Essays

Globalization of the Amazon Soy and Beef Industries: Opportunities for Conservation

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Abstract: *Amazon beef and soybean industries, the primary drivers of Amazon deforestation, are increasingly responsive to economic signals emanating from around the world, such as those associated with bovine spongiform encephalopathy (BSE, "mad cow disease") outbreaks and China's economic growth. The expanding role of these economic "teleconnections" (coupled phenomena that take place in distant places on the planet) led to a 3-year period (2002–2004) of historically high deforestation rates. But it also increases the potential for large-scale conservation in the region as markets and finance institutions demand better environmental and social performance of beef and soy producers. Cattle ranchers and soy farmers who have generally opposed ambitious government regulations that require forest reserves on private property are realizing that good land stewardship—including compliance with legislation—may increase their access to expanding domestic and international markets and to credit and lower the risk of "losing" their land to agrarian reform. The realization of this potential depends on the successful negotiation of social and environmental performance criteria and an associated system of certification that are acceptable to both the industries and civil society. The foot-and-mouth eradication system, in which geographic zones win permission to export beef, may provide an important model for the design of a low-cost, peer-enforced, socioenvironmental certification system that becomes the mechanism by which beef and soy industries gain access to markets outside the Amazon.*

Keywords: conservation policy, deforestation, green certification, hoof-and-mouth disease, soy, beef markets, tropical conservation

Globalización de las Industrias de Soya y Ganado del Amazonas: Oportunidades para la Conservación

Resumen: *Las industrias de soya y de ganado en el Amazonas, los principales factores de la deforestación del Amazonas, están incrementado su sensibilidad a las señales emanadas de todo el mundo, como las asociadas con brotes de encefalopatía esponjosa bovina (EEB, "enfermedad de las vacas locas") y el crecimiento económico de China. El creciente papel de estas "teleconexiones" económicas (combinadas con fenómenos que pudieran ocurrir en sitios distantes sobre el planeta) condujo a un período de 3 años (2002–2004) de tasas de deforestación históricamente altas. Pero también incrementa el potencial para la conservación a gran escala en la región a medida que los mercados y las instituciones financieras demandan mejor actuación ambiental y social a los productores de ganado y de soya. Los ganaderos y los productores de soya, que generalmente se han opuesto a las ambiciosas regulaciones del gobierno que requieren reservas forestales en terrenos privados, se están dando cuenta que un buen uso del suelo—incluyendo el cumplimiento de la legislación—puede incrementar su acceso a los mercados domésticos e internacionales en expansión, a créditos y a un menor riesgo de "perder" sus tierras por reformas agrarias. El entendimiento de este potencial depende de la negociación exitosa de criterios de actuación social y ambiental y un sistema de certificación asociado que sean aceptables*

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tanto para la industria como para la sociedad civil. El sistema de erradicación pies y boca, en el que las zonas geográficas obtienen permisos para exportar ganado, puede proporcionar un modelo importante para el diseño de un sistema de certificación socioambiental de bajo costo e implementado por pares, que sea el mecanismo mediante el cual las industrias de soya y de ganado obtengan acceso a los mercados fuera del Amazonas.

Palabras Clave: aftosa, certificación verde, conservación tropical, deforestación, mercado de ganado, merado de soya, políticas de conservación

Introduction

The Amazon economy is increasingly responsive to national and international markets through a process of globalization that is accelerating the rate at which agriculture and cattle ranching are substituting or impoverishing native forests (Fig. 1). Strategies for managing this transition to minimize its negative impacts on the region's forests, rainfall system, biological wealth, and cultural heritage must be reexamined (Alencar et al. 2004; Clay 2004; Hecht 2005). Expansion of the protected-area network and command-and-control implementation of ambitious environmental legislation are important components of a revised strategy for Amazon conservation, but, alone, they are insufficient (Soares-Filho et al. 2006). We present an approach by which the globalization of the Amazon economy might be harnessed to foster (1) broader landholder compliance with land-use legislation, (2) the adoption of agricultural and ranching practices that are less damaging to the environment and that provide more social benefits, and (3) improvements in land-use zoning laws.

The Drivers of Amazon Deforestation: 1970–1997

For many years, the causes of deforestation in the Brazilian Amazon could be traced to federal government policies designed to integrate the region with the Brazilian national economy and to defend it from international intervention (Hecht & Cockburn 1989). Roads cut into the rainforest were accompanied by government colonization programs in the 1970s and generous fiscal incentives for large-scale cattle ranching in the 1970s and 1980s (Browder 1988; Schmink & Wood 1992; Carvalho et al. 2002). Policies promoting the development of cattle pastures were primary drivers of deforestation, and forest conversion to cattle pasture became the predominant form of deforestation (Hecht 1993). By 1990 587,000 km^2 of forest had been clearcut (Houghton et al. 2000), 15% of the closed canopy forests of the Brazilian Amazon.

Until recently, the Amazon cattle industry, responsible for more than two-thirds of annual deforestation, was largely isolated from market forces operating outside the region because of the presence of foot-and-mouth disease (FMD) in the Amazon herd (Kaimowitz et al. 2004; Margulis 2004; Arima et al. 2005). Beef exports to neighboring regions were banned because of the risk of disease spread. Poor pasture- and herd-management practices in combination with inadequate transportation infrastructure further inhibited cattle production in the region (Arima et al. 2005). Despite the low profitability of cattle production and the reduction of government fiscal incentives, ranching continued to expand, in part because of its utility to investors and land speculators in helping them claim title to land whose value was rapidly escalating (Hecht 1993; Arima et al. 2005). Land titling in Brazil depends on demonstration of "productive use" of the land, and one of the cheapest ways of achieving this is through the creation of pastures (Schmink & Wood 1992).

Soybean production was trivial in the Amazon during the 1980s and early 1990s in part because of the lack of soybean varieties adapted to Amazon soils and climate and the scarcity of grain storage and processing infrastructure. The poor performance of ranching and agriculture reinforced earlier claims that permanent agriculture and animal husbandry is not viable in the Amazon (Goodland & Irwin 1975; Hecht 1985).

Recent Growth of the Cattle Industry

In recent years, several factors have begun to shift the drivers of Amazon deforestation from Brazil's domestic economy and policies to the international market. The surge in deforestation in 2002, 2003, and 2004 (Fig. 1) was primarily a result of growth of the cattle herd, which expanded 11% annually from 1997 to its 2004 level of 33 million head (including only those Amazon *municípios* with closed-canopy forest comprising at least 50% of their native vegetation, IBGE-PAM 2005). The causes of this expansion include progress in eradicating FMD, devaluation of the Brazilian currency (the Real), bovine spongiform encephalopathy (BSE) outbreaks in Europe, and improvements in beef production systems.

Perhaps the most important change that has strengthened the role of markets in fostering expansion of the Amazon cattle industry was the FMD-free status conferred on a large ($\sim$1.5 million km^2) forest region in the southern Amazon, including the states of Mato Grosso, Acre, and the southern half of the state of Pará (Kaimowitz et al. 2004; ABIEC 2005; Arima et al. 2005), that has allowed the export of beef outside the Amazon. This status could change at any moment, however, with immediate consequences for the cattle industry. For example, after the

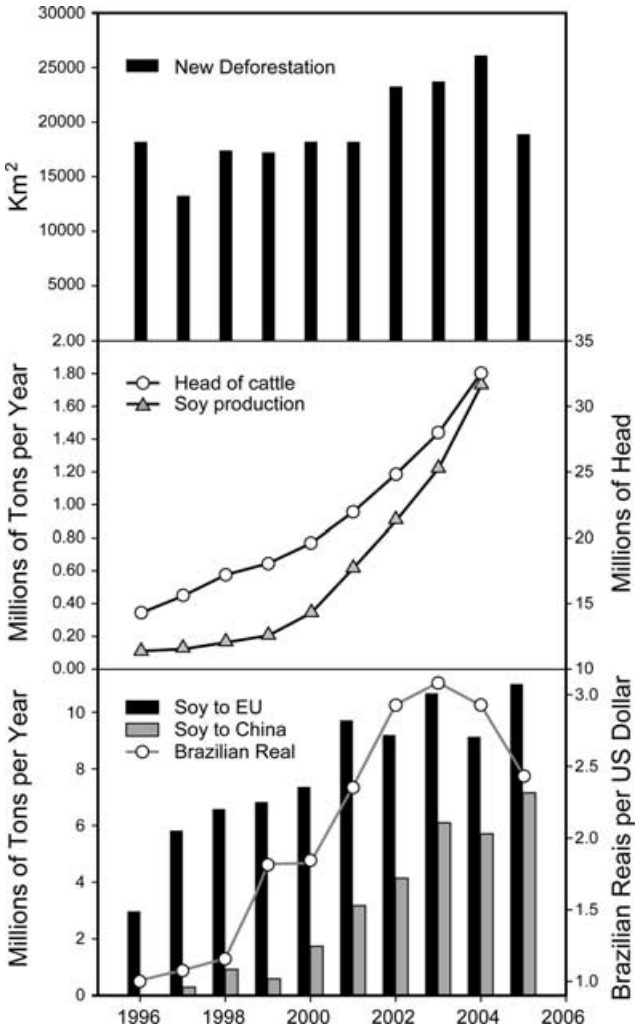

Figure 1. Trends in annual Amazon deforestation, the Amazon cattle herd, Amazon soy production, total soy exports from Brazil to the Europe Union (EU) and China, and the value of the Brazilian Real (in U.S. dollars). Cattle herd and soy production were calculated for those municípios *(political land units similar to counties) in the Brazilian Amazon with at least 50% original forest cover calculated from IBGE (2005) data, excluding those municípios in which the original vegetation is primarily cerrado woodland. (Sources: IBGE-PPM 2005; INPE 2005; People's Daily Online 2005, CONAB 2006; BACEN 2006.)*

discovery of FMD in the central Brazilian state of Mato Grosso do Sul in September 2005, 52 countries temporarily suspended the import of Brazilian beef (MAPA 2005). The well-financed effort to eradicate FMD throughout the Americas (PAHO 2004), however, suggests that the long-term trend will be one of diminishing risks of further FMD outbreaks in the region and greater access to international beef markets. The success of the FMD eradication program may have important lessons for an Amazon conservation strategy.

The southern Amazon cattle industry has also modernized, with the adoption of improved genetic lines of cattle, artificial insemination, and better pasture-management techniques (Margulis 2004; Arima et al. 2005). The global trend toward tracking and labeling commodities through the production and commercialization chain has also reached the Brazilian cattle industry, driven by increasingly restrictive national and international standards designed to lower health and disease risks associated with beef commercialization and consumption. The Brazilian agriculture ministry's "SISBOV" system of cattle tracing requires that the land holding where each animal originated, the animal's vaccination history, the method by which the animal was raised, and the animal's importer be recorded for each individual through a system of ear tagging (Rocha & Lopes 2002; MAPA 2005). Although extensive, low-input cattle ranching motivated by land speculation or (meager) profit margins (Hecht 1985; Arima et al. 2005) continues to dominate the Amazon beef industry in terms of areal coverage, it is gradually being replaced by modern, high-input, market-oriented beef operations, which prioritize product quality and cost reduction (Mattos & Uhl 1994; Kaimowitz et al. 2004; Margulis 2004; Arima et al. 2005). Amazon slaughterhouses are exporting a growing proportion of their beef from the region and from Brazil (Arima et al. 2005).

Trade liberalization currently underway—such as Brazil's successful challenge, through the World Trade Organization (WTO), of U.S. cotton subsidies and the European Union's (EU's) sugar import barriers (BBC 2004)—represent the beginning of a trend that could eventually lower trade barriers against beef imports by both the United States and Europe, further stimulating Amazon beef production (Anderson & Martin 2006). Agricultural trade was one of the most contentious topics leading up to the Hong Kong meeting of the Doha round of WTO negotiations, which means that it may continue to be a priority in future negotiations.

Both the improvements in the health, productivity, and "traceability" of the Amazon cattle herd and the trend toward trade liberalization coincide with growing international demand for open-range beef (Roosevelt 2006). The BSE has expanded markets for open-range, grass-fed cattle, such as produced in the Amazon and throughout Brazil, because of health concerns associated with ration-fed systems of cattle production. In 2004 Brazil became the world's leading beef exporter, with 38% of its exports destined for the EU, 12% for the Middle East, and 10% for Russia (MDIC 2005).

The Arrival of Soybeans

Soy expansion into the Amazon began in the late 1990s as new varieties were developed that tolerated the moist, hot Amazon climate (Fearnside 2001) and as a worldwide

shortage of animal-feed protein boosted soy prices (Hard 2002; LMC International 2003; Brookes et al. 2005). The growing demand for soybeans combined with the low land prices and improved transportation infrastructure of southeastern Amazonia prompted major soy companies to invest in storage and processing facilities in the region (Diaz et al. 2006). As a result, the production of soybeans in the closed-canopy forest region of the Amazon (i.e., excluding savanna regions) increased 15% per year from 1999 to 2004 (Fig. 1, IBGE-PAM 2005). Private investments in the region that have stimulated soy expansion include the development of a small barge system and associated deepwater port in Itacoatiara, in the central Amazon, for transporting soy along the Madeira River (Grupo A. Maggi 2006). Cargill completed a second deepwater port in Santarem, farther east along the Amazon River (Fearnside 2001; Nepstad et al. 2002). Both of these port facilities created large incentives to pave existing federal highways that would connect them to areas of soy production in the southern Amazon and Cerrado and they fostered soy cultivation in their immediate vicinities (Nepstad et al. 2002; Diaz et al. 2006). Highway paving stimulates deforestation by creating improved access to vast areas of unclaimed—or loosely claimed—land along the highways' flanks (Nepstad et al. 2000, 2001; Soares-Filho et al. 2004).

The EU has become the most important new market for soybeans grown in the Amazon through a complex set of industry and government reactions to Europe's widespread BSE outbreaks (Hard 2002; Brooke et al. 2005; OIE 2005). The EU imposed a ban on the feeding of animal-protein–based ration to all livestock in 2001 in an attempt to reduce the risk of further BSE outbreaks (Fig. 2, DEFRA 2005). Great Britain and the EU imposed partial restrictions on the use of carcasses in animal ration in 1988 and 1994, respectively (Brookes 2001; DEFRA 2005). The resulting shortage of protein for animal ration has been filled primarily by soy meal, whose amino acid composition and nutritional properties are superior to those of other vegetable meals and oils. European consumer opposition to genetically modified (GM) crops has meant that most of the protein deficit has been supplied by northern Brazil, including the Amazon, which is the world's largest supplier of non-GM soy. One half of the EU's soy imports—about 6 million tons—are from Brazil (Brookes et al. 2005; LMC International 2005) (Fig. 1).

The Chinese economy, which has grown 9% per year since 1999, has also bolstered international demand for soy (Figs. 1 & 2) as a growing middle class consumes more soy-fed pork and poultry (Naylor et al. 2005). In 2003 China imported 21 million tons of soybeans, 10% of world production and 83% more than it imported in 2002; 29% of this soy came from Brazil (Fig. 1; ASA 2003; People's Daily Online 2004).

These trends have been enhanced by the devaluation of the Brazilian Real. From 1997 to 2003 the number of Reals per dollar increased nearly threefold, from 1.04 to 3.05

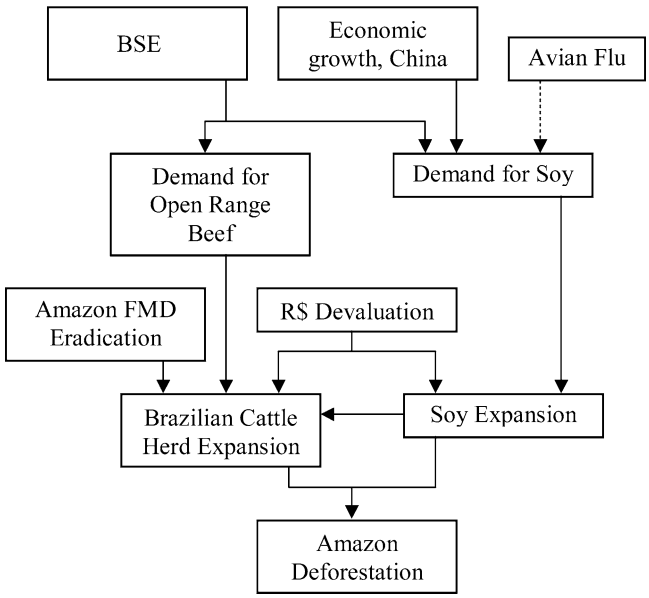

Figure 2. "Economic teleconnections" driving recent increases in Amazon deforestation (FMD, foot-and-mouth disease; BSE, bovine spongiform encephalopathy; R$, Brazlian Real). The dashed arrow represents suppression of soy expansion associated with the avian flu.

(BACEN 2006) (Fig. 1), stimulating virtually all of Brazil's export industries. The number of Reals per dollar fell in 2004 and 2005 to 2.45, partially reversing this trend. This is one of the factors causing the decline in soy exports to the EU and China (Fig. 1).

The expansion of the Brazilian soybean industry into the Amazon may have driven expansion of the Amazon cattle herd indirectly through its effect on land prices, which have increased 5- to 10-fold in many areas of Mato Grosso. Many cattle ranchers who own properties suitable for soy production have sold off their holdings with enormous capital gains, enabling them to expand their herds and purchase land farther north, where prices are lower (J. C. C., unpublished data).

Continuance of the Decline in Deforestation

The increase in Amazon deforestation from 2002 through 2004 is the symptom of a larger trend of Brazilian agroindustrial expansion. This trend is a boon to the national economy, with the agroindustrial complex contributing 35% of the gross national product (MAPA 2005). Brazil is the world's leading exporter of poultry, beef, oranges, and sugar cane and will soon be the leading exporter of cotton, soybeans, and biofuels (Brown 2004). Hence, the overarching trend in Brazil is continued agroindustrial expansion, perhaps sustaining the high levels of Amazon deforestation seen in 2002–2004 (Fig. 1). In the short term, deforestation may remain supressed by low prices

for soy and beef. Reduced consumption of poultry associated with the spread of avian flu, for example, has decreased demand for poultry ration and, hence, for soy meal, lowering soy prices (Rocha & Bouças 2006).

The 2002–2004 deforestation spike was caused by several economic "teleconnections" that will have an increasingly important role in driving Amazon land-use activities. (The term *teleconnection* was coined originally by climatologists [Philander 1990] and refers to coupled climatic phenomena that take place in distant places on the planet.) These teleconnections drove up demand for Brazilian beef and soy as the value of the Brazilian Real plummeted, lowering the price of Brazilian commodities in the international marketplace (Figs. 1 & 2). Most of the deforestation increase can be traced to expansion of the cattle herd (Kaimowitz et al. 2004), but the cattle and soy industries do not operate independently of one another. Hence, the 30% decline of soy prices from 2003 to 2005 and the increased cost of Brazilian exports associated with the 25% increase in the strength of the Real (Fig. 1) were important factors that decelerated both the expansion of agroindustry and cattle ranching in the region, as reflected in deforestation estimates for 2005 (Fig. 1). Many soy producers were unable to pay back the credit extended to them by suppliers of seed and agrochemicals and by finance institutions, which robbed the region of the capital that had been used in previous years to acquire new land and convert forest to pasture and cropfields (D.N., unpublished data).

The Brazilian government also claimed a leading role in slowing deforestation in 2005 through a series of measures ranging from the creation of 8-million ha of land along the BR163 highway in which land titling was prohibited, the designation of 5-million ha of new parks and reserves in the eastern Amazon, the imprisonment of dozens of environmental enforcement personnel suspected of corruption, and the dispatching of 2000 troops to the Amazon in the wake of Sister Dorothy Stang's assassination (Soares-Filho et al. 2006). These remarkable government interventions may have reduced deforestation by increasing the likelihood that fraudulent deforestation activities were detected and punished. The relative contribution of the government's increased investments in command-and-control implementation of the law in the Amazon and economic teleconnections in slowing deforestation in 2005 remains to be rigorously analyzed. It is likely, however, that higher prices for soybean or beef, or a weakening Real, will increase deforestation rates in the future even if the Brazilian government's laudable achievements in controlling illegal land-use activities were to continue into the future.

Environmental and Social Impacts

The growing links between the drivers of Amazon deforestation (cattle ranching and soybean expansion) and the global economy may herald a long-term trend in which economic returns to ranching and soy farming increase, leading to higher deforestation rates such as those observed in 2002–2004 (Fig. 1). The new dynamic of Amazon deforestation therefore represents greater emissions of greenhouse gases to the atmosphere, expanded threats to ecoregions that lie in the path of the agroindustrial frontier, impoverishment of watersheds whose headwaters are suitable for soybeans and cattle production, threats to the regional rainfall system through reduction in latent heat transfer (Silva Dias et al. 2002), a greater risk of forest fire (Nepstad et al. 1999, 2001), and the loss of plant and animal species whose ranges are contained within the areas of heaviest impact (Soares-Filho et al. 2006). With the advent of industrial agriculture, the use of agrotoxins in the Amazon will also increase, threatening surface and ground water supplies.

Rolling topography, rocky soils, and poor drainage may prevent cattle ranching and, in particular, soy farming from expanding into large portions of the Amazon Basin, but enormous areas of the region are vulnerable to conversion. On the basis of assessments of soil aptitude, climate, transportation infrastructure, and storage facilities, further expansion of soy and ranching could occupy an additional 1.4 to 1.7 million km^2 in Brazil alone, equal to the entire cultivated cropland area of the United States (USDA-FAS 2003). Approximately one-fourth of this area is located in the Amazon. In a separate analysis that integrates a climate- and soil-sensitive model of soy yield and transportation costs, it is estimated that nearly 30% of the closed-canopy forests of the Amazon could support economically viable soy production once the BR-163 highway is paved (Diaz et al. 2006); more than 80% of the Brazilian Amazon could sustain profitable cattle production (Arima et al. 2005).

Agroindustrial expansion also brings threats to Amazon society. It displaces smallholder farmers and indigenous communities and the diversified farming systems that they have developed, which are responsible for a large portion of the food staples consumed in Brazil. This expansion brings with it land speculation and rural violence as multiple claims on properties lead to land wars, particularly where land tenure is unclear (Schmink & Wood 1992; Simmons 2004). Laborers on remote ranches and farms can also become locked into debt peonage systems. An estimated 25,000 Brazilian laborers were trapped in debt peonage in 2004, tied to farms and ranches in remote regions by debts incurred with their employers (Gentile 2004).

Conservation Opportunities

The conservation opportunities presented by Brazil's agroindustrial growth are found in the growing pressure on soy farmers and cattle ranchers from finance institutions and purchasing companies, from the consumers

and producer organizations in importing countries, and from Brazilian consumers, to reduce the negative ecological and social impacts of their production systems (Clay 2004). Perhaps the most far-reaching driver of the reform of agroindustrial commodity producers is the Equator Bank initiative, in which finance institutions representing more than 80% of project finance world-wide, including four Brazilian banks, are developing environmental and social standards and beginning to apply these standards as conditions to loans extended to the private sector (BankTrack 2004). In one of the most dramatic examples of how this trend can influence the land management decisions made by large numbers of producers, a $30 million loan from the International Finance Corporation (Stickler et al. 2004; Stickler & Almeida 2006) was used by the Grupo A. Maggi soy company to prefinance 510 soybean farmers in the Brazilian cerrado woodland and adjoining Amazon forest. As a condition of this prefinancing, participating producers were required to comply with environmental and labor legislation, use only certified agrochemicals, employ no-till cultivation techniques, and prohibit hunting, among other practices (Grupo A. Maggi 2006). Although an independent assessment of the performance of these prefinanced properties has yet to be conducted, the potential for this mechanism to leverage positive changes in the environmental performance of agroindustrial farms is tremendous.

A second force motivating the adoption of environmental and social standards by soybean farmers and cattle ranchers is the concern expressed within importing countries—especially in the EU—that Brazilian soybeans and beef provoke Amazon deforestation, slave labor, and the risk of disease (Gentile 2005; Monbiot 2005). A large Swedish grocery store chain announced that it would restrict imports of Amazon soybean that do not meet environmental criteria. The United Kingdom's National Beef Association cited concerns with Amazon deforestation and its contribution to global warming when they called for a boycott of Brazilian beef (IcWales 2003).

Some of these concerns have an element of protectionism. The first call to boycott Brazilian beef issued by the U.K. National Beef Association complained primarily of its low price and the threat it posed to U.K. beef producers (IcWales 2003). Against the global trend toward trade liberalization manifested most recently in the completion of the Doha round of WTO negotiations, the environmental, social, and sanitary risks associated with Brazilian beef production could become a tool for protecting the domestic beef producers of European nations from unwelcome competition.

The pressure on Amazon beef and soy producers is also coming from within Brazil as consumers demand beef produced with lower environmental and social impacts. For example, a growing number of beef retailers in southern Brazil (e.g., the supermarket chains Carrefour and Pão de Açucar) and meat processors (e.g., Friboi, Bertim) are looking to the Amazon for reliable sources of high-quality beef produced on ranches that obey environmental legislation and use good land-management techniques (D.N. and O.A., unpublished data).

Merely complying with land-use regulations in the Amazon could go a long way toward reducing the environmental impacts of Amazon soy and cattle. For example, Brazil's environmental legislation requires that 80% of the forests and all of the riparian zones on private landholdings in the Amazon be maintained as reserves, although this legislation has been difficult to enforce (Lima et al. 2005).

Although Amazon forest legislation is ambitious, the state government of Mato Grosso, where >40% of Amazon deforestation takes place, has started to implement a system of satellite-based monitoring of private-land forest reserves (Fearnside 2003; Wertz-Kanounnikoff & Chomitz 2005). Thus far, this state has licensed deforestation on properties with a combined area of 80,000 km^2, which is approximately 30% of the closed-canopy forest area outside of protected areas (Lima et al. 2005). Because they are based on satellite images, they could be made public on the Internet, thus permitting independent audits of the licensing system. Although the system is underfinanced and flawed in its implementation, it could potentially gain tremendous political and financial support if beef and soy producers begin to associate access to lucrative markets in southern Brazil or Europe with compliance. State agencies responsible for animal sanitation are emerging as the unexpected advocates for improved implementation of deforestation licensing systems as they advance sophisticated, integrated systems for tracking the health, environmental, and social risks associated with beef production (D.N., C.S., and O.A. unpublished data).

The prospects for transforming the Amazon beef and soy sectors into practitioners of good land stewardship may be diminished, however, by the high costs of compliance with environmental legislation. The profits of cattle producers decline to nearly zero when they must set aside 80% of their land holdings as forest reserves (O.A., unpublished data). Under the current interpretation of this legislation, even some landholders who were in full compliance with the 50% forest reserve requirement that was in effect until 1998 must demonstrate 80% forest cover on their combined properties. In the context of the Amazon, where enforcement of environmental regulations is partial at best (Lima 2006), the considerable economic cost of complying with these regulations represents one of the most important obstacles to achieving the legality that is a prerequisite for a growing number of export markets and financial institutions.

One way to compensate beef and soy producers for the costs of complying with environmental regulations is to establish a system of environmental certification recognized by markets in Brazil and abroad, providing

greater market access and, perhaps, higher beef and soy prices. Environmental certification systems established for the timber industry, for example, provide a seal for timber from forest management systems that are approved by third-party evaluations of environmental performance and trace the timber through the custody chain to the consumer. In the case of beef and soy production, certification could be provided to producers who demonstrate their compliance with forest-reserve legislation and who adopt "best management practices" such as those that are being used by Grupo A. Maggi (2006) and other soy and cattle producers.

Environmental certification of Amazon soy and beef producers could potentially foster greater deforestation rates and a more rapid disruption of smallholder and indigenous communities if producers gain better access to foreign markets and, perhaps, command higher prices for their products. Management of the agroindustrial sector will therefore require land-use zoning to prevent runaway expansion of agroindustry and ranching across the region. Every state in the Brazilian Amazon has an "ecological/economic land-use zoning" plan, although none have been implemented with the full force of the law (Mahar 2004). But the regional planning and zoning process underway for the BR-163 highway, which includes a moratorium on land titles in an 8-million-ha area, demonstrates the potential for zoning to play an important role in governing the Amazon frontier. The test, now, is for the government to sustain its decrees through investments in enforcement.

One of the key goals of zoning must be to identify and protect those forest lands for which the potential profitability of agricultural production or cattle ranching is low and the value for biodiversity and maintenance of the rainfall system are high. Approximately one-third of the forestlands cleared for agriculture and ranching in the Amazon have been abandoned and now support regrowth forests (Houghton et al. 2000), as has occurred in virtually all of the world's forest lands (Rudel et al. 2005). Zoning could prevent the clearing of such lands, diminishing deforestation at a very low cost to the regional economy.

The FMD eradication system also demonstrates that zoning schemes are feasible with sufficient government support, and that the ranching industry is prepared to enforce itself when provided with the carrot of improved market access. Here government and producers join forces to eradicate FMD disease from states and districts throughout Brazil. Producers who do not vaccinate their herds threaten the potential of the regional industry to export beef and, hence, come under intense pressure from neighbors, industry, and government to comply with regulations. If the Amazon soy and cattle industries come to understand that their access to international markets depends on environmental and social certification within a system of land-use zoning, then ecological and social criteria could be added to the FMD standards for export. These criteria could restrict the expansion of Amazon soy production and ranching to areas of appropriate soil and climate and protect consolidated frontiers of smallholders and indigenous lands and areas of high biodiversity value, potentially extending the socioenvironmental performance of soy and ranching to foster regional land-use planning and zoning.

Reduction of the environmental and social costs of ranching and agroindustrial expansion in the Amazon might be achieved through a threefold program that (1) forces producers to comply with ambitious environmental legislation through improved monitoring and enforcement capacity among government agencies, (2) rewards compliance through socioenvironmental certification that facilitates access to lucrative international and domestic markets and to the credit of finance institutions, and (3) adopts an FMD-type model of zoning to prevent runaway expansion of cattle ranching and agroindustry into inappropriate areas. The considerable transaction costs of certification might be reduced by certifying zones of producers, instead of individual properties. This three-part program differs from the Amazon timber certification campaign, which has certified only 5% of Amazon timber production after more than a decade of effort. The slow rate of certification for Amazon timber production may be a reflection of the unwillingness of wood consumers to pay substantially more for certified products, the high cost of certification, the difficulty of monitoring illegal logging, and the prevalence of illegal timber producers in the Amazon, who flood the timber market with cheap wood (Richards 2004).

It is a new era for Amazon development and conservation. The economic forces driving forest destruction have grown more powerful, threatening to repeat the world's legacy of agricultural replacement of the great forests (Woodwell 2002). Protection of the Amazon's climate system, its biodiversity, its indigenous cultures, and the health of its rivers and streams will require the maintenance of most Amazon forests (Soares-Filho et al. 2006). But in those Amazon regions where cattle ranching and agroindustry are highly lucrative, it will be very difficult to achieve forest conservation purely through command-and-control approaches. By restricting access to world markets to those producers who implement sound environmental management of their properties in regions with effective land-use zoning systems, the rainforest "hamburger connection" denounced 2 decades ago (Myers 1981; Kaimowitz et al. 2004) could become an important new mechanism for protecting, not destroying, the world's largest tropical rainforest.

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Literature Cited

Alencar, A., et al. 2004. Desmatamento na Amazônia: Indo Além da 'Emergencia Crônica. Instituto de Pesquisa Ambiental da Amazônia (IPAM), Belém, Brazil. Available from www.ipam.org.br (accessed February 2006).

Anderson, K., and W. Martin. 2006. Agriculture, trade reform, and the Doha agenda. Pages 3–36 in K. Anderson and W. Martin, editors. Agriculture and trade reform and the doha development agenda. The World Bank, Washington, D.C.

ABIEC (Associação Brasileira de Indústrias de Carne). 2005. Foot-and-mouth disease outputs, Brazil. ABIEC, Sao Paulo, Brazil. Available from www.abiec.com.br (accessed December 2005).

Arima, E., P. Barreto, and M. Brito. 2005. Pecuária na Amazônia: Tendências e implicações para a conservação ambiental. Instituto do Homem e Meio Ambiente da Amazônia, Belém, Pará, Brazil. Available from www.imazon.org.br (accessed January 2006).

ASA (American Soybean Association). 2003. China soybean imports running at record level. ASA Weekly Archives. ASA, St Louis, Missouri. Available from www.asa.org (accessed July 2005).

BACEN (Banco Central do Brasil). 2006. Exchange rate. BACEN, Brasilia. Available from http://www.bacen.gov.br (accessed January 2006).

BankTrack. 2004. Principles, profits, or just PR? Triple P investments under the equator principles. An anniversary assessment. BankTrack, Amsterdam.

BBC (British Broadcasting Company). 2004. Brazil wins double trade victory. 8 September. BBC, London. Available from http://news.bbc.co.uk/1/hi/business/3639620.stm (accessed January 2006).

Brookes, G. 2001. The EU animal feed sector: protein ingredient use and the implications of the ban on use of meat and bonemeal. Brookes West, Canterbury, United Kingdom.

Brookes, G., N. Craddock, and B. Kniel. 2005. The global GM market: implications for the European food chain. An analysis of labelling requirements, market dynamics and cost implications. Brookes West, Canterbury, United Kingdom.

Browder, J. O. 1986. Logging the rainforest: a political economy of timber extraction and unequal exchange in the Brazilian Amazon. Ph.D. dissertation. University of Pennsylvania, Philadelphia, Pennsylvania.

Brown, L. 2004. The Brazilian dilemma. Pages 157–176 in outgrowing the earth: the food security problem in an age of falling water tables and rising temperatures. Earth Policy Institute. Norton, New York.

Carvalho, G., D. C. Nepstad, D. G. McGrath, M. del C. V. Diaz, M. Santilli and A. C. Barros. 2002. Frontier expansion in the Amazon: balancing development and sustainability. Environment **44:**34–45.

Clay, J. 2004. Agriculture and the environment. World Wildlife Fund-U.S., Washington, D.C.

CONAB (Companhia Nacional de Abastecimento). 2006. Indicadores agropecuários. CONAB, Brasília, D.F., Brazil. Available from http://www.conab.gov.br (accessed May 2006).

DEFRA (Department for Environment, Food, and Rural Affairs). 2005. BSE: legislation. DEFRA, London. Available from http://www.defra.gov.uk/animalh/bse/legislation/index.html (accessed January 2006).

Diaz, M. del C. V., R. Kaufmann, D. Nepstad, and P. Schlesinger. 2006. Soybean yield in the Amazon Basin: climatic, edaphic, and economic determinants. Agricultural Economics: in press.

Fearnside, P. M. 2001. Soybean cultivation as a threat to the environment in Brazil. Environmental Conservation **28:**23–38.

Fearnside, P. M. 2003. Deforestation control in Mato Grosso: a new model for slowing the loss of Brazil's Amazon forest. Ambio **32:**343–345.

Gentile, C. 2004. Slave laborers number 25,000 in Brazil. United Press International, Washington, D.C. Available from http://washingtontimes.com/upi-breaking/20040719–071214-4181r.htm (accessed February 2006).

Goodland, R., and H. Irwin. 1975. Amazon jungle: green hell to red desert? Elsevier, Amsterdam.

Grupo A. Maggi. 2006. Rondonópolis, Mato Grosso, Brazil. Grupo A. Maggi. Available from http://www.grupomaggi.com.br/br/grupo (accessed February 2006).

Hard, D. L. 2002. Innovative developments in the production and delivery of alternative protein sources. Pages 125–140 in Protein sources for the animal feed industry. Animal and Production Health Proceedings, Food and Agriculture Organization, Rome.

Hecht, S. B. 1985. Environment, development and politics: capital accumulation and the livestock sector in eastern Amazonia. World Development **13:**663–684.

Hecht, S. B. 1993. The logic of livestock and deforestation in Amazonia. BioScience **43:**687–695.

Hecht, S. 2005. Soybeans, development and conservation on the Amazon frontier. Development and Change **36:**375–404.

Hecht, S., and A. Cockburn 1989. The fate of the forest: developers, defenders, and destroyers of the Amazon. HarperCollins, New York.

Houghton, R. A., D. L. Skole, C. A. Nobre, J. L. Hackler, K. T. Lawrence, and W. H. Chomentowski. 2000. Annual fluxes of carbon from deforestation and regrowth in the Brazilian Amazon. Nature **403:**301–304.

IBGE-PAM (Instituto Brasileiro de Geografia e Estatística, Produçao Agrícola Municipal). 2005. IBGE-PAM. Indicadores da economia mundial. Available from http://www.sidra.ibge.gov.br/bda/agric (accessed December 2005).

IBGE-PPM (Instituto Brasileiro de Geografia e Estatística, Produçao Agrícola Municipal). 2005. Brasília, Brazil. Available from http://www.sidra.ibge.gov.br (accessed January 2006).

IcWales. 2003. Call to boycott beef from Brazil. IcWales, Cardiff, Wales, United Kingdom Available from http://icwales.icnetwork.co.uk/0100news/0200wales/content_objectid=13402774_method=full_siteid=50082_headline=–Call-to-boycott-beef-from-Brazil-name_page.html#story_continue (accessed January 2006).

INPE (Instituto Nacional de Pesquisas Espaciais). 2005. Monitoramento da Floresta Amazonica Brasileira por Satelite Projecto Prodes. Available from http://www.obt.inpe.br/prodes/ (accessed January 2006).

Kaimowitz, D., B. Mertens, S. Wunder, and P. Pacheco. 2004. Hamburger connection fuels Amazon destruction. Center for International Forestry Research, Bogor, Indonesia. Available from www.cifor.cgiar.org (accessed February 2005).

Lima, A., C. T. Irigaray, R. T. Silva, S. Guimaraes, and S. Araujo. 2005. Sistema de Licenciamento Ambiental em Propriedades Rurais do Estadode Mato Grosso: Análise de Lições na Sua Implementação (Relatório Final). Ministério do Meio Ambiente/Secretaria de Coordenação daAmazônia/Programa Piloto para a Proteção das Florestas Tropicais do Brasil/Projeto de Apoio ao Monitoramento e Análise, Brazilia.

LMC International. 2003. Supply chain impacts of further regulation of products consisting of, containing, or derived from, genetically modified organisms. LMC International, Oxford, United Kingdom. Prepared for DEFRA and Food Standards Agency. Available from http://www.defra.gov.uk/environment/gm/research/pdf/epg_1–5-212.pdf (accessed July 2006).

Mahar, D. 2002. Ecological/economic land-use zoning: lessons from Rondônia. Chapter 5 in C. Woods and R. Porro, editors. Pattern and process of land use and forest change in the Amazon. University of Florida, Gainesville, Florida.

Margulis, S. 2004. Causes of deforestation in the Brazilian Amazon. World Bank, Washington, D.C.

Mattos, M. M. de, and C. Uhl. 1994. Economic and ecological perspectives on ranching in the eastern Amazon. World Development **22:**145–158.

MAPA (Ministério de Relações Exteriores). 2005. Agroindustria. MAPA, Columbia, Tennesee. Available from http://www.mre.gov.br/cdbrasil/itamaraty/web/port/economia/agric/apresent/apresent.htm (accessed July 2006).

MDIC (Ministério de Desenvolvimento da Indústria e Comércio). 2005. Available from http://aliceweb.desenvolvimento.gov.br/ (accessed January 2006).

Monbiot, G. 2005. The price of cheap beef: disease, deforestation, slavery, and murder. The Guardian, 18 October. Available from http://www.guardian.co.uk/bse/article/0,,1594799,00.html (accessed 28 June 2006).

Myers, N. 1981. The hamburger connection: how Central America's forests become North America's hamburgers. Ambio **10:**3–8.

Naylor, R., H. Steinfeld, W. Falcon, J. Galloway, V. Smil, E. Bradford, J. Alder, and H. Mooney. 2005. Losing the links between livestock and land. Science **310:**1621–1622.

Nepstad, D. C. 1999. Large-scale impoverishment of Amazonian forests by logging and fire. Nature **398:**505–508.

Nepstad, D. C., G. O. Carvalho, A. C. Barros, A. Alencar, J. P. Capobianco, J. Bishop, P. Moutinho, P. A. Lefebvre, U. L. Silva, and E. Prins. 2001. Road paving, fire regime feedbacks, and the future of Amazon forests. Forest Ecology and Management **154:**395–407.

Nepstad, D., J. P. Capobianco, A. C. Barros, G. Carvalho, P. Moutinho, U. Lopes, P. Lefebvre, and M. Ernst. 2000 Avança Brasil: os custos ambientais para a Amazônia (Avança Brasil: the environmental costs for Amazonia). Instituto de Pesquisa Ambiental da Amazônia, Belém, Brazil. (Also available from http://www.ipam.org.br).

Nepstad D., D. McGrath, A. Alencar, C. Barros, G. Carvalho, M. Santilli, and M. del C. Vera Diaz. 2002. Frontier governance in Amazonia. Science **295:**629–631.

OIE (Office International des Epizooties). 2005. World Organization for Animal Health. Annual incidence rate of bovine spongiform encephalopathy (BSE) in OIE Member Countries that have reported cases, excluding the United Kingdom. Available from http://www.oie.int/eng/info/en_esbincidence.htm (accessed May 2006).

PAHO (PanAmerican Health Organization). 2004. The Houston declaration. Agreed upon at the Hemispheric conference on the eradication of foot-and-mouth disease. PAHO, Washington, D.C. Availabe from http://www.paho.org/English/AD/DPC/VP/Houston-Declaration.htm (accessed July 2006).

People's Daily Online. 2004. Last year saw China's soybean import hit a record high in history. Also available from http://english.peopledaily.com.cn/200402/14/eng20040214_134838.shtml (accessed July 2006).

Philander, G. 1990. El Niño, La Niña, and the Southern Oscillation. Academic Press, San Diego, California.

Richards, M. 2004. Certification in complex socio-political settings: looking forward to the next decades. Forest Trends, Washington, D.C.

Rocha, A. do A., and, C. Bouças. 2006. Propagacao da gripe das aves já reduz preço da soja. Valor **1457:**A1.

Rochas, J. L. P., and M. A. Lopes. 2002. Rastreabilidade e certificacao da producao bovina: um comparativo entre alguns sistemas. Revista Brasileira de Agroinformatica **4:**130–146.

Roosevelt, M. 2006. The grass-fed revolution. Time 11 June. Available from http://www.time.com/time/magazine/article/0,9171,1200759,00.html (accessed 28 June 2006).

Rudel, T. K., O. T. Coomes, E. Moran, F. Achard, A. Angelsen, J. C. Xu, and E. Lambin 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change—Human Policy Dimensions **15:**23–31.

Schmink, M., and C. Wood. 1992. Contested frontiers. Columbia University Press, New York.

Silva Dias, M. A. F., et al. 2002. Cloud and rain processes in biosphere-atmosphere interaction context in the Amazon region. Journal of Geophysical Research, DOI:10.1029/2001JD0003353.

Simmons, C. 2004. The political economy of land conflict in the eastern Brazilian Amazon. Annals of the Association of American Geographers **94:**183–206.

Soares-Filho, B., D. Nepstad, L. Curran, G. Cerqueira, R. Garcia, C. Ramos, E. Voll, A. McDonald, P. Lefebvre, and P. Schlesinger. 2006. Modeling Amazon conservation. Nature **440:**520–523.

Soares-Filho, B., A. Alencar, D. Nepstad, G. Cerqueira, M. C. V. Diaz, S. Rivero, L. Solorzano, and E. Voll. 2004. Simulation of deforestation and forest regrowth along a major Amazon highway: the case of the Santarém-Cuiabá highway. Global Change Biology **10:**745–764.

Stickler, C., L. Bartels, M. DiGiano, R. M. Veluci, K. J. Keefe, and W. Hart. 2004. An evaluation of International Finance Corporation financing of Grupo André Maggi (project 11344) in the soybean sector: environmental and social impact considerations. University of Florida, Gainesville. Available from www.amazonia.org.br (accessed January 2005).

Stickler, C., and O. Almeida 2006. Harnessing international finance to foster sound land stewardship in the Amazon soy sector: the case of Grupo Maggi and IFC in Brazil. Sustainable Forestry: in press.

USDA-FAS (United States Department of Agriculture, Foreign Agriculture Service). 2003. Future agricultural expansion potential underrated Brazil. USDA-FAS, Washington, D.C. Available from http://www.fas.usda.gov/current2003.html (accessed May 2005).

Wertz-Kanounnikoff, S., and, K. M. Chomitz. 2005. Measuring the initial impacts on deforestation of Mato Grosso's program for environmental control. Policy research working paper series WPS3672. World Bank, Washington, D.C.

Woodwell, G. 2002. Forests in a full world. Yale University Press, New Haven, Connecticut.