4).

The current deforestation rate in the Amazon is estimated at 28,240 km^2yr^{-1}, which translates into approximately 1.3 Gt of annual CO_2 emissions (Table 4.1). The economic value of carbon emissions can be calculated according to their replacement value in existing international markets. Approximately $13 billion would purchase an equivalent amount of industrial-based carbon credits; if that payment were repeated every year for 30 years, it would have a total value of $388 billion, which corrected for inflation and expressed in today's currency, would equal $134 billion (Table 4.1 and Appendix A.2). These figures provide an estimate of the value of the ecosystem services provided by the Amazon forest in the context of today's markets for CO_2 emission reductions. This estimate is based on the current value of carbon credits, and if a RED mechanism is approved by the UNFCCC, then a surge of forest-based carbon projects could conceivably drive down prices. However, it is more likely that countries will increase their commitments to reduce emissions so as to combat global warming and that the price of carbon credits will increase in value.[69]

Although a market-based mechanism for monetizing carbon credits from the avoidance of deforestation may soon materialize, Amazonian countries will not necessarily be willing to participate in that market. Given social and demographic constraints, any initiative to completely halt land-use change—no matter how lucrative—would not be acceptable to the residents of the Amazon. However, a stepwise reduction in the annual rate of deforestation might be socially and politically feasible. For example, the first 5 percent reduction in annual deforestation rates would generate a modest $647 million, but similar 5 percent annual reductions made over 30 years would rapidly increase the annual payment and eventually generate about $10 billion annually, for a total value of $195 billion or $41 billion in inflation adjusted currency (see Appendix, Table A.3).

Because the payments are spread over many years they could be framed as a "rent" for carbon storage rather than payment for a capital asset sequestered in the forest.[70] This would avoid de-

68 The Coalition of Rainforest Nations presently includes Bolivia, Central African Republic, Chile, Costa Rica, Democratic Republic of Congo, Dominican Republic, Fiji, Gabon, Guatemala, Nicaragua, Solomon Islands, Panama, Papua New Guinea, Republic of Congo, and Vanuatu.

69 Evidence for this potential increase is indicated by the recent interest of hedge funds in the future market of tradable carbon credits.

70 Rent is also covered by the proposals for a temporary crediting scheme as occurs under CDM A/R projects.

Figure 4.4. Carbon credits are increasingly being treated as a commodity, and proposals to certify reductions in emissions from deforestation (RED) may soon be approved for trading on international markets (©Corvis).

Table 4.1. Value of carbon stocks in the Amazon forest based on their replacement value in international markets for energy-based carbon credits

	Forest Cover 1990 (×1,000 ha)	Forest Cover 2000 (×1,000 ha)	Forest Cover 2005 (×1,000 ha)	Annual Rate of Deforestation (×1,000 ha yr^{-1})	Carbon Emissions @ 125 t/ha (×1,000 t)	CO_2 Emissions (×1,000 t)	Value of Emissions @ \$10/t CO_2 (\$ Million)
Bolivia[1]	48,355	46,862	46,070	240	30,001	110,105	1,101
Brazil[2]	364,922	348,129	336,873	2,250	281,250	1,032,188	10,322
Colombia[3]	59,282	57,839	57,117	144	18,044	66,221	662
Ecuador[3]	12,333	11,953	11,764	38	4,748	17,423	174
Peru[3]	72,511	71,727	71,335	78	9,800	35,966	360
Venezuela[3]	43,258	42,529	42,164	73	9,119	33,466	335
Guayana[4]	15,104	15,104	15,104	—	—	—	—
Suriname[4]	14,776	14,776	14,776	—	—	—	—
French Guiana	13,000	13,000	13,000	—	—	—	—
Total	643,540	621,919	608,202				
Annual Rates				2,824	352,961	1,295,369	
						Annual Total	12,954
						30-Year Total	388,611
						NPV[5] for 30-Year Total	134,325

1. Killeen *et al.* 2007b.
2. Derived from published reports of total forest cover for the Brazilian Amazon (Btito-Carreres *et al.* 2005, PRODES 2007).
3. Unpublished results of a deforestation study of the Andean countries recently completed by Conservation International (Harper *et al.* 2007).
4. FAO 2005.
5. NPV = Net present value, financial adjustment for inflation (10 percent).

bates over sovereignty, as well as hard-wire these agreements with an ongoing commitment to meet deforestation reduction targets to maintain payments.

The CDM requires a rigorous monitoring system to quantify the carbon that is sequestered via existing reforestation and afforestation mechanisms (CDM R/A). Similarly, whatever compensation scheme is adopted for deforestation avoidance will require comprehensive monitoring that is accepted by local communities, national governments, and international markets. One important issue that must be resolved is "leakage," a technical term used to refer to emissions that aren't really reduced or that are merely displaced from one region to another. Unfortunately, there is considerable empirical evidence that protected areas merely exclude deforestation from certain areas, while the overall national or regional rate of deforestation remains the same.

Two methods have been proposed to manage leakage. The most straightforward approach would be to certify compliance at the national level so that regional decreases and increases in deforestation automatically cancel each other out in a national bookkeeping system. National reductions would be real, easily verifiable, and could be commercialized in international markets without any difficulty. The second approach involves local-scale projects that attempt to stop deforestation in a circumscribed target area. Leakage is monitored by documenting deforestation in a larger buffer zone adjacent to the target area (also known as a reference case). Local-scale emission reductions can only be certified if the deforestation rate in the reference case is held constant or (even better) if it decreases.

This second methodology is currently being used in so-called voluntary projects where investors accept that their efforts are not yet certifiable under the strict guidelines of the Kyoto Protocol and the UNFCCC. Nonetheless, they pursue their investments because they are confident that they will lower deforestation rates and reduce carbon emissions, while simultaneously conserving biodiversity and promoting sustainable development.[71] Most analysts believe that local-scale projects must eventually be combined with a broader societal commitment to lower deforestation at the national level.

Local-scale deforestation avoidance initiatives will be particularly challenging to implement on the agricultural frontiers in the eastern and southern Amazon, where deforestation is occurring in highly fragmented landscapes via the incremental reduction of forest patches distributed among tens of thousands of individual land holders. In contrast, much of the western Amazon is wilderness. Current deforestation in the Andean Amazon is approximately 5,000 km^2 per year, and the complete cessation of deforestation would represent an annual payment of about \$2.3 billion in carbon credits. This would amount to \$68.8 billion if paid every year for 30 years, equivalent to \$23.3 billion dollars at its net present value (see Appendix, Table A.2).

The present, however, is not the future, and a baseline derived from historical deforestation rates might not provide sufficient economic compensation to effectively avoid deforestation. For instance, IIRSA highway investments will alter the dynamic of land use change on the Andean piedmont as agroindustrial enterprises and peasant farmers respond to the economic opportunities of inexpensive land and improved access to Pacific Rim markets. Annual deforestation rates under a business-as-usual scenario will increase and probably approach the rates of change now observed in Santa Cruz, Bolivia, and Acre, Brazil (see Figure

71 The Noel Kempff Climate Action Project in Bolivia is the most well known of these voluntary projects.

2.2). If a deforestation reduction agreement were implemented as part of a reformed IIRSA, carbon credits could be calculated by comparing the land use change in a RED scenario (5 percent annual reduction in deforestation rates) with the potential land use change in a business-as-usual scenario (2.5 percent annual increase in deforestation rates).[72] Annual payments from such an agreement would start at about $172 million but would eventually reach $4 billion in Year 30, and equal about $68 billion over the life of a 30-year agreement (see Appendix, Table A.4). Obviously, these projections are based on several large assumptions—most importantly the willingness of the region's landholders to forgo standard economic alternatives and participate in deforestation reduction initiatives.

Regardless of the models used for calculating carbon stocks or the potential value for reductions in carbon emissions in international markets, the Amazon has demonstrable economic value as a carbon reserve. Environmental studies commissioned for IIRSA projects have not addressed the potential impact of deforestation on global and national carbon emissions, or the potential economic benefits from a deforestation avoidance policy. A policy to reduce deforestation would provide economic resources that could be used to subsidize sustainable development. It could also provide cash payments directly to local government and communities to support key social services, and in so doing provide a powerful incentive for forest conservation.

For example, there are approximately 1,000 municipalities in the Amazon lowlands, and if the annual income from a stepwise reduction in emissions from deforestation (see Appendix A.3) were equally distributed among those municipalities to support social services, in the Year 2020, it would translate into approximately $6.5 million per year to each municipality. A more sophisticated distribution model would be needed to compensate municipalities based on the degree of threat and historical deforestation rates and to incorporate some degree of geographic equality, but the numbers are sufficiently large to be taken seriously by local and national elected officials.

WATER AND REGIONAL CLIMATE

It has become cliché to state that the most important natural resource is fresh water and that the world's largest reserve of fresh water is the Amazon basin. Assigning value to that resource, however, is difficult because the law of supply and demand fixes the value of any resource, and water supply in the Amazon surpasses demand by several orders of magnitude. It is not inconceivable that some day in the not too distant future, large tankers will load water at the mouth of the Amazon for transport to other parts of the globe. However, until this scenario becomes a reality, it will be difficult to convince traditional economists to valuate the water of the Amazon rivers as a commodity. Another approach is to demonstrate how the climate over the Amazon contributes to global climate stability and how deforestation will affect the climate of the Amazon and other regions of the planet.

There is broad consensus among climatologists that extensive deforestation will reduce precipitation and increase temperatures in the Amazon. These impacts will exacerbate changes caused by global warming and will be linked to climate change in other parts of the world (Avissar & Werth 2005, Feddema *et al.* 2005). The long-distance effects or "teleconnections" of Amazonian deforestation are modulated by a phenomenon known as the Hadley Circulation, in which warm air rises at the equator, moves toward the poles, descends at higher latitudes, and returns toward the equator along the surface of the earth. Recent models show that deforestation in the Amazon is linked to reduced precipitation in the lower Midwest of the United States during the spring and summer growing seasons (Avissar & Werth 2005).

In addition to these global processes, meteorologists have also documented a weather system that directly links the western Amazon with the Rio Plata basin (Figure 4.5), one of the most important agricultural regions on earth. In this system, a major gyre originates with the Atlantic trade winds and passes over the Amazon before curving southward as it nears the Andes to form the South American Low Level Jet (SALLJ) (Nogués-Paegle *et al.* 2002, Marengo *et al.* 2004a). The impact of the SALLJ is most noticeable during the austral summer when the region of maximum rainfall is displaced to the beginning of the South American monsoon (Nogués-Paegle *et al.* 2002) and migrates northwest–southeast across the Amazon basin (Hastenrath 1997) into the seasonally dry regions of subtropical South America. Together with convective processes, the SALLJ provides much of the annual precipitation in south-central and southern Brazil as well as northern Argentina and Paraguay (Berbery & Barros 2002, Marengo *et al.* 2004a).

A shift in the climate regime of the Amazon would affect this moisture transport system from the Amazon to La Plata and potentially reduce precipitation associated with the SALLJ. Because the La Plata basin is the mainstay of both the Argentine and Paraguayan economies and constitutes the largest component of the Brazilian agricultural sector with an estimated annual gross production of crops and livestock of $100 billion,[73] this shift would likely affect agricultural production. In addition, the region is heavily dependent on hydroelectric energy, so a reduction in precipitation would also affect urban economies (Berri *et al.* 2002). The potential effect on the high Andes would be even more pronounced because 100 percent of the precipitation in the Andes originates from the Amazon.

The amount of precipitation in the Rio Plata basin that originates in the Amazon has not yet been quantified, but even a 1 percent drop in agricultural production would reverberate through the national economies of the Southern Cone. Several GCMs show that if the Amazon suffers increasing drought, the Rio Plata will become wetter (Milly *et al.* 2005). This apparent contradiction has two possible explanations: the lost Amazonian water will be replaced by rains that originate over the South Atlantic (Berbery & Collini 2000), or global warming will cause

72 This is a very conservative estimate of the potential growth in deforestation. In Santa Cruz, the globalization of the agricultural frontier led to increases in the annual rate of deforestation of 15 percent per year between 2001 and 2005 (Killeen *et al.* 2007b).

73 This is a conservative estimated derived from several online sources for Argentina, Brazil, and Paraguay, including http://www.cideiber.com/infopaises/menupaises1.html, http://www.argentinaahora.com/extranjero/espaniol/bot_ppal/conozca_arg/produccion.asp, and http://www.ibge.gov.br/home/estatistica/economia/pamclo/2005/default.shtm.

an increase in SALLJ events, increasing precipitation over southern Brazil and northern Argentina via local convective systems (Marengo *et al.* 2004b).

Future research will eventually resolve the uncertainty of these global and regional climate models. In the meantime, the precautionary principle and the logic of risk management should be applied to public policy. The relationship between Amazonian deforestation, precipitation, and the region's economies has not been effectively communicated to the region's policymakers and the general public. Public support for IIRSA is largely based on the assumption that it will lead to greater economic growth, and questioning of IIRSA has largely revolved around its potential impact on the conservation of biodiversity. However, the potential economic impact caused by a reduction in ecosystem services should motivate policymakers to reevaluate the net benefits that will accrue from IIRSA investments in the Amazon.

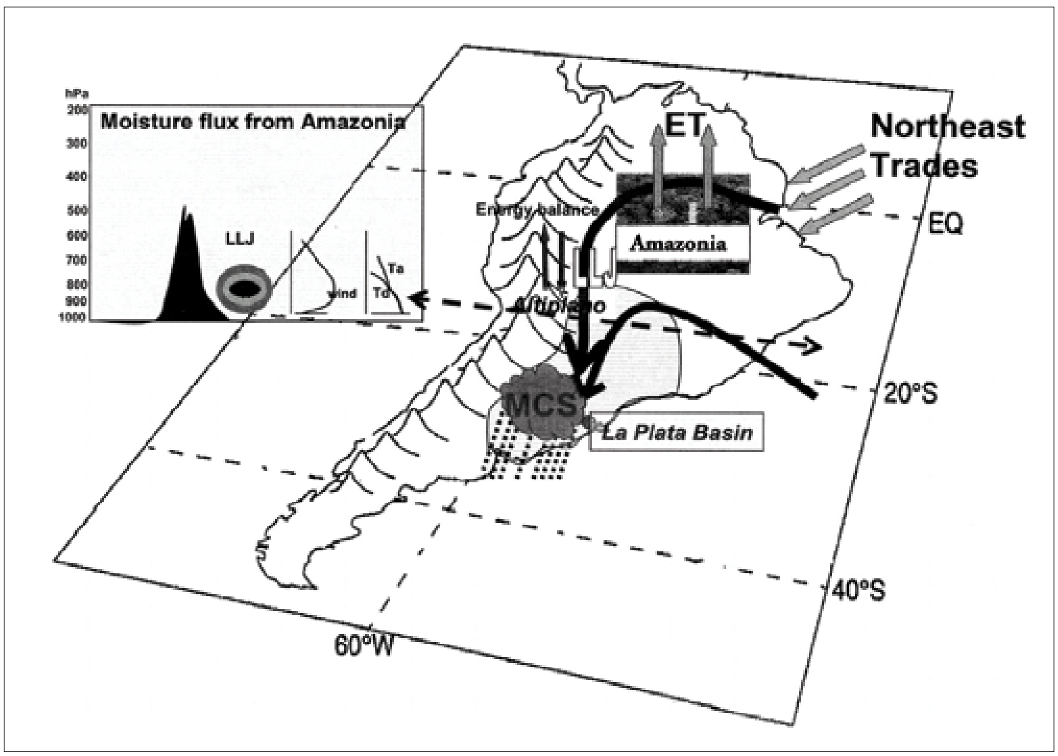

Figure 4.5. The South American Low-Level Jet (SALLJ) transports water from the central Amazon to the agricultural regions of the Rio Plata basin. Deforestation and climate change threaten this important ecosystem service; even a small reduction in precipitation would lead to an annual economic loss in the hundreds of millions of dollars (Modified from Marengo *et al.* 2004a; © American Meteorological Society).

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CHAPTER 5

Social Landscapes

Round village of Kayapo Indigenous People. The Amazon is home to hundreds of traditional communities, including the Kayapo, who successfully maintained their cultural traditions (©Russell A. Mittermeier/ CI).

People who live in the Amazon's rural areas are among the poorest inhabitants of the continent,[74] with some of the highest rates of illiteracy and worst health conditions in Latin America (IBGE, 2006). The region's poverty is partially the result of its geographic isolation. IIRSA investments in transportation infrastructure will greatly reduce this isolation and will undoubtedly promote economic growth and create new businesses opportunities and jobs—all of which will increase tax revenues and improve public services. Not surprisingly, most policymakers and the average citizen assume that the social impacts of IIRSA will be overwhelmingly positive. However, a more careful evaluation reveals that the distribution of these social effects will not benefit many of the region's current residents. Moreover, the relatively rapid introduction of economic and social change will generate a range of negative impacts in rural communities, including indigenous societies.

[74] We make this statement with a caveat: indicators based on income are not wholly indicative of well-being and must be interpreted carefully. Because most rural Amazonian economies have limited access to wage labor and rely on subsistence activities to provide life's necessities, lower incomes are to be expected.

The conservation value of Amazonia stems in large part from its relative lack of human intrusion (Mittermeier *et al.* 2003), a direct result of the dispersed rural settlement that characterizes the region. Most Amazonian communities are small and contain a few hundred people. Even among the population centers with more than 1,000 individuals, the vast majority (78 percent) have fewer than 30,000 inhabitants, indicating that most villages and towns are modest in size. Despite its sparse population, Amazonia is culturally diverse with more than 281 different indigenous, nonmigrant languages; of this total, 213 are unique to the region (Figure 5.1). In addition, numerous distinct immigrant groups have settled in the area in the centuries since Francisco de Orellano first sailed down the Amazon from the Andes in 1542. Many of these nonindigenous and mestizo communities have unique social customs that have evolved over time and depend on the exploitation of the natural resources of the region. Consequently, the social landscape of the Amazon is characterized by sparse human habitation that is distributed among small settlements but contains considerable cultural diversity, reflecting the persistence of traditional indigenous and nonindigenous cultures.

MIGRATION, LAND TENURE, AND ECONOMIC OPPORTUNITY

IIRSA and PPA investments in highway corridors will stimulate the migration of hundreds of thousands, if not millions, of people into the region. This mass migration will include impoverished peasants looking for a small plot of land, middle class farmers, and affluent cattle ranchers, as well as corporations seeking large tracts of inexpensive land or rich mineral deposits.[75] However, in addition to this land rush, there will be parallel growth of regional urban centers as part of an evolving settlement hierarchy (Haggett *et al.* 1977, Ellis & Allard 1988); this will create opportunities for commerce that will be exploited primarily by urban migrants from other parts of the continent.[76]

Many of the Amazon's rural inhabitants will experience substantial adverse impacts from this migratory onslaught. One of the most obvious will be increased competition for land and other resources. Most of the traditional communities have never experienced such competition. With a rural population density of only 1.1 persons per square kilometer (Mittermeier *et al.* 2003), Amazonia provides its residents with access to large tracts of forest and aquatic habitats for food, fiber, timber, and other resources as part of a subsistence lifestyle that is fundamental to their cultures (Steward 1948). This access is defined by cultural mores that have developed because of sparse human settlement and low levels of demand: many have land parcels, but they rarely have legal title and rely instead on the principle of physical occupation and land tenure based on culturally defined patterns of inheritance that may extend over several decades of prior fam-

75 The precedents for this type of migratory phenomena are historically abundant and include most of the settling of the U.S. Midwest. Some of Oklahoma's "Sooner" settlers, for example, ignored the regulatory framework by arriving before the official date of land distribution.

76 Two famous historical precedents are the California gold rush, where merchants who sold supplies to gold miners went on to form businesses that eventually evolved into the famous Levi Straus, the Central Pacific Railroad, and Armour Meat Packers (http://www.baltimoreopera.com/studyguide/fanciulla_04.asp). Many of the first commercial enterprises in the Amazon were founded by Lebanese migrants whose descendents are still residents of the region, or who occupy prominent positions in the São Paulo business and professional community (http://www.la.utexas.edu/research/paisano/EECtext.html).

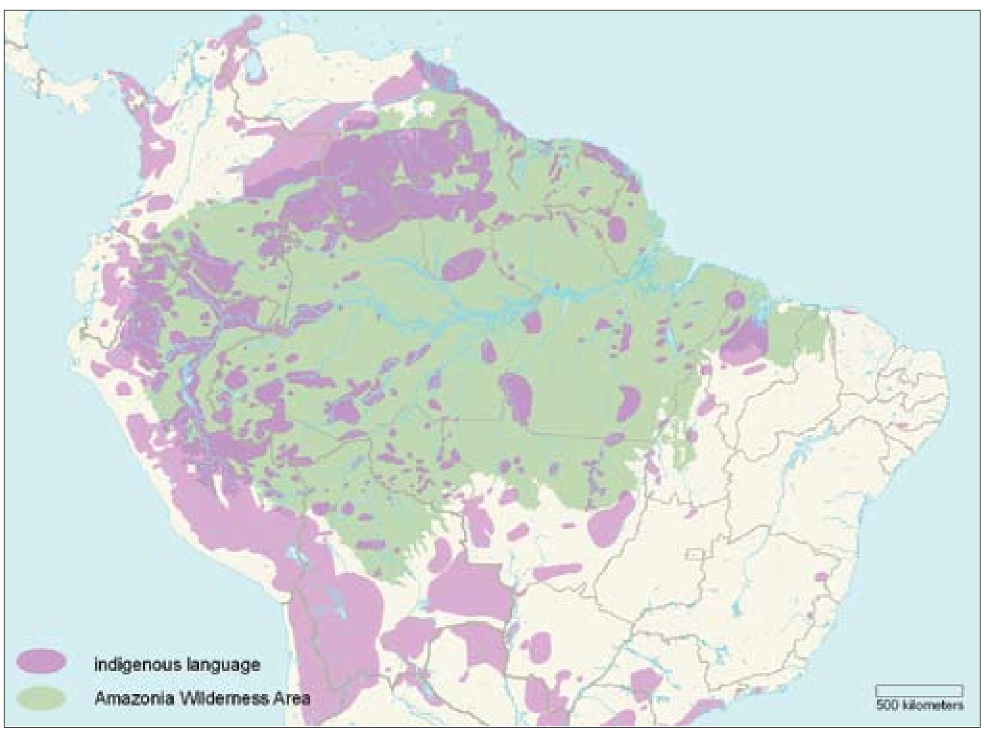

Figure 5.1. The Amazon is one of the last redoubts of indigenous cultures, with 231 extant languages scattered across the basin, particularly in the more remote wilderness areas of the western Amazon and Guayana Shield (language data from Global Mapping International 2006, www.gmi.org/wims).

ily use. The migration of new residents, both rich and poor, will increase competition and restrict access of traditional groups to both forest and aquatic resources, interfering with long-established patterns of resource use and land tenure (Figure 5.2).

Less obvious but not less serious are the impacts that rural peoples will suffer due to the rapidity of change in their previously isolated communities. Change to cultures is inherent, and all cultures react and adapt. However, rapid, large-scale change often exceeds the capacity of some traditional cultures to adapt successfully. One example of the adverse effects associated with rapid modernization and the opening of a previously isolated wilderness is Alaska during the final decades of the twentieth century. Although the region had experienced development of sorts over many decades, it remained relatively isolated due to a lack of infrastructure and a harsh climate that impeded settlement. However, the construction of a 1,350-kilometer-long oil pipeline to connect production fields on the North Slope with shipping facilities at Prince William Sound introduced change at a scale new to the region. Large numbers of migrant workers arrived at the same time that the new roads penetrated previously inaccessible areas. Such development generated many benefits for Alaska, but it also introduced a variety of negative impacts for rural peoples, including the indigenous groups who were the primary inhabitants of the region (Berry 1975). Among the most alarming were high rates of alcoholism and substance abuse that led to high rates of suicide, all of which can be linked to rapid culture change (Kraus & Buffler 1979, Kettl & Bixler 1991). Although the Amazon is very different from Alaska, the similarities of the situation (wilderness areas and the predominance of isolated traditional communities) and the emergence of similar impacts as a result of rapid culture change (Hezel 1987, 2001) are more than sufficient to warrant that these negative impacts be given serious analysis.

One source of cultural stress will be the introduction of new ideas and values that will compete with traditional ways of life. For example, individuals who are successful in dealing with migrants may have more status than traditional leaders, a phenomenon that has been observed under similar conditions elsewhere, and one that introduces stress and conflict within indigenous communities. Most residents will not be competitive in an increasingly sophisticated urban job market. Although they have traditional knowledge that serves them well in their forest and riverside communities, rural schools with limited budgets and antiquated curriculums have not provided them with the skills required by a modern economy.

Local elites will fare better than the general population and may even benefit from the land rush because they occupy administrative positions in regional and local government. They can use their political influence to obtain title over land and then sell it to newcomers. On the Andean piedmont, leaders of peasant unions (sindicatos) obtain titles to large sections of land, divide it into smaller properties, and sell plots to settlers, who are usually a mixture of new arrivals and second-generation migrants expanding family assets, as well as to long-time residents and even indigenous families who realize that the world is changing and that formal title to a small plot is a better bet than traditional use rights to a rapidly shrinking resource. The frontier landscape is often distributed as larger properties as well. These are sold directly to ranchers and agroindustrial enterprises or are subdivided into medium-sized farms and ranches. Many medium- to large-sized properties are owned by urban elites who are putting their savings into what is perceived to be a safe investment.

State land is literally up for grabs, and even protected areas and forest reserves are subject to invasion because the state has not effectively exercised its authority. In almost all instances, migrants and locals are fully aware that their land deeds have a

Figure 5.2. Many of the Amazon's rural communities are composed of indigenous groups or descendents of migrants who came to the Amazon during rubber or gold booms; most families lack basic services such as water and most depend on forest resources for food and fuel (© Hermes Justiniano/ Bolivianature.com).

questionable legal history but expect government to cede title to avoid social conflict. Most feel completely justified, viewing themselves as citizens with a right to occupy empty lands either because they have been denied economic opportunities (*sem terras*) or because their investment will create jobs and wealth for the country (urban investors and cattlemen). Private property is not exempt from invasion and settlement—especially because many of the original land deeds were acquired via fraudulent means.

The lack of a functional regulatory land tenure system in much of the region and the inability of the judicial system to punish noncompliance are important factors in the land use dynamic (Fearnside 2001b). The failure of the system is manifest not only in the chaotic settlement process, but also in the levels of violent conflict that characterize many parts of the Amazon. The murder of Sister Dorothy Stang is the most recent prominent manifestation of this conflict over land. Sister Stang was an advocate of small land holders and forest dwellers and was working to create a forest reserve opposed by loggers and cattle ranchers, in Pará, Brazil.[77] IIRSA will contribute to this social conflict by opening up more land and increasing land values in the areas surrounding the new transportation corridors. To mitigate this situation effectively, the issue of land tenure and the corruption that accompanies most aspects of the land titling process must be addressed.

77 According to the Pastoral Land Commission, about 1,380 people have been killed in land conflicts in Brazil since the mid-1980s (http://www.washington-post.com/wp-dyn/articles/A40503-2005Feb20.html).

INDIGENOUS GROUPS AND EXTRACTIVE RESERVES

Fortunately, many indigenous groups have responded to the changing social dynamic in the greater Amazon and have organized their communities to file claim to large tracts of land (Figure 5.3). Their success speaks to the resilience of their internal social organization and the timely assistance they have received from civil society and international organizations. Indigenous communities are vocal advocates of sustainable development and forest conservation; these affirmations are amply supported by satellite images, which show dramatic differences in land use between indigenous reserves and adjacent nonindigenous areas, with the indigenous lands remaining relatively intact next to large-scale deforestation (Figure 5.4) (Schwartzman *et al.* 2000, Ruiz-Pérez *et al.* 2005). The success of indigenous reserves in halting deforestation highlights the importance of land tenure. Although their proactive efforts to protect their land are certainly a factor in avoiding deforestation within their land holdings, equally important is the knowledge that squatters will not be able to acquire title to that land. Farmers and ranchers do not randomly invade and occupy lands; they do so only when there is a high probability that their actions will eventually allow them to obtain title and that their investments in infrastructure and land clearing will not be lost, either to the true landowner or by the inability to sell the land and recoup their investments.

The conflict between cattle ranchers and forest dwellers, including indigenous groups and immigrant populations descended from rubber tappers, gave birth to the environmental and social movement led by Chico Mendes, the peasant activist who was murdered in 1988 for challenging individuals engaged in land speculation (Hecht & Cockburn 1989, Cowell 1990). Since then,

Figure 5.3. During the 1990s, large tracts of land were ceded to traditional communities in recognition of their historical claims to forest and aquatic resources; most of these lands are zoned for forest management and are an important complement to the protected area system throughout the Amazon.

fifty-eight extractive reserves have been created in the Brazilian Amazon, and similar reserves exist in Bolivia and Peru; most are quasi-protected areas where the exploitation of rubber and Brazil nuts is encouraged, but logging and agriculture are theoretically restricted. Extractive reserves have many enthusiastic proponents who seek to reconcile conservation with demands for social justice and have received significant investments from Brazilian institutions and from the World Bank.[78] Political activism by forest dwellers in Acre has brought about policies to subsidize rubber production; it has also created cooperatives and local processing facilities that improve the quality and add value to rubber and Brazil nut production (Campos *et al.* 2005, Ruiz-Pérez *et al.* 2005).

However, economists continue to question whether extractive reserves can fulfill their development objectives (Bennett 2002, Goeschl & Igliori 2004). Their success as a conservation option and economic management system ultimately depends on the ability of residents to generate higher incomes by diversifying forest products. Unfortunately, this has not yet happened, and forest inhabitants are opting for increased agricultural production and timber extraction (Ruiz-Pérez *et al.* 2005).[79] Extractive reserves will require additional economic inputs to make them viable; the only realistic source of these funds would be direct payment for ecosystem services to compensate inhabitants for forest conservation (Hall 2004, Fearnside 2005b). Similarly, the long-term conservation of indigenous lands must ultimately be based on economic incentives, or many of these groups will be tempted to exploit their timber resources nonsustainably over the medium term to improve their standard of living (Fearnside 2005b).

78 The Brazilian Environment Ministry and the World Bank have invested $17 million in four extractive reserves in Brazil since the mid-1980s (World Bank 2006).

79 In Bolivia, there is an ongoing land tenure conflict between Brazil nut concessionaires who have long dominated the region with large land concessions, and peasant settlers, many of whom are former employees of the concessionaires who have established communities and land claims adjacent to concessionaire properties. Settlers establish their land claims under Bolivian law by clearing and farming lands. A recent study of peasant perceptions of land value established that agricultural use was considered the first priority and that the forest was viewed as a secondary resource to be exploited for Brazil nut and timber.

MIGRATION AND HUMAN HEALTH

Land use change can also have serious effects on the health of human communities, both long-time forest residents and recent arrivals. The history of diseases introduced to indigenous populations is as old as the first journey down the Amazon River by Francisco Orellana. Since then, the settlement of the Amazon has been characterized by periodic booms that inevitably lead to catastrophic epidemics in isolated populations with little resistance to cosmopolitan diseases such as measles, mumps, and chicken pox (Mann 2005). The most recent well-publicized example of this unfortunate phenomenon is the Yanomami indigenous group of Roraima, Brazil and southern Venezuela, who experienced outbreaks of diseases after contact with *garimpeiro* miners, missionaries, and possibly even anthropologists (Neel 1974, Sousa *et al.* 1997, Tierney 2000). Even today, there are documented cases of indigenous groups living in voluntary isolation in southwestern Peru where construction of the Inter Oceanic Highway, an IIRSA-sponsored investment, will soon begin. Increased logging activity in the Alto Purus region has apparently caused some of these communities to migrate into Manu National Park (pers. comm. N. Pitman 2005).

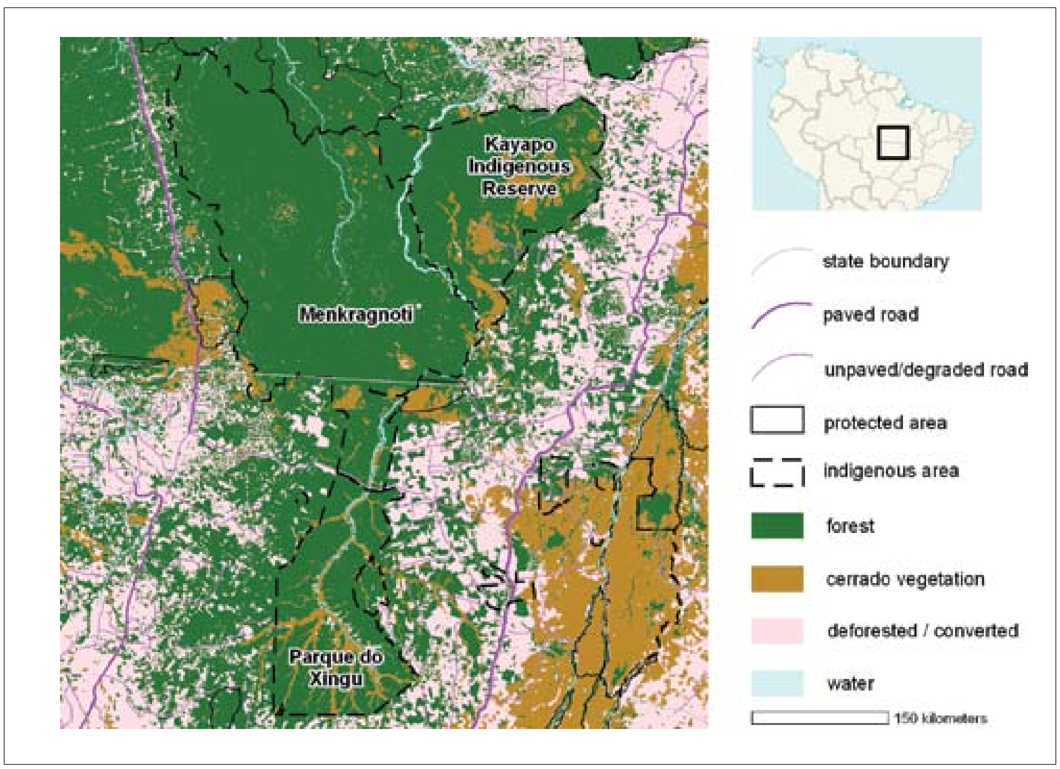

Figure 5.4. Land tenure is an important driver of deforestation, as shown by this map of the Kayapo Indigenous Reserve in Mato Grosso, Brazil. Deforestation occurs up to the boundaries of the reserve, which remains largely intact. The efforts of the Kayapo to protect their land are assisted by the certain knowledge that squatters will never be able to acquire title to it.

The health of migrant settlers also suffers from tropical diseases that have traditionally been associated with forest ecosystems. Recent studies in Iquitos, Peru, show that malaria transmission is greatest in deforested areas because the malarial vector, a specific mosquito species, is more abundant in the grassy habitats and stagnant pools characteristic of recently deforested landscapes (Vittor *et al.* 2006). Even those diseases believed to be highly dependent on forest mammals as alternative hosts, such as the leischmaniasis parasite, which has been shown to increase in colonized areas because the parasite's vector organism, the sand fly (Figure 5.5), has successfully managed to infect both dogs and humans (Campbell-Lendrum *et al.* 2001). The impact of deforestation on human health is not limited to forest dwellers or small farmers living in primitive conditions on the edge of the forest. The increasing incidence and severity of forest fires is also causing increased respiratory illnesses in both rural and urban settlements across the continent.

One of the most serious threats to human health in local populations will be the introduction of the human immunodeficiency virus (HIV). Research over the past two decades has shown that in-migration is almost always accompanied by the introduction or increased incidence of HIV infections (Colvin *et al.* 1995). The regional integration and improved transportation systems that are at the heart of IIRSA will almost certainly increase the incidence of HIV in remote corners of the Amazon, following a pattern that has been amply documented in other parts of the world (UNAIDS 2006). The introduction of HIV will coincide with an increase in prostitution that is all too common in the frontier areas of the Amazon. Outbreaks of HIV will outpace the capacity of local health systems to manage the spread of the virus and the consequences of a subsequent AIDS epidemic. In a manner not unlike the initial exposure of once-isolated people to the common childhood diseases of the Old World, HIV in the first decades of the twenty-first century could devastate local traditional populations, a dreadful and needless repetition of history.

Environmental changes are intimately connected to social impacts, and many of the social impacts associated with IIRSA investments will have a distinctly local character and will be difficult to predict. What may appear as a largely positive social impact may have negative consequences for certain sectors of the population. Similarly, a project that may benefit a nation or group of nations may not benefit local populations. The new methodologies for environmental evaluation incorporate an extensive participatory process that is increasingly enforced by lending agencies and national governments. The purpose of this process is to identify the concerns, needs, and aspirations of the local population before the onset of migration. These evaluation methodologies are discussed in the next chapter in the context of past development and the failure of governments and multilateral agencies to manage economic growth on the Amazonian frontier.

THE MANAUS FREE TRADE ZONE

Manaus presents a stark contrast to other cities of the western Amazon. The prosperity in Manaus stems largely from the creation of a free trade zone and policies to promote economic growth. Manaus has experienced steady economic growth over four decades and created the only economy in the Amazon that is not dependent on natural resource extraction. Tax incentives and the avoidance of import tariffs have been the most important motivation for both foreign and national companies to establish assembly plants (Fabey 1997). Initial investments were largely in the electronics industry, motorcycles, and chemicals, but now also include biotechnology. Economic growth has spurred the creation of other businesses that provide the growing population with a broad range of goods and services typical of any modern economy. Tourism is an important component in the Manaus economy and is considered to have almost unlimited growth potential.

Figure 5.5. Previously rare diseases are spreading as human population increases in colonized areas, and pathogens adapt to changing environments. This sand fly (*Lutzomyia* sp.) is the vector for the leshmaniasis parasite, now a common disease in colonized regions of Bolivia (© Peter Nasrecki/CI).

The Brazilian state is now seeking to diversify the Manaus economy by creating a value-added manufacturing sector based on the renewable natural resources of the Amazon, a strategy that will rely on the region's fisheries, timber, and nontimber forest products. The free trade zone will be expanded to 153 urban areas cities in the Brazilian Amazon, and the Getúlio Vargas Foundation will search for economically viable and environmentally sustainable business opportunities.[80]

Commerce plays a large role in the local economy and is a strategic component of the free trade zone. Manaus relies on three separate but linked transportation models. Air cargo services provide rapid and efficient connections for high-value products and supplies. River transport links Manaus with overseas ports, as well as being the conduit for the sale of manufactured goods to the rest of Brazil. IIRSA investments in highways will provide the third leg of this transportation model, particularly the ability of manufactured goods from Manaus to compete in the Andean market.

Within Manaus growth has led to a variety of environmental problems common to urban areas; however, the central Amazon has avoided the widespread regional deforestation that accompanies resource-based economic growth. The low deforestation rate is partly due to the limitations of the region's extremely infertile soils, but the Manaus experience demonstrates that a modern economy based on the manufacture of goods and services can provide economic opportunity to the inhabitants of the Amazon.

80 The resources for this program have been budgeted at $183 million. The largest part ($58.85 million or 32 percent of the total) is dedicated to Amazonas state. See http://www.suframa.gov.br/modelozfm_desregional_id.cfm.

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CHAPTER 6

Environmental and Social Evaluation and Mitigation

The Ciuiabá gas pipeline in eastern Bolivia is seen by many as a threat to the conservation of this pristine forest region (© Hermes Justiniano/ Bolivianature.com).

Multilateral development banks have been harshly criticized for failing to identify and mitigate the environmental and social impacts associated with the projects they finance. Beginning in the 1980s, the World Bank promoted guidelines for its investments that included environmental impact analyses (EIAs) and environmental management plans (World Bank 1991, 2003a). However, this approach has shown serious shortcomings. Traditional EIAs tend to focus on direct impacts in the implementation phase of projects, failing to identify secondary impacts from economic, social, or environmental phenomena associated with the infrastructure investments. Similarly, most EIAs did not consider cumulative impacts or the synergistic impacts of a project when aggregated with other projects. The consequences of any individual project might not be noteworthy, but the secondary, synergistic, and cumulative impacts that emerge amid a combination of projects and market phenomena may cause repercussions far beyond the project's direct impacts (Fogelman 1990). Finally, traditional EIAs have not been able to influence investment decisions made by the development banks because they have been conducted after financial and planning processes have already been set in motion. Viewed cynically, their intent was to meet a regulatory requirement or to manage a specific environmental problem, not to influence the design of a project or the decision to proceed with an investment. The public consultative processes of traditional EIAs were indicative of this inherent flaw: they were conducted after the study was completed to inform civil society, rather than to involve society in decisions about whether to proceed, modify, or reject the planned investment.

STRATEGIC ENVIRONMENTAL ASSESSMENT

Because of the deficiencies inherent in the traditional EIA, a new evaluation process has been developed to incorporate broader geographic and thematic criteria (Partidário & Clark 2000, Espinoza & Richards 2002). Dubbed Strategic Environmental Assessment (SEA), this approach intends to integrate environmental considerations into decision-making (Partádario 1999). It is meant to evaluate policies, plans, and programs—an expanded focus that encompasses many of the large-scale, complex projects that arose during the 1980s and 1990s, and that characterize IIRSA's current portfolio.

As with an EIA, "environment" in SEA refers to both the natural and the human, or social, environment. One goal of SEAs is to identify accurately the full range of a potential project's direct, indirect, and cumulative impacts on the natural and human environment, so that effective mitigation can be designed and implemented, and to ensure that civil society participates proactively in both the investigation and recommendation phases of the study. Recommendations are organized in an environmental action plan that provides a framework for mitigating negative impacts, enhancing positive impacts, and designing development initiatives that will meet the specific environmental goals identified in the SEA. With these broader assessments and the engagement of society early in the planning and implementation phases to ensure a democratic process, the SEA can foster sustainable development environmentally, socially, and economically. Table 2 lists the main components of an SEA.

The IDB has been a leader in developing the SEA methodology. It financed the first SEA in Bolivia in 1999 preliminary to the construction of the Corridor Puerto Suárez–Santa Cruz (part of the IIRSA Central Inter Oceanic Hub)[81] and later for a northern transportation corridor intended to connect La Paz with Riberalta and Cobija. In Peru, CAF has assumed the responsibility of organizing the SEAs and their environmental action plans.[82] CAF has also made a commitment to incorporate environmental evaluation as an integral part of the planning process at the design phase and has financed the creation of an environmental planning tool that includes multiple databases of environmental and social information for the Andean region.[83]

The IDB also played an important role in coordinating the environmental evaluation and management plans for the *Camisea* pipeline, and although it provided relatively little of the total financing, this leadership effectively reduced the political and environmental risk, making the investment more attractive to private banks.[84]

81 The original recommendation estimated around $60 million for the Environmental Action Plan, representing approximately 20 percent of the total cost of the highway construction; the plan was eventually financed by the IDB with a budget of $21 million. Implementation experienced a 3-year delay as the IDB and government agencies negotiated over the management of the program. See http://www.snc.gov.bo/obras/corredores/index.html.

82 Recently, CAF ($10 million) and the Peruvian government ($7million) committed to implementing an environmental action plan for the southern corridor, which included about $1 million for a strategic environmental assessment.

83 CONDOR was developed by Conservation International (http://www.caf.com/view/index.asp?pageMs=14890&ms=11).

84 In contrast to CAF and IDB, FONPLATA provides no information on its portal regarding environmental policy.

Despite the positive developments in designing and conducting comprehensive impact assessments, these approaches do not appear to have been applied to IIRSA, nor to many of the projects contemplated in the Brazilian PPA. Essentially, the member governments presented a list of priority projects that were subsequently put on the fast track for future funding. Although IIRSA's Web site states that environmental themes were incorporated in a feasibility analysis during its preparatory stages in 2003 and 2004, the results of this analysis have not been presented to the public. According to the Bank Information Center, a watchdog group that monitors multilateral funding agencies, IIRSA's participating institutions have not indicated how they intend to harmonize their environmental standards (BICECA 2006b). Unfortunately, it appears that CAF and the IDB have not taken full advantage of the resources within their own institutions; for example, a cursory examination of the maps presented on the IIRSA Web site reveals that important protected areas are not shown within their database, including Madidi, Tambopata, and Cordillera Azul. Errors in the public presentation of their projects raise serious questions as to the adequacy of the environmental review process.

In a recent article, Robert Goodland, former director of the World Bank's environmental unit, commented on the deficiencies in the environmental policies of multilateral lending agencies. Among his many recommendations, three are particularly important for IIRSA. First, Goodland identifies the need to expand the scope of environmental analysis so that all loans are evaluated in the context of environmental and social impacts, including structural adjustment loans and short-term loans to manage balance of payment and macroeconomic aspects of national economies.[85] Second, Goodland recommends that all loans be evaluated in the context of global climate change, examining the risk climate change represents to the investment as well as the risk the investment represents to the global climate. Finally, Dr. Goodland suggests that strategic environmental and social evaluation be incorporated as a core element in developing the country assistance strategy, the planning document that establishes the framework for the entire lending portfolio for each multilateral institution (Goodland 2005).

Pressure from civil society will motivate governments and financial agencies to conduct fairly complete environmental and social evaluations for each of the IIRSA transportation corridors, and these will produce management plans that will attempt to limit the direct and indirect environmental impacts. However, a piecemeal approach to environmental evaluation and the formulation of separate management plans will not significantly alter the eventual outcome of global warming, widespread deforestation, and forest degradation. The issue is specifically that of cumulative and synergistic impacts. Taken individually, projects may not seem likely to generate significant adverse impacts and are unfortunately implemented with little real concern for

85 Recently, the International Monetary Fund (IMF) required that Ecuador proceed on construction of the OCP pipeline to assure long-term economic growth; the OCP will impact Amazonian tropical forest, but the IMF does not engage in environmental evaluation for its loans for macroeconomic measures (pers. comm., Rosanna Andia, Bank Information Center).

Table 2. Contents of a Strategic Environmental Assessment

Description of policies and programs	A narrative identifying the activities of the policy or program to be implemented, and the environmental impacts that will occur if implemented
Rationale for choosing policies and programs	Identifies activities that could affect the environment
Objectives	Clearly states the objectives of the policy or program, indicating beneficiary groups and geographic target areas
Scope	The geographic scale of the evaluation should be the same or larger than the scope of the policy or program under consideration
Alternatives	Identifies why a given policy or program has been selected
General baseline	Quantitatively and qualitatively describes the area before the implementation of the policy or program
Identification of impacts	Identifies significant positive and negative environmental and social impacts in the context of the previous environmental situation and predicts direct, indirect, and cumulative impacts
Environmental impact assessment	Assesses the positive and negative impacts that the policy or programs will incur, taking into account the country's regulatory framework. Justifies and appraises the policy or program using models and simulations. Identifies environmental conditions, considering worst-case scenarios.
Definition of environmental goals	Defines the environmental goals of the policy or program and identifies an environmental action plan detailing the measures necessary to meet those goals
Environmental action plan for goal achievement	A plan to facilitate compliance with the proposed environmental goals, particularly to mitigate negative impacts and enhance positive impacts. It should assure citizen participation throughout the process and monitor proposed action plans.

Modified from Espinoza & Richards (2002)

avoiding or mitigating negative consequences. When taken as aggregate, however, as discussed in Chapter 2, the various development projects under IIRSA will have major synergistic impacts that can and should be identified and addressed.

According to the guidelines outlined by the IDB, environmental analysis should be conducted at the scale appropriate for the policies, plans, and programs being implemented (Espinoza & Richards 2002). Because IIRSA is a continental-scale initiative, analysis should be conducted at the continental scale to identify cumulative impacts. That evaluation should likewise focus on the synergistic effects of all IIRSA projects in the context of other regional and global development phenomena. Recommendations must also be international in perspective and should incorporate solutions that respond directly to the human behaviors driving ecosystem degradation in the Amazon.

SUSTAINABLE DEVELOPMENT PLANS

One of the most important components of an SEA is the environmental action plan, an instrument that puts forth steps to avoid, mitigate, or compensate for the primary and secondary impacts identified in the evaluation. More importantly, however, this plan is supposed to operate as a sustainable development road map to achieve the goals that the SEA has defined. Environmental action plans are executed by local governments, usually with the financial assistance of the multilateral agency involved in the project.[86] The primary objective of an action plan is to create a legal framework and provide incentives for sustainable development in the region that will be affected by the project. For example, integrated farming systems are promoted in areas identified as suitable for permanent agriculture and agroforestry, whereas sustainable forest management, which includes both timber and nontimber forest products, is promoted on landscapes identified as appropriate for those activities. Key to both sets of recommendations is an agro-ecological zoning study to delimit appropriate land use.

An environmental action plan is intended to mitigate social liabilities in frontier areas by making priority investments in social infrastructure and services while producers are given financial credit to make the recommended investments. Efforts to resolve land tenure conflict and protect indigenous rights figure prominently, as do programs to consolidate protected area systems. The most recent example of an environmental action plan is the Sustainable Development Plan for BR-163, the highway that

86 Examples include the environmental action plan for the Corridor Puerto Suarez–Santa Cruz and The Sustainable Development Plan for BR-163.

Text Box 6

Deforestation: It's the Economy

Perhaps the most important lesson learned from the PLANAFLORO project in Rondônia in the 1990s is the recognition that community-based efforts are not enough to achieve sustainable development. Deforestation is almost entirely caused by the actions of individual land-holders, both family and corporate, pursuing economically advantageous production models. This conclusion is succinctly summarized in the "Lessons Learned" chapter of the PLANAFLORO evaluation (World Bank 2003b):

> The objective of the project was to change behavior of private and public agents in the use of the natural resources of tropical rain forests. The project concept did not recognize the strong existing economic and political forces that were (and still are) working in favor of continued expansion of forest clearing—the "political economy" of the frontier states . . . They [the project initiatives] accommodated one part of society ("organized civil society") but not private sector interests, on the basis of a vague strategy of community-driven development, largely without any solid and proven natural resource management technologies that would have reverted the mainstream use (clearing) of rain forests.

connects Cuiabá with Santarém in the Brazilian Amazon. Regardless of the good intentions of governments and financial agencies to identify and mitigate both primary and secondary impacts of infrastructure investments, recent history shows how difficult it is to manage development in the Amazon. In the 1980s and 1990s, the Brazilian government attempted to manage the settlement process via two ambitious projects in the State of Rondônia. The first, known as the PoloNordeste Project, was financed by the World Bank despite an internal due diligence evaluation that identified almost all of the risks that eventually came to plague the project (Redwood 2002). The World Bank was severely criticized for its role in designing and executing the project and eventually agreed to a follow-up natural resource management project, known as PLANAFLORO, which was intended to create a legal framework and incentive structure for sustainable development in Rondônia (Schwartzman 1985).

The experience of PLANAFLORO provides important lessons for attempts to "fix" development in the Amazon. An internal review conducted at the termination of the project revealed it to be a mixed success (World Bank 2003b) (see Text Box 6). On the plus side, investments in health and educational services were deemed adequate, the strengthening of community organizational and civil society was considered to be very good, and investments in improving the physical infrastructure such as water, rural electricity, and road maintenance were considered to have been adequately executed. Another bright spot was that conservation units and indigenous territories were consolidated; the federal government and the State of Rondônia demarcated 4.75 million hectares as protected areas and 4.81 million hectares as indigenous lands, which jointly represents approximately 40 percent of the land surface of the State of Rondônia.[87]

Unfortunately, PLANAFLORO was unable to slow deforestation. Approximately 35 percent of the total surface of Rondônia has now been deforested, which accounts for almost 70 percent of the forest area outside of conservation units and indigenous territories. In practical terms, that means virtually all existing forests outside of protected areas have been degraded due to wildfire and fragmentation. Moreover, there are widespread reports of illegal logging in conservation areas and indigenous reserves (Pedlowski *et al.* 2005), which are also routinely subject to fire.

There is always hope that future efforts to manage development will work better, which is essentially the motivation for the Sustainable Development Plan for BR-163. Noteworthy in that effort is the emphasis on repeating what is known to work, mainly the designation of all currently existing forested landscapes as conservation units or indigenous reserves. The evident goal is to create a girdle around the development corridor and, one hopes, limit deforestation to a narrow corridor adjacent to the highway. Perhaps the most important difference between PLANAFLORO and Plano BR-163 is the participation of federal, state, and municipal governments in its design and implementation.

Unfortunately, the environmental action plans associated with IIRSA investments may also struggle with implementation. In Bolivia, the action plan for the IIRSA transportation corridors between Santa Cruz and Puerto Suárez is plagued by administrative problems, whereas in Peru the SEA is being conducted concurrent with the construction phase of the InterOceanic Corridor. In Ecuador, the new government has proposed a highway to connect Manaus with the Ecuadorean lowlands, and in Colombia, civil unrest and illicit drugs will complicate any organized effort to manage development.

87 The World Bank project in Rondônia was known as PLANAFLORO (World Bank 2003b); a similar project with similar results (PRODEAGRO) was designed, funded, and implemented in Mato Grosso (World Bank 2003c).

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CHAPTER 7

Avoiding the End of the Amazon

The future of the Amazon will depend in large part on the educational opportunity provided to its residents; payments for carbon storage could be used to invest in health and educational services (© Hermes Justiniano/ Bolivianature.com)

The two most serious threats to the conservation of the Amazon's biodiversity are climate change and deforestation, both of which will be greatly stimulated by IIRSA and PPA investments. Deforestation and forest degradation are fully underway along the margins of the Amazon. IIRSA and related initiatives will lead to the further fragmentation of the Amazon, accelerate forest degradation in the Andes, and complete the conversion of the Cerrado savannas to cropland.

Without a radical change in the nature of modern development, efforts by governments, financial institutions, and civil societies to limit the degradation will be unsuccessful. Regional and global markets will continue to dominate the dynamic on the agricultural front, and standard remedies for slowing or limiting deforestation will have little chance of success. Although sustainable development has been promoted as a philosophical framework to reconcile development and conservation, it has, in practice, only ameliorated the most egregious aspects of development and has had no substantive impact on slowing the rate of tropical deforestation (Figure 7.1).

Figure 7.1. The Amazon needs a new development paradigm in which natural resources are transformed into goods and services that are competitive in global markets; for example, this experimental fish farm in Bolivia relies on the region's abundant surface water, native herbivorous fish, and locally produced soy and corn (© Pep Barba/Estación Piscícola Mausa).

Under the best of circumstances, protected areas and indigenous reserves will be consolidated to function as biological reserves. However, it is unlikely that more than 30–40 percent of the land surface in the Amazon will be set aside for this purpose. In addition, indigenous and extractive reserves will face increased degradation unless the so-called sustainable forestry model is significantly modified or communities choose to opt out of that exploitation alternative. Outside of the protected area and indigenous reserve systems, the landscape will be subject to the inevitable forces of the market.

Policies to slow deforestation on privately held land over the past 20 years have depended on improving "governance," but unfortunately, these have been largely—if not entirely—ineffective. The two most common approaches have been 1) to invest in land use planning studies that promote forest management, and 2) to promulgate regulations that require landholders to retain a specified amount of their land in natural habitat.[88] Deforestation, however, continues at near-record levels, and Brazil's recent report that the annual rate of deforestation has fallen is probably a short-term phenomenon caused by weak international commodity markets rather than the success of government policies to suppress land use change. Landowners routinely ignore requirements to maintain a certain percentage of a property in forest cover. Similarly, regulations that prohibit land clearing along water courses and on steep slopes to create environmental easements are either ignored or unknown. Despite limited success to improve forest management most timber originates from the agricultural frontier where forest landscapes are cleared of their timber resources before the land is converted to crops or pastures. Some analysts are hopeful that the current trend to decentralize administrative responsibility to regional and municipal governments will decrease deforestation. They believe that local governments will be more effective at convincing land holders to conserve forest, limit the use of fire, and avoid the overexploitation of terrestrial and aquatic ecosystems (Nepstad *et al.* 2002). Although improving local government is a laudable goal, it is unlikely that private landholders will react differently to overriding market conditions, or that local governments will be less corrupt or any more attuned to environmental issues than national governments (Fearnside 2003).

Landholders will always act to maximize their own economic benefits, and no amount of regulation will successfully alter that behavior. Landholders will also probably dominate local government and its policies. In the developed world, the right of the landowner to manage private property is considered a foundation of a free market economy and a basic element of human nature. It is unreasonable to expect Amazonian landowners, most of whom come from this cultural tradition, to believe or behave differently, regardless of legal systems that seek to control the exploitation of the natural resources in the national interest.

If markets are destined to prevail and statutory land use regulations prove ineffective, then alternative approaches for saving the Amazon must be developed and implemented that recognize the predominance of the market, or society must accept the fact that most of this forest will eventually be degraded. One approach is to recognize the predominance of markets and to manipulate them through regulatory mechanisms that have been effective in other regions of the world. Almost all markets are regulated to some degree, to avoid extreme situations that are characterized as an abuse of the marketplace. As recent history has shown, unregulated land and commodity markets will eventually lead to the complete deforestation of the Amazon, which can logically and appropriately be considered an abuse of the marketplace.

Market regulations take many forms, but the most effective are those based on financial incentives that motivate individuals to choose voluntarily what is in their short-term economic interest. In North America, Europe, and Japan, subsidies and tax incentives guide land use and promote certain production activities. Agriculture is the most obvious example of how subsidies maintain a land use that would not otherwise be economically competitive. Countries with agricultural subsidies argue that they are necessary to ensure traditional activities, essential to their economy, and provide social welfare to an important sector of the population. This argument applies equally well for the conservation of the Amazon forest ecosystem. Brazil and the Andean countries have recognized that the conservation of the Amazon is a strategic priority. Combine this with the even greater strategic priority for economic growth to improve the social welfare of their populations, and it fully justifies the use of direct and indirect subsidies to ensure investments and activities that promote economic growth while simultaneously conserving the Amazon ecosystem.

The challenge is to find a source of revenue large enough to finance the requisite subsidies. Equally important is to identify economic models that produce goods and services while also avoiding deforestation. Fortunately, the growing recognition

[88] The Forest Code of Brazil establishes this value at 80 percent in the Amazon and 20 percent in the Cerrado.

that ecosystem services have real market value is creating an opportunity to finance this new development paradigm. Key policy options must be elucidated and selected over the next decade to generate the revenues and to ensure a framework that delivers the right economic incentives to the individuals who live and work in the Amazon.

Below are some recommendations for policies and mechanisms that would provide a new development paradigm for the Amazon. This list is by no means exhaustive or particularly novel, but it identifies opportunities for reducing deforestation while addressing the major impediments to sustainable development in the Amazon, Cerrado, and Andes.

RAISING THE MONEY: MONETIZING ECOSYSTEM SERVICES

There is now worldwide concern over global warming and awareness that the conservation of tropical forests can partially mitigate this threat. Given this context, a framework for the transfer of funds from developed nations to developing countries with threatened tropical ecosystems can serve as one source of revenue for conservation and subsidize development that is truly sustainable. The bulk of this revenue would come from carbon credits, which will eventually be implemented under reformed rules of the United Nations Framework Convention on Climate Change (UNFCCC 2006).

- Carbon credits would be earned by reducing emissions from deforestation and forest degradation (REDD according to UNFCCC terminology). For example, lowering the annual deforestation rate in the Amazon basin by 5 percent would generate approximately $650 million in the first year of a multiyear commitment; amounts would multiply dramatically as avoided emissions increased over 30-year commitment periods (see Appendix, Table A.3).
- For countries with currently high levels of deforestation, reductions would be calculated on the basis of historical deforestation; other countries would negotiate a different compensation package so as not to be penalized for past (or recent) low levels of deforestation.
- The issue of leakage— the displacement of existing emissions to other regions rather than actual reductions—would be managed by setting deforestation reduction targets at the national level. Consequently, shifts in land use within a country would cancel each other out or, more optimistically, add up.
- Reforestation and afforestation projects need to be greatly increased in developing countries to restore ecosystem function on previously degraded landscape. Current rules within the Clean Development Mechanism (CDM) have not fostered carbon sequestration in many countries because of implementation and certification burdens. Many of these measures were imposed to address concerns that carbon credits derived from reforestation projects might perversely stimulate the drivers of deforestation. The past decade has demonstrated, however, that this is not the case, and reforestation projects in the developing world have subsequently lagged.
- National commitments to reduce emissions from deforestation (RED) and sequester carbon (CDM) within the confines of the UNFCCC could be complemented by individual projects financed via voluntary markets with a less stringent certification process than the UNFCCC, especially when these bring strong benefits for biodiversity conservation and human welfare. Voluntary certifications could be fortified by adhering to the standards outlined in the Convention on Biological Diversity and the Millennium Development Goals.
- Carbon credit compensation schemes should be designed and managed by the governments of sovereign states as part of their national strategy to reduce carbon emissions. Some countries may adopt market mechanisms, whereas others may choose to create compensation funds that are replenished from both the private and public sectors.[89]
- In recognition of the fact that their agricultural production and hydropower depend partially on the Amazon, the Southern Cone countries of Argentina, Paraguay, and Uruguay join Brazil in making payments for ecosystem services according to the percentage of water each Mercosur nation receives from the Amazon and its degree of economic development.

A FAIR EXCHANGE: ECOSYSTEM SERVICES FOR SOCIAL SERVICES

Frontier populations rank education and health care as their two most important needs; thus, direct economic subsidies that link forest conservation to social services would create a powerful local constituency for conservation. To reduce deforestation, each nation must involve the actors responsible for deforestation and monitor the efficacy of the program on an annual basis. Although the administration of economic subsidies will vary among countries, resources and benefits must flow to local communities, regardless of the mechanism selected. Because local governments are usually responsible for providing essential social services, they are logical candidates for administering these programs (see below).

- Transfer payments to local governments for carbon credits and other ecosystem services should be dedicated to improving education and health care.
- Payments for ecosystem services would not be entitlements. Positive incentives in the form of increased budgets could be used to reward communities for going beyond commitments, while communities that fail to meet commitments would face budget reductions.
- A similar mechanism to reduce forest fires could generate additional carbon-based revenues. A reduction in fire would benefit forest management, local health, and contribute to more robust rainfall regimes.

89 Brazil has proposed that transfer payments be made as part of development assistance programs, whereas the Alliance for Rainforest Nations has proposed that market-based systems be used to govern the transfers.

QUID PRO QUO

Although ecosystem services can provide an important new source of national revenue, individual nations may need additional incentives to enter into ecosystem services agreements. In particular, Brazil and the Andean nations may be resistant to participate in mechanisms that seem to limit their sovereignty over the natural resources of the Amazon. To make participation politically palatable, compensation systems related to ecosystem services could also relate to other national priorities such as commerce and international security.

- Agricultural subsidies in Europe and North America are a major point of contention in world trade talks. Brazil is a leader among developing countries in contending that agricultural subsidies must be reduced if commerce in industrial goods and services is to be liberalized. Shifting subsidies from domestic agriculture to forest conservation via reduced emissions from deforestation would limit agricultural expansion in the Amazon and indirectly protect European and North American farmers.[90] Brazil would open its markets to industrial goods and services, while developed countries would open their markets to food and biofuels from Brazil.
- Global climate change represents a real and present threat to the planet's security—one that the collapse of the Amazon ecosystem would dramatically exacerbate.[91] Although the United Nations Security Council has not traditionally addressed environmental security, an increase in climate-related natural disasters has highlighted the vulnerability of the planet. Recognizing the importance of the Amazon to global security would provide additional weight to Brazil's petition for a permanent seat on the Security Council.
- In the Manaus Free Trade Zone, international companies have demonstrated a willingness to invest in an Amazonian urban center when offered tax advantages and lower tariffs. This could be used as a model for manufacturing and commercial centers in other regional cities, providing an alternative to development based solely on natural resource exploitation. Any such initiative must also include incentives for technology transfer so that these centers evolve past the initial assembly line (masquilladora) stage of development.

SUBSIDIZING ALTERNATIVE PRODUCTION SYSTEMS

The inhabitants of the Amazon need and deserve increased economic opportunity. Revenues generated by the monetization of ecosystem services could subsidize production systems that both stimulate economic growth and remain compatible with forest conservation. A number of systemic constraints to economic growth exist in the region. The most important is the insecurity of land tenure, followed by poor transportation systems, the absence of affordable credit, and a lack of reliable energy supplies. Current development models provide no adequate solutions for any of these impediments and tend to promote deforestation. The following alternative models conserve ecosystem services and could replace the existing models if markets are effectively regulated and are accompanied by subsidies to counterbalance existing market forces.

People by Air and Cargo by Water

As an alternative to highways that degrade and fragment the Amazon, the countries of the region could adopt a bimodal transportation model that uses airlines and river barges. This system could complement a limited highway network envisioned by IIRSA, but would erase the need for other projects promoted by national and state transportation ministries.[92] As part of a modified IIRSA investment program, it would provide cost-effective alternatives for transporting people and commodities.

- Airline and barge companies could be supported indirectly by tax abatements, as well as subsidized fuel prices and below-market interest rates for capital investments. Services to remote areas could be directly subsidized by cash payments to ensure reliable and regular services.
- Air service could promote regional integration by offering cross-border flights without routing through capital cities or large regional hubs.
- A greatly expanded air service would benefit the tourism industry by opening up remote areas, which would have the added benefit of reducing the environmental impact on areas with high tourist loads.
- A subsidized river transport service would provide a cost-effective solution for moving bulk commodities (i.e., timber, grain, minerals, and biofuels).

Land Tenure for Conservation

Reformed land tenure systems are central to stopping deforestation. People seeking land tenure are one of the principal causes of deforestation because the current titling process rewards land tenants who deforest lands and it castigates those who do not. The goal would be to maintain a forest matrix by subsidizing land use models that follow the 80:20 (forest:cultivated land) rule stipulated by the Brazilian Forest Code.[93] Both governmental regulations and market-based economic incentives are needed to ensure that intensive production systems are linked to forest conservation.

90 Subsidies in Europe and North America fluctuate between \$50 to \$75 billion annually. The proposed payments for carbon sequestration services represent only 1 percent of this total.

91 The U.S. military recently recognized global climate change as an important national security threat (MAB 2007).

92 All of the Andean countries have different versions of a piedmont highway that would transect various national parks, whereas Brazil plans a second Transamazonian highway (BR-210), known as Perimetral Norte, that would parallel the Amazon river approximately 8 degrees north of the equator.

93 Even the most optimistic land use change scenarios predict that at least 20 percent of the Amazon will be converted to intensive or semi-intensive production systems over the next century, with pessimistic scenarios forecasting up to 50 percent deforestation. Thus, a land use model in which 20 percent of the landscape is deforested but linked to the conservation of 80 percent would result in reduced deforestation.

- Enterprises that agree to a contractually binding ratio of 80:20 in perpetuity would enjoy an expedited titling process.[94]
- The state would distribute land by commercial transactions rather than land grants, and the terms of the mortgage would stipulate the 80:20 land use ratio.
- In heavily deforested landscapes, access to low-interest credit and expedited land titles would be offered to enterprises that agree to plant trees to meet the 80:20 land use rule.
- Enterprises that agree to the 80:20 land use rule would have access to low-interest loans to implement high-intensity production models (see next section).
- Compliance with the 80:20 land use rule would be monitored with remote sensing technology and with land registries managed by local and national governments. Failure to comply would lead to an immediate revocation of credit and the reversion of land to the state.

Economic Growth and Job Creation

Intensive production needs to predominate on landscapes that have been converted to agriculture, livestock, or tree plantations.[95] This production must ensure long-term sustainability and be diversified to ensure economic stability in fluctuating international commodity markets. Subsidized credit, transportation, and energy are paramount and should be considered as legitimate components of Amazonian production models; however, producers must provide commercially attractive goods and services that are competitive in real markets.

- A diversified tourist industry could focus on ecotourism, but it would also include sport fishing, cultural tourism, adventure leisure activities (water skiing and scuba diving), and luxury cruise lines.
- The tourist industry should be democratized by involving local communities as shareholders in new enterprises. Subsidized credit can be given to enterprises that enlist local communities as shareholders.
- Fish farming should be promoted as the primary production system in the Amazon.[96] Water is the region's most abundant and valuable resource and should form the foundation for its economic growth. Fish farming is the most efficient method of converting vegetable matter to animal protein and can be organized into small units managed by families.[97] It can also be a key component in a production chain that links the granaries of Mato Grosso and Santa Cruz with overseas markets.[98]
- Tree plantations in previously deforested regions will sequester carbon while also creating an economic resource over the medium term. Subsidies in the form of low-interest loans, technical support, and direct payments can be used to reforest landscapes.
- Mineral and hydrocarbon exploitation will continue to be important sources of revenue for national economies.[99] Royalty revenues from these activities should be used to secure additional resources from deforestation avoidance initiatives; for example, hydrocarbons are often produced within protected areas, so a portion of the royalties could be used to finance the management of the protected area. This would link fossil fuel production to positive actions that will reduce greenhouse gas emissions.
- Nonresource-dependent economic models need to be created to diversify the region's economy; the example of Manaus as a free trade zone that developed a high-tech industry should be duplicated in other Amazonian urban centers.

Innovation in Energy

Economic growth requires energy. The remoteness of the Amazon increases the cost of traditional fossil fuels, creating both challenges and opportunities. Clean energy should be the paradigm for production systems that are subsidized by ecosystem services payments, and the Amazon can create opportunities for strategic partnerships in the research, development, and commercialization of alternative energy.

- Solar power will be the most competitive option for most remote localities with moderate energy needs; investments in this technology could be subsidized by ecosystem service payments.
- Tax abatements, tariff preferences, and direct subsidies should be provided to multinational corporations that establish solar panel manufacturing facilities in Amazonian urban centers.
- Because water is the Amazon's most important natural resource, hydroelectric power will be an important component of the energy model. The potential for hydroelectric power in the Amazon is enormous, but facilities should not be constructed on the major tributaries of the

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94 Ten percent of the Amazon is equivalent to about 25,000 km². At an average productivity of $500 per hectare (based on low soybean yields and low prices in Bolivia), this would generate $1.2 billion in annual revenues for the region. The potential from biofuels will be several times higher than this figure.

95 In some parts of the humid tropics, only 5 percent of deforested lands are under production, while the other 95 percent is left as secondary forest fallow.

96 Fish farming, or aquaculture, is now the fastest growing form of food production in the world. Since 1990, it has increased at a rate of 10 percent per year. If this trend continues, within a decade, more seafood will come from farms than from the wild.

97 Yields of 3,682 kg/ha have been obtained in fisheries of commercial *Colossoma macropomum* (tambaqui), a frugivorous species that is fed a commercial diet in stocked ponds; 10,000 ha of ponds would produce 35,000 metric tons of fish per year, matching the total wild harvest of all species in Loreto, Peru in 1994 (Peralta & Teichert-Coddington 1989).

98 This production model would need to incorporate guidelines to avoid or minimize potentially negative environmental impacts, such as the conversion of wetlands, the introduction of exotic species, and the pollution of fresh water from the inappropriate treatment of wastewater and effluents from fish ponds.

99 Neither mines nor hydrocarbon concessions should have trouble meeting the 80:20 rule if local populations collaborate by not invading concessions.

Amazon (e.g., Madeira and Xingu) in order to limit the impact of dams on aquatic ecosystems.
- Biofuel crops, including African oil palm to produce biodiesel and elephant grass to produce cellulosic alcohol, will probably be the most successful agricultural enterprise in the Amazon. Locally produced biodiesel could provide an economically competitive source of fuel for the barge industry.
- Although the cultivation of biofuel crops probably poses the largest single future threat to the Amazon, this threat can be mitigated by requiring the 80:20 land use model and—most importantly—subsidizing biofuel production on previously deforested, degraded landscapes.
- Propane and butane (i.e., liquefied petroleum gas—LPG) are usually abundant in natural gas fields and provide an energy-rich, clean, and portable fuel source. Although LPG is separated out at refineries and sold as subsidized fuel to urban populations, small gas plants can be built in the Amazon, and LPG can become one of several energy options.
- Fossil fuels for the airline industry will have to be subsidized to support the people-by-air cargo-by-water transportation model; however, technological innovation should eventually allow for the conversion of vegetable oils to produce kerosene and aviation fuel.

HARNESSING THE POWER OF LOCAL GOVERNMENT

Statutory regulations have been ineffective because they have been isolated from market mechanisms. Similarly, economic incentives will be insufficient to change the development dynamic in the Amazon if they are implemented in a lax regulatory environment. Subsidies are easily abused, and strong institutions are required to ensure that market forces operate as intended. Thus, all the subsidies and market mechanisms proposed here are linked to regulatory requirements, particularly the 80:20 land use rule that offers one of the few realistic options to limit deforestation. Most laws and regulations are initiated at the national level, but municipal and regional governments have an important and growing role in enforcement. The conservation of the Amazon will depend on a large extent on the capacity of local governments to fulfill their role as public institutions.

- Land title registries must be a priority investment across the Amazon region. Questionable land tenure is a source of violence and corruption in frontier areas. Local governments must create and maintain rural and urban land registers as the foundation for long-term growth and good government. Land tenure would be the basis for local taxes, and access to credit would be granted on the basis of the patrimonial value of land.
- Independent watchdog agencies must be established to monitor deforestation, and municipal governments will need remote sensing and geographic information system (GIS) capacity to enforce bans on deforestation and fires. In Brazil, this capacity exists at the national level and has recently been decentralized in Mato Grosso[100]; however, no such coordinated effort exists in any of the Andean countries.
- Regional universities will need an infusion of investment to support revitalized educational and health systems. Resources channeled to state universities should be linked to governance reforms and support expanded research programs linked to extension and focusing on rural development.[101]
- University-based research will help subsidize and improve intensive production systems, particularly to discover novel uses for the biological and genetic resources of the Amazon and Andes.

DESIGNING CONSERVATION LANDSCAPES

In addition to conserving large blocks of the Amazon within an expanded protected area system, it will also be necessary to design and implement "conservation corridors" in strategic areas where transportation corridors are considered requisite for the physical and economic integration of the region. A conservation corridor is a landscape that is designed to promote biodiversity conservation. It consists of protected areas strategically situated within a matrix of different land use types so that species can move and exchange genetic resources. As IIRSA highways are constructed and deforestation belts expand over time, and as global warming brings about shifts in the environmental gradients that control species distribution, the importance of habitat connectivity will become ever more important.

- Large blocks of forest must be conserved to minimize the impact of edge effects and to provide sufficient area for the survival of rare species.
- The western Amazon should receive special consideration because it is the most biologically diverse region and has enjoyed the most stable climate over millennia.
- Although much of the landscape outside of protected areas will eventually become "production forests," these should be established with timber harvest cycles of approximately 100 years to maintain the essential characteristics of forest wilderness.
- Incentives must be developed for communities to conserve forest landscapes adjacent to highways so that wildlife can migrate across these barriers.[102]
- The connectivity between the piedmont and the montane ecosystems of the Tropical Andes Hotspot must be main-

100 The System for Environmental Licensing in Rural Properties uses remote sensing technology provided by the national space agency (INPE) to monitor deforestation in approximately real time and compares that information with land tenure data acquired through a licensing program.

101 Brazil has adopted a relatively efficient governance structure for its public university, but Andean countries cling to an outdated, highly politicized model in which students and faculty choose university authorities via an electoral process. This model tends to reward teaching while penalizing research and extension.

102 The recently published environmental management plan for the BR-163 transportation corridor between Cuiabá and Santarém incorporates a Jamanxim National Park that literally straddles the highway (Plano BR-163).

Text Box 7

Protected Areas: Enough Is Enough—or Not Nearly Enough?

The 1990s witnessed the creation of many protected areas throughout the Amazon, with the goal to designate approximately 20 percent of the total surface of each country as some type of protected area, with different levels of natural resource use (IUCN 1994). At the same time, indigenous peoples began to gain the titles for their traditional lands, acquiring about 20 percent of the region, which many conservationists hope will function as surrogate protected areas.

Brazil is still actively expanding its protected area system under a range of categories with flexible development options. Slightly more than 70 percent of Amapá and almost half the area of Pará, Acre, and Roraima states have been incorporated into some form of conservation unit, including indigenous areas and productive forest reserves. Peru has likewise set aside almost half (45 percent) of its Madre de Dios Province, and Colombia has essentially ceded almost all of its lowland Amazon region to indigenous groups (see Figure 5.3 and Tables A.5 to A.7). However, the basin-wide total is still a long way from 50 percent, and even if 50 percent is eventually set aside, the eventual deforestation and degradation of the remaining half is far from an attractive proposition

Many people, particularly in the private sector and the prodevelopment ministries, believe that "enough is enough" and fear that more protected areas will make large regions unavailable for mining, hydrocarbons, and timber. However, conservationists argue that what has been set aside is "not nearly enough," particularly because parallel efforts to slow forest degradation and deforestation have failed (see Figure 2.1).

These apparently opposed positions will eventually be resolved via democratic processes. It is hoped that both groups will realize that there can be common ground: that a protected area may have multiple uses, that mining and hydrocarbon production do not necessarily have to lead to widespread deforestation, and that logging might be truly sustainable. One hopes, too, that people will see conservation as an investment in the planet's future. Once the natural ecosystem is permanently altered, there is no turning back. If a mistake is to be made, it would only seem prudent to err on the side of caution and be generous with future generations when deciding "how much is enough?"

tained (or restored) to ensure that lowland species can migrate into the foothills in response to climate change.

- River Corridors should be another priority because they incorporate moist valley bottoms that will be resilient to future drought, and they protect both terrestrial and aquatic ecosystems. The southern Amazon tributaries (e.g., Xingu, Madeira) will also function as latitudinal corridors.
- Topographic features that would offer refuge to lowland species migrating in response to global change should be identified as priority areas for protection; this highlights the importance of the hills, ridges, and valleys of the Brazilian and Guayana Shield regions.

CONCLUSIONS

The Amazon Wilderness Area is facing inexorable changes resulting from economic development and environmental degradation, processes that have already transformed the Cerrado into a vast agroindustrial estate. The tropical forests of the Andes have been subject to a long history of degradation, but in the past this settlement has been characterized by isolation, with small circumscribed regions linked to a single urban area in the highlands; IIRSA proposed to integrate the isolated regions of the Andean piedmont and link them with national, regional, and global markets. IIRSA, the PPA, and other public and private initiatives will amplify the impacts of human migration, agricultural expansion, timber extraction, mining, hydrocarbon production, and climate change. The existing paradigm of sustainable development has failed to arrest deforestation and forest degradation. Unfortunately, traditional development is largely incompatible with conservation because it cannot produce the economic incentives to promote the long-term preservation of natural forest habitat. Efforts to use community-based initiatives to slow deforestation have failed—and will continue to fail—because the ever-expanding Amazon frontier is populated with individuals who make decisions on the basis of their economic interests for the short term. Even the most amenable production systems, such as the current model of sustainable forestry, will lead to the eventual degradation of forest ecosystems and conversion to tree plantations.

The traditional solution of creating protected areas will likely be an integral but insufficient solution because it will encompass only 20–30 percent of the landscape, and these protected areas will become increasingly isolated in a matrix of degraded forest and anthropogenic landscapes. Indigenous lands and extractive reserves offer an important complement to protected areas, but these may be co-opted into the current forest management model unless communities have a more attractive economic alternative. Even if indigenous lands are preserved intact and the protected area system is expanded, they will not exceed 50 percent of the total land surface of the Amazon, even in the most optimistic scenario. That explicitly leaves the remaining 50 percent exposed to the forces of international commodity markets and the search for personal wealth that characterizes modern society.

The Amazon requires a new development paradigm unique to its special characteristics and global importance. This new paradigm must ensure its inhabitants a dignified level of prosperity while making important contributions to the economies of the nations that are custodians of the Amazon. If the Amazon forest is a global asset worth preserving, then it is only reasonable that the custodians be paid for their efforts.

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APPENDIX

Tables A.1 through A.4 provide simple models that estimate the value of the carbon stored in Amazonian forests (Table A.1), the value of the carbon released each year via deforestation (Table A.2), the potential value of a 5 percent reduction in deforestation in the eight countries of the greater Amazon Wilderness Area compared against the documented baseline deforestation rates (Table A.3), and the potential value of a 5 percent reduction in deforestation for four Andean countries when compared to a Business as Usual Scenario (Table A.4). Tables A.5 through A.7 provide statistics on protected areas and indigenous lands.

Table A.1. A model estimating the economic value of the Amazon forest based on the carbon stored in its biomass; forest cover estimates are derived from published and on-line studies using satellite images; the value of 125 metric tons of carbon per hectare is a conservative estimate derived from plot-based biomass studies (Baker *et al.* 2004); the market value of a metric ton of carbon ($10) is near the current value quoted on the Chicago Climate Exchange for carbon financial instruments.

	Forest cover (×1,000 ha)	Carbon @125 t/ha (×1,000 t)	Gt C	Gt CO_2	Value of Standing Forest @ $10/t CO_2 ($ billion)
Bolivia[1]	46,070	5,758,750	5.8	21.1	211
Brazil[2]	336,873	42,109,109	42.1	154.5	1,545
Colombia[3]	57,117	7,139,606	7.1	26.2	262
Ecuador[3]	11,764	1,470,438	1.5	5.4	54
Peru[3]	71,335	8,916,825	8.9	32.7	327
Venezuela[3]	42,164	5,270,494	5.3	19.3	193
Guyana[4]	15,104	1,888,000	1.9	6.9	69
Suriname[4]	14,776	1,847,000	1.8	6.8	68
French Guiana[4]	13,000	1,625,000	1.6	6.0	60
Total	608,202	76,025,221	76.0	279	2,790

1. Killeen *et al.* 2007b.
2. Derived from published reports of total forest cover for the Brazilian Amazon (Btito-Carreres *et al.* 2005, PRODES 2007).
3. Unpublished results of a deforestation study of the Andean countries recently completed by Conservation International (Harper *et al.* 2007).
4. FAO 2005.

Table A.2. A model estimating the economic value of the Amazon forest based on the carbon released each year into the atmosphere from deforestation. Cover estimates are derived from published and online studies using satellite images; the value of 125 metric tons of carbon per hectare is a conservative estimate derived from plot-based biomass studies conducted in the Amazon (Baker *et al.* 2004); the price of a metric ton of carbon ($10) is near the current value quoted on the Chicago Climate Exchange for carbon financial instruments.

Amazon Countries	**Forest Cover 1990 (×1,000 ha)**	**Forest Cover 2000 (×1,000 ha)**	**Forest Cover 2005 (×1,000 ha)**	**Annual Rate of Deforestation (×1,000 ha yr^{-1})**	**Carbon Emissions@ 125 t/ha (×1,000 t)**	**CO_2 Emissions (×1,000 t)**	**Value of Emissions @ $10/t CO_2 ($ million)**
Bolivia[1]	48,355	46,862	46,070	240	30,001	110,105	1,101
Brazil[2]	364,922	348,129	336,873	2,250	281,250	1,032,188	10,322
Colombia[3]	59,282	57,839	57,117	144	18,044	66,221	662
Ecuador[3]	12,333	11,953	11,764	38	4,748	17,423	174
Peru[3]	72,511	71,727	71,335	78	9,800	35,966	360
Venezuela[3]	43,258	42,529	42,164	73	9,119	33,466	335
Guyana[4]	15,104	15,104	15,104	-	-	-	-
Suriname[4]	14,776	14,776	14,776	-	-	-	-
French Guiana[4]	13,000	13,000	13,000	-	-	-	-
Total	643,540	621,919	608,202				
Annual rates				2,824	352,961	1,295,369	
						Annual Total	12,954
						30-Year Total	388,611
						Net Present Value for 30 Year Total	134,325

Andean Countries	**Forest Cover 1990 (×1,000 ha)**	**Forest Cover 2000 (×1,000 ha)**	**Forest Cover 2005 (×1,000 ha)**	**Annual Rate of Deforestation (×1,000 ha yr^{-1})**	**Carbon Emissions @ 125 t/ha (×1,000 t)**	**CO_2 Emissions (×1,000 t)**	**Value of Emissions @ $10/t CO_2 ($ million)**
Bolivia[1]	48,355	46,862	46,070	240	30,000	110,100	1,101
Colombia[3]	59,282	57,839	57,117	144	18,000	66,060	661
Ecuador[3]	12,333	11,953	11,764	38	4,748	17,423	174
Peru[3]	72,511	71,727	71,335	78	9,800	35,966	360
Total	192,481	188,381	186,285				
Annual rates				500	62,548	229,549	
						Annual Total	2,295
						30-Year Total	68,865
						Net Present Value for 30-Year Total	23,803

1. Killeen *et al.* 2007b.
2. Derived from published reports of total forest cover for the Brazilian Amazon (Btito-Carreres *et al.* 2005, PRODES 2007).
3. Unpublished results of a deforestation study of the Andean countries recently completed by Conservation International (Harper *et al.* 2007).
4. FAO 2005.

Table A.3. A model estimating the economic value of a Sustainable Scenario where Amazonian countries agree to reduce the annual rate of deforestation by 5 percent every year for 30 years. The Baseline Scenario is based on estimates of deforestation derived from published and online studies using satellite images (see Table A2). The value of 125 metric tons of carbon per hectare is a conservative estimate derived from plot-based biomass studies conducted in the Amazon (Baker *et al.*, 2004); the price of a metric ton of carbon ($10) is near the current value quoted on the Chicago Climate Exchange for carbon financial instruments.

Year	Baseline Scenario Forest Cover (1,000 ha)	Baseline Scenario Deforestation Rate (1,000 ha yr^{-1})	Sustainable Scenario Deforestation Rate (1,000 ha yr^{-1})	Sustainable Scenario Forest Cover (1,000 ha)	Difference in Deforestation between Scenarios (1,000 ha)	Total Accumulated Carbon Offset 125 t/ha (x1,000 t)	Total CO_2 Emissions (×1,000 t)	Total Accumulated Value @ $10/t CO_2 (×$1,000)	Annual Payment @ $10/ t CO_2 (x$1,000)	Total Accumulated Value at NPV @ $10/t CO_2 (x$1,000)	Annual Payment at NPV @ $10 / t CO2 (x$1000)
2007	608,202										
2008	605,378	2,824	2,683	605,519	141	17,648	64,768	647,684	647,684	647,684	647,684
2009	602,554	2,824	2,548	602,971	416	52,062	191,067	1,910,669	1,262,984	1,632,593	984,908
2010	599,731	2,824	2,421	600,550	819	102,403	375,819	3,758,188	1,847,519	3,020,661	1,388,069
2011	596,907	2,824	2,300	598,250	1,343	167,875	616,102	6,161,016	2,402,828	4,661,825	1,641,164
2012	594,083	2,824	2,185	596,065	1,982	247,722	909,139	9,091,386	2,930,371	6,481,354	1,819,530
2013	591,260	2,824	2,076	593,989	2,730	341,224	1,252,292	12,522,922	3,431,536	8,418,367	1,937,013
2014	588,436	2,824	1,972	592,018	3,582	447,699	1,643,057	16,430,566	3,907,644	10,423,606	2,005,239
2015	585,612	2,824	1,873	590,144	4,532	566,499	2,079,051	20,790,512	4,359,946	12,457,553	2,033,947
2016	582,789	2,824	1,780	588,365	5,576	697,007	2,558,014	25,580,145	4,789,633	14,488,825	2,031,272
2017	579,965	2,824	1,691	586,674	6,709	838,637	3,077,798	30,777,980	5,197,835	16,492,815	2,003,991
2018	577,141	2,824	1,606	585,068	7,927	990,834	3,636,361	36,363,608	5,585,628	18,450,544	1,957,728
2019	574,317	2,824	1,526	583,542	9,225	1,153,069	4,231,764	42,317,638	5,954,031	20,347,682	1,897,138
2020	571,494	2,824	1,450	582,093	10,599	1,324,841	4,862,165	48,621,652	6,304,013	22,173,730	1,826,048
2021	568,670	2,824	1,377	580,715	12,045	1,505,672	5,525,815	55,258,149	6,636,497	23,921,327	1,747,597
2022	565,846	2,824	1,308	579,407	13,561	1,695,109	6,221,051	62,210,505	6,952,356	25,585,666	1,664,339
2023	563,023	2,824	1,243	578,164	15,142	1,892,723	6,946,293	69,462,928	7,252,423	27,164,004	1,578,339
2024	560,199	2,824	1,181	576,984	16,785	2,098,104	7,700,041	77,000,414	7,537,486	28,655,256	1,491,251
2025	557,375	2,824	1,122	575,862	18,487	2,310,864	8,480,871	84,808,710	7,808,296	30,059,646	1,404,391
2026	554,552	2,824	1,066	574,797	20,245	2,530,634	9,287,428	92,874,276	8,065,565	31,378,431	1,318,784
2027	551,728	2,824	1,012	573,784	22,057	2,757,064	10,118,425	101,184,247	8,309,971	32,613,655	1,235,224
2028	548,904	2,824	962	572,823	23,919	2,989,820	10,972,640	109,726,404	8,542,157	33,767,962	1,154,307
2029	546,081	2,824	914	571,909	25,829	3,228,587	11,848,914	118,489,138	8,762,733	34,844,428	1,076,467
2030	543,257	2,824	868	571,041	27,785	3,473,063	12,746,142	127,461,419	8,972,281	35,846,436	1,002,008
2031	540,433	2,824	824	570,217	29,784	3,722,964	13,663,277	136,632,770	9,171,351	36,777,563	931,127
2032	537,609	2,824	783	569,434	31,824	3,978,017	14,599,324	145,993,238	9,360,468	37,641,497	863,934
2033	534,786	2,824	744	568,690	33,904	4,237,966	15,553,337	155,533,367	9,540,129	38,441,965	800,469
2034	531,962	2,824	707	567,983	36,021	4,502,566	16,524,417	165,244,174	9,710,807	39,182,683	740,718
2035	529,138	2,824	672	567,311	38,173	4,771,584	17,511,712	175,117,124	9,872,951	39,867,307	684,623
2036	526,315	2,824	638	566,673	40,358	5,044,799	18,514,411	185,144,111	10,026,987	40,499,402	632,095
2037	523,491	2,824	606	566,067	42,576	5,322,001	19,531,743	195,317,434	10,173,322	41,082,420	583,018
	Remnant Forest Cover					Totals		Totals			
	86%			93%		5,322,001	19,531,743		195,317,434		41,082,420

Table A.4 A model estimating the economic value of a scenario where four countries (Bolivia, Peru, Ecuador and Colombia) agree to reduce the annual rate of deforestation by 5% every year for 30 years (Sustainable Scenario) compared to a scenario with an annual increase of 2.5% in deforestation that may accompany IIRSA highway projects on the Andean piedmont (Business As Usual Scenario). The baseline value is derived from published and on-line studies using satellite images (see table A2); the value of 125 metric tons of carbon per hectare is a conservative estimate derived from plot-based biomass studies conducted in the Amazon (Baker *et al.*, 2004); the market value of a metric ton of carbon ($10) is near the current value quoted on the Chicago Climate Exchange (CCX) for carbon financial instruments.

Years	Baseline Scenario Forest Cover (1,000 ha)	Baseline Scenario Forest Cover (1,000 ha)	Business As Usual Scenario Deforestation Rate (1,000 ha yr^{-1})	Sustainable Scenario Deforestation Rate (1,000 ha yr^{-1})	Business As Usual Scenario Forest Cover	Sustainable Scenario Forest Cover (1,000 ha)	Difference in Deforestation between Scenarios (1,000 ha)	Total Accumulated Carbon Offset 125 t/ha (x1,000 t)	Total Reduced CO^2 Emissions (×1,000 t)	Total Accumulated Value @ $10/t CO_2 (x$1,000)	Annual Payment @ $10/t CO_2 (x$1,000)	Total Accumulated Value at NPV @ $10/t CO_2 (x$1,000)	Annual Payment at NPV @ $10/t CO_2 (x$1,000)
2007	186,285												
2008	185,785	500	513	475	185,772	185,810	38	4,691	17,216	172,162	172,162	172,162	172,162
2009	185,284	500	526	452	185,246	185,358	112	13,956	51,218	512,182	340,020	437,519	265,357
2010	184,784	500	539	429	184,707	184,929	221	27,686	101,608	1,016,079	503,897	816,104	378,585
2011	184,283	500	552	408	184,155	184,521	366	45,781	168,018	1,680,180	664,101	1,269,694	453,590
2012	183,783	500	566	387	183,589	184,134	545	68,150	250,111	2,501,111	820,931	1,779,428	509,734
2013	183,283	500	580	368	183,009	183,766	758	94,708	347,578	3,475,781	974,670	2,329,604	550,176
2014	182,782	500	595	349	182,414	183,417	1,003	125,378	460,137	4,601,373	1,125,592	2,907,210	577,606
2015	182,282	500	610	332	181,804	183,085	1,281	160,091	587,533	5,875,331	1,273,959	3,501,521	594,311
2016	181,782	500	625	315	181,179	182,770	1,590	198,783	729,535	7,295,354	1,420,023	4,103,750	602,228
2017	181,281	500	641	300	180,539	182,470	1,931	241,400	885,938	8,859,383	1,564,029	4,706,750	603,001
2018	180,781	500	657	285	179,882	182,185	2,303	287,891	1,056,559	10,565,592	1,706,209	5,304,766	598,016
2019	180,280	500	673	270	179,209	181,915	2,706	338,212	1,241,238	12,412,383	1,846,790	5,893,211	588,444
2020	179,780	500	690	257	178,520	181,658	3,139	392,326	1,439,837	14,398,372	1,985,990	6,468,481	575,270
2021	179,280	500	707	244	177,813	181,414	3,602	450,201	1,652,239	16,522,389	2,124,017	7,027,801	559,320
2022	178,779	500	725	232	177,088	181,182	4,094	511,811	1,878,347	18,783,466	2,261,077	7,569,085	541,284
2023	178,279	500	743	220	176,345	180,962	4,617	577,134	2,118,083	21,180,831	2,397,365	8,090,821	521,736
2024	177,778	500	761	209	175,584	180,753	5,169	646,155	2,371,390	23,713,903	2,533,072	8,591,976	501,155
2025	177,278	500	780	199	174,803	180,554	5,751	718,863	2,638,229	26,382,286	2,668,383	9,071,908	479,932
2026	176,778	500	800	189	174,003	180,365	6,362	795,252	2,918,576	29,185,764	2,803,478	9,530,300	458,391
2027	176,277	500	820	179	173,183	180,186	7,003	875,321	3,212,430	32,124,295	2,938,531	9,967,093	436,794
2028	175,777	500	840	170	172,343	180,016	7,673	959,074	3,519,801	35,198,007	3,073,712	10,382,446	415,352
2029	175,277	500	861	162	171,481	179,854	8,372	1,046,518	3,840,719	38,407,194	3,209,186	10,776,682	394,236
2030	174,776	500	883	154	170,599	179,700	9,101	1,137,665	4,175,231	41,752,310	3,345,116	11,150,258	373,576
2031	174,276	500	905	146	169,693	179,554	9,860	1,232,533	4,523,397	45,233,969	3,481,659	11,503,736	353,478
2032	173,775	500	928	139	168,766	179,415	10,649	1,331,143	4,885,294	48,852,940	3,618,970	11,837,752	334,016
2033	173,275	500	951	132	167,815	179,283	11,468	1,433,519	5,261,014	52,610,140	3,757,200	12,153,002	315,250
2034	172,775	500	975	125	166,840	179,158	12,318	1,539,690	5,650,664	56,506,639	3,896,499	12,450,217	297,216
2035	172,274	500	999	119	165,841	179,039	13,198	1,649,691	6,054,365	60,543,650	4,037,011	12,730,157	279,940
2036	171,774	500	1,024	113	164,817	178,926	14,108	1,763,557	6,472,253	64,722,530	4,178,881	12,993,592	263,434
2037	171,274	500	1,050	107	163,768	178,818	15,051	1,881,329	6,904,478	69,044,781	4,322,250	13,241,293	247,702
	Remnant Forest Cover												
	92%				88%	96%		1,881,329	6,904,478		68,872,619		13,241,293

Table A.5 Protected Areas and Indigenous Lands in the Amazon Wilderness Area (See Figure 5.3).

Amazon Wilderness Area	Area (km²)	Protected Area Total (km²)	% Protected Area	Indigenous Land Total (km²)	% Indigenous Land	Total Protected Areas and Indigenous Lands (km²)	% Protected Areas and Indigenous Lands
Brazil	4,231,358	951,235	22.5	941,760	22.3	1,758,856	41.6
Bolivia	354,496	37,282	6.3	76,722	21.6	103,565	25.7
Colombia	448,130	62,549	14.0	211,110	47.1	256,320	57.2
Ecuador	70,840	16,434	23.2	12	0.0	16,445	23.2
Peru	659,586	154,692	21.0	154,317	12.8	205,831	31.2
Venezuela	416,919	300,675	72.1	1,835	0.4	300,806	72.1
French Guiana	83,267	39,847	47.9	0	-	39,847	47.9
Guayana	210,025	5,157	2.9	6,693	3.2	11,850	5.6
Suriname	146,101	22,184	15.2	0	0.1	22,184	15.2
Total	6,620,722	1,590,055	24.0	1,392,449	21.0	2,715,705	45.0

Table A6. Protected Areas and Indigenous Lands in the Legal Amazon of Brazil (modified from the Instituto Socioambiental (http://www.socioambiental.org/uc/quadro_geral).

Brazilian State	Area (km²)	Protected Area total (km²)	% protected	Indigenous Area total (km²)	% indigenous area	Total Protected and Indigenous (km²)	% Protected and Indigenous
Acre	152,581	51,230	33.6%	24,283	15.9%	75,513	49.5%
Amapá	142,815	89,152	62.4%	11,860	8.3%	101,012	70.7%
Amazonas	1,570,746	260,682	16.6%	428,719	27.3%	689,401	43.9%
Maranhão	331,983	13,862	4.2%	19,220	5.8%	33,082	10.0%
Mato Grosso	903,358	28,360	3.1%	135,129	15.0%	163,489	18.1%
Pará	1,247,690	308,742	24.7%	284,397	22.8%	593,139	47.5%
Rondônia	237,576	56,480	23.8%	49,659	20.9%	106,139	44.7%
Roraima	224,299	14,467	6.4%	103,843	46.3%	118,309	52.7%
Tocantins	277,621	10,672	3.8%	23,914	8.6%	34,586	12.5%
Legal Amazon	5,088,668	833,646	16.4%	1,081,023	21.2%	1,914,669	37.6%

Table A.7 Protected Areas and Indigenous Lands in the Countries of Northern South America

Individual Countries	Area (km²)	Protected Area Total (km²)	% Protected	Indigenous Area Total (km²)	% Indigenous Land	Total Protected Area and Indigenous Land (km²)	% Protected Area and Indigenous Land
Bolivia	1,085,047	186,486	17.19	202,778	18.69	326,978	30.13
Brazil	8,484,839	1,234,755	14.24	1,051,632	12.40	2,152,224	25.06
Colombia	1,137,921	106,374	9.35	263,264	23.14	344,861	30.31
Ecuador	256,212	49,103	19.17	97	0.04	49,196	19.20
French Guiana	83,267	39,847	47.86	0	0.00	39,847	47.86
Guayana	210,025	5,157	2.90	6,693	3.19	11,850	5.64
Peru	1,291,445	203,909	15.79	174,735	13.53	260,982	20.21
Suriname	146,101	22,184	15.18	0	0.00	22,184	15.18
Venezuela	912,557	400,558	43.89	2,041	0.22	400,878	43.93
Total	13,607,414	2,248,373	16.5	1,701,240	12.5	3,609,002	29.0

Figure A.1. IIRSA investments in the northwest Amazon and on the Andean piedmont will link the waterways of Amazonian tributaries (Putumayo, Napo, Marañon, and Ucuyali) via trans-Andean highways to the Pacific Coast. However, these East - West highways will also create a piedmont corridor that stretches from Pucallpa in central Peru to the Putumayo in Colombia. Development and deforestation along that corridor will isolate the Andean and Amazonian biota and limit the ability of numerous species to adapt to future climate change.

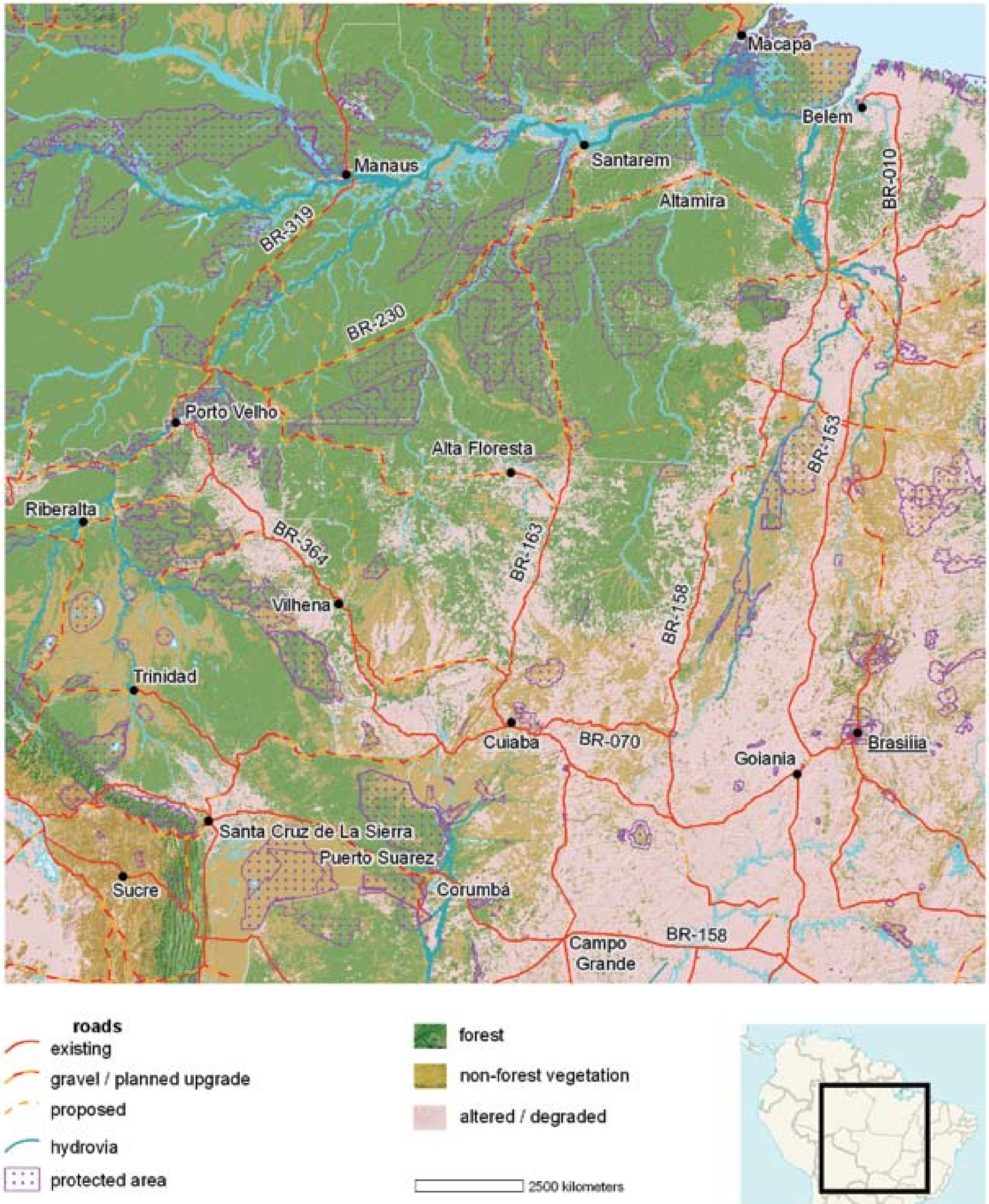

Figure A.2. The southwest Amazon and adjacent regions of the central Andes will be heavily impacted by four IIRSA highway corridors that will connect the Brazilian Cerrado with Pacific ports: (1) the Bioceanic Corridor between Mato Grosso do Sul and the Chilean coast via Santa Cruz, Bolivia; (2) the Bolivian Northern Highway, will connect the Bolivian Altiplano with the frontier regions adjacent to Acre and Rondônia; (3) the Inter-Oceanic Highway of southern Peru will connect Acre and Rondônia with the Pacific coast of Peru; and (4) the Rio Branco-Cuzeiro de Sul-Pucallpa Highway, which will transect some of the most remote regions of the western Amazon. In the other direction, the Maderia– Mamore hydrovia will be linked to the main trunk of the Amazon River by the dams and locks between Puerto Velho, Rondônia and Riberalta, Bolivia.

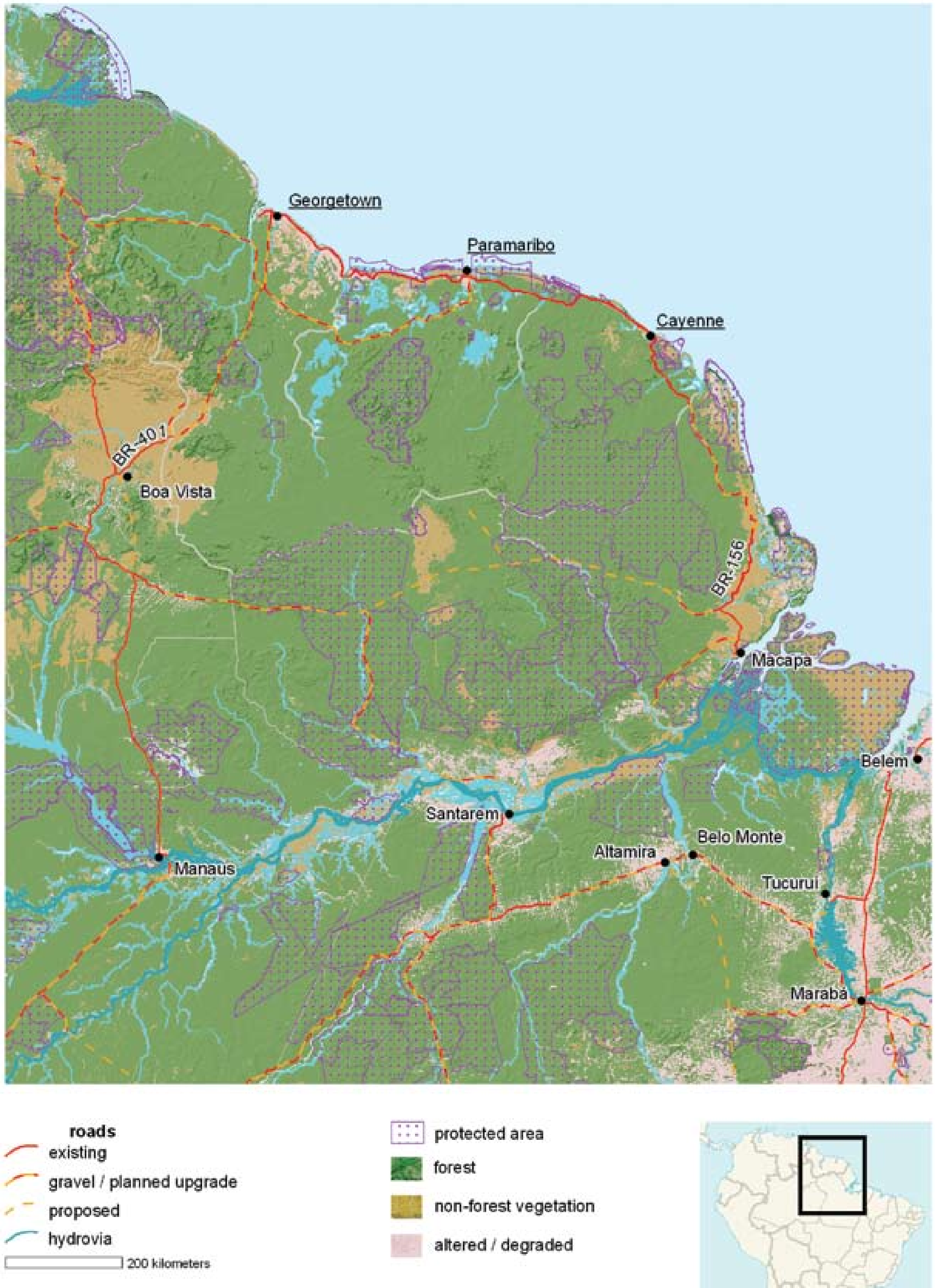

Figure A.3. The ArcoNorte refers to the highway system that will integrate the countries of the Guayana Shield in the northeastern Amazon. This sparsely populated region is generally considered to be the least threatened region of the Amazon, and large areas in Brazil have been designated as protected areas; however, the exploitation of the region's rich mineral and timber resources may become economically attractive following the completion of IIRSA investments.

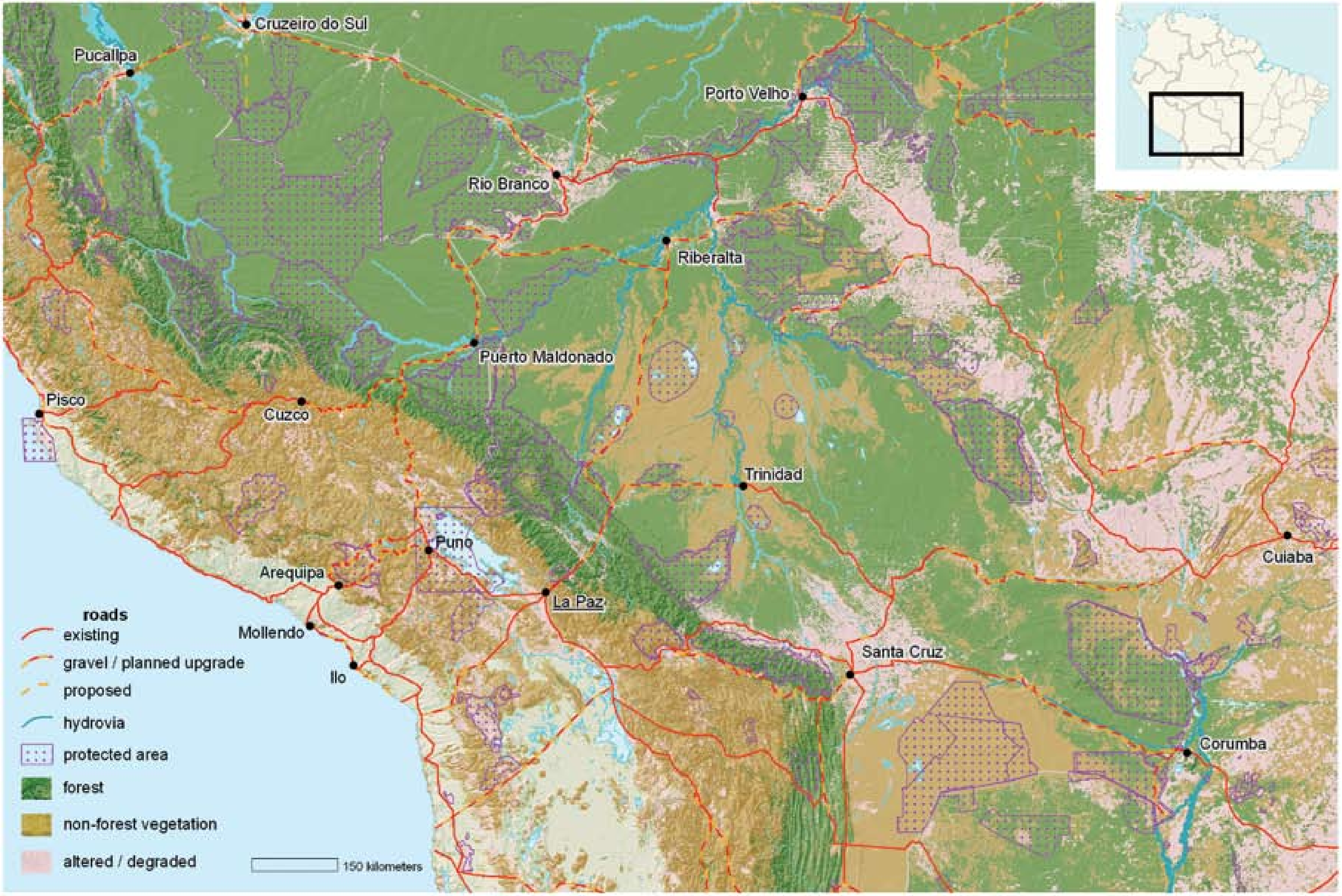

Figure A.4. The southeastern Amazon is also known as the arc of deforestation because most development has occurred here over the past 30 years. Investments in transportation will accelerate this trend by improving regional highway networks and hydrovias. New railroads will provide export corridors for the region's agricultural commodities.