CHAPTER 4 Ecosystem Services

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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

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 nonbiological 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.

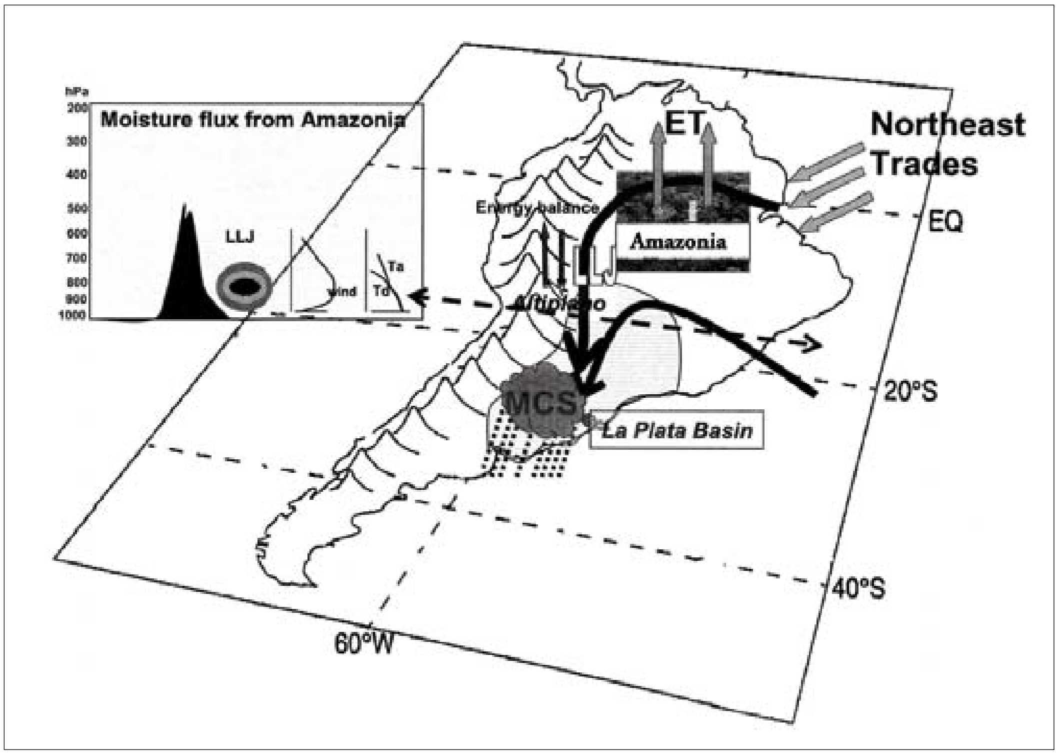

Figure 4.5. The South American Low-Level Jet (SALLJ) transports water from the central Amazon to the agricultural regions of the Rio Plata basin. Deforestation and climate change threaten this important ecosystem service; even a small reduction in precipitation would lead to an annual economic loss in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