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Challenges for Low-Carbon Agriculture and Forest Conservation in Brazil

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ACRONYMS

ARPA	Amazon Region Protected Areas
BLUM	Brazilian Land Use Model
CCBA	Climate, Community and Biodiversity Alliance
CO_2	Carbon Dioxide
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
GCF	Governors' Climate & Forest Task Force
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use and Land Use Change and Forestry
MRV	Measuring, Reporting, and Verifying
NCCP	National Climate Change Plan
PA	Protected Area
PAS	Sustainable Amazon Program
PPCDAM	Plan of Action for the Prevention and Control of Deforestation in the Amazon
PROAMBIENTE	Program for the Socio-Environmental Development of Rural Family Production in the Amazon
REDD	Reducing Emissions from Deforestation and Forest Degradation
UNFCCC	United Nations Framework Convention on Climate Change

CONTENTS

1. BACKGROUND

Brazil sits squarely under the magnifying glass of international scrutiny as both one of the largest carbon dioxide (CO_2) emitters from land use change and the custodian of the largest tropical forest in the world. Recent efforts on the part of the Brazilian government to curb deforestation on private properties, crack down on illegal logging,[1] and establish vast tracts of native forests as protected areas (more than 790,000 km^2 created since 2002, now covering 46 percent of the Brazilian Amazon biome),[2] when combined with the recent downturn of the agricultural sector, helped reduce deforestation in 2011 by 68 percent of the historical baseline of 19,600 km^2 per year between 1996 and 2005, resulting in a CO_2 reduction of more than 1 billion tons—equivalent of twice the target of the Kyoto Protocol for the 2008–2012 period.[3] In addition, voluntary registries that encourage responsible land management by cattle ranchers and soy farmers[4] and the perception among Amazon farmers and ranchers that standing for ests will soon gain value through a carbon market[5] are sustaining further reductions in deforestation.[6] These perceptions and voluntary initiatives have been bolstered by international commodity certification systems as well as by moratoriums on growing soy and beef on recently cleared lands, which attempt to exclude illegal deforesters from international commodity markets.

In Copenhagen in 2009, Brazil reported a large reduction in Amazon deforestation—its major source of carbon emissions—and announced its official goal to reduce greenhouse gas (GHG) emissions by 36–39 percent by 2020.[7] Today Brazil is a world leader in both committing to and achieving GHG reductions and also a leading exporter of agricultural commodities. Brazil is the number one exporter by volume of beef, coffee, and sugar, is poised to become the top exporter of soy in 2012, and is behind only the United States in corn and ethanol exports. In large part this success stems from the role of the federally funded agricultural research and development corporation, EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), which led a revolutionary campaign to improve crop yields on tropical lands. Today soy yields in Brazil are

[1] Serviço Florestal Brasileiro & Instituto do Homem e Meio Ambiente da Amazônia 2010.
[2] Soares-Filho et al. 2010.
[3] Nepstad et al. 2011.
[4] Nepstad et al. 2009.
[5] Nepstad et al. 2009; Soares-Filho et al. 2010.
[6] Nepstad et al. 2011.
[7] Brasil 2009.

higher than in the United States,[8] and agricultural policies, such as the national ethanol program, have contributed to the success of Brazilian agribusiness, which in general thrives despite receiving fewer price supports and subsidies than agribusiness in the United States or the European Union.

The dilemma surrounding how to conserve Brazil's vast forests while at the same time expanding agricultural production to meet increasing domestic and global demand is therefore driving the current debate about the fate of the Forest Code. Brazil's powerful agricultural sector hopes to double agricultural and livestock output by 2020, which threatens to undermine targets for the National Climate Change Plan (NCCP).[9] The government's Growth Acceleration Plan, for example, is a heavily capitalized, interministerial program that has few environmental safeguards and will increase the profitability of deforestation-dependent activities by lowering the costs of transportation, storage, and energy.

Intensification of the cattle industry has been suggested as one way to reduce pressure on forest margins and spare land for soybean or sugarcane production,[10] and this is the cornerstone of Brazil's plan for reducing GHG emissions. The NCCP and Brazil's proposed Nationally Appropriate Mitigation Actions aim to constrain the land area occupied by extensive cattle ranching by intensifying production. To this end, federal credit programs such as the low-carbon agriculture program[11] and R&D activities in Brazil are aligning to support intensification goals, but there is no guarantee that this will decrease the demand for land at the forest margin, particularly if land tenure issues are not thoroughly resolved through a comprehensive land titling and zoning program and if enforcement of existing environmental laws remains inconsistent in frontier regions.[12] Moreover, the attack on the Brazilian Forest Code as well as federal and private investments in infrastructure continue to threaten the progress toward NCCP targets. Thus Brazil, like many developing countries, faces an immense challenge as it weighs how to both encourage development and reduce GHG emissions.

[8] Nass et al. 2007.
[9] Brasil, 2009.
[10] Gouvello et al. 2010.
[11] MAPA and MDA 2011.
[12] Bowman et al. 2012.

In this respect, there is a pressing need to develop policies that are compatible with Brazil's plan to expand agricultural production and its target of reducing national CO_2 emissions. Within this context, this paper discusses the feedbacks between climate change, deforestation, and agricultural expansion and presents scenarios of agricultural demand and forest conservation and restoration policies in Brazil. In addition, it discusses the implications of these scenarios for food and befoul supply, the provision of ecosystem services, and climate change mitigation. Modeling these scenarios provides an integrated assessment of plausible pathways for achieving the goals of the National Climate Change Plan, for making an objective source of information available for the debate on the Forest Code, and for supporting Brazil's cropland expansion plan as well as anticipating potential conflicts.

2. DIRECT AND INDIRECT IMPACTS OF AGRICULTURAL EXPANSION

The capacity of the planet to sustain life is waning due to increasing anthropogenic use of natural resources.[13] In this context, land use and cover change in Brazil has become a global concern, given its historical contribution to global carbon emissions.[14] The Brazilian Amazon lost about 20 percent of its forests between 1970 and 2011,[15] and conversion of cerrado vegetation has occurred over 40 percent of the biome and continues at a rate of 4,000 km^2 annually.[16] Only 12–16 percent of the heavily fragmented Atlantic forest biome remains,[17] and it continues to be deforested at an annual rate of 562 km^2 (1995–2005 period).[18]

In Brazil, forest conversion to pasture, cropland, and urban areas is driven by diverse causes, including government programs that provide perverse incentives for frontier expansion, land speculation in the absence of land titling and governance, logging, and cropland and cattle herd expansion in response to the growing demand for biofuels and for food and fueled by advances in tropical agriculture. Internal migration associated with spontaneous settlement and

[13] Brown 2011.
[14] Houghton 2008; Leite et al. in review.
[15] INPE 2011a.
[16] Ferreira et al. 2011.
[17] Ribeiro et al. 2009.
[18] SOS MA 2011.

smallholder settlement programs on forested land, infrastructure expansion and improvement, and urban sprawl, among other factors,[19] also exacerbate expansion and the conversion of forests to other uses.

These causes of deforestation are complex and frequently interrelated.[20] In the past, for example, fiscal incentives and state-settlement projects, together with the opening of arterial roads, triggered a large inflow of migrants to the Amazon region—migrants who continue to clear land at the forest frontier in search of new opportunities.[21] The expansion of large-scale farms and ranches was fed by progress in tropical agriculture that enabled a rapid occupation of the central-western cerrado.[22] These properties have been responsible for a large share of deforestation in recent years,[23] while recent deforestation in the Atlantic forest is mostly driven by real estate speculation around large urban centers[24] as well as by charcoal production in more remote regions for iron smelters (primarily in Minas Gerais).

Today, soy and sugarcane occupy large swaths of the southern and central-western Brazilian cerrado and have expanded into the Amazon region despite the official ban on growing sugarcane there,[25] raising concerns about environmental and social consequences. In addition to the direct impacts of traditional land management practices on soil fertility and carbon emissions, water consumption, and pollution from fertilizers and herbicides, the conversion of native vegetation to croplands is associated with biodiversity losses and the loss of carbon sequestration services as native vegetation is cleared.[26] The latter, together with carbon emissions from deforestation, further aggravates global warming. In addition, deforestation modifies regional climate and river regimes[27] due to changes in surface albedo,[28] temperature and evapotranspiration,[29] and water cycling.[30] Thus, forest conversion to agriculture in the Amazon

[19] Soares-Filho et al. 2005; 2008a.
[20] Soares-Filho et al. 2008a.
[21] Garcia et al. 2007.
[22] Jepson et al. 2010.
[23] Ferreira et al. 2011.
[24] Texeira et al. 2009.
[25] Manzatto et al. 2009.
[26] Foley et al. 2007.
[27] Coe et al. 2009.
[28] Costa et al. 2007.
[29] Loarie et al. 2011.
[30] Bruijnzeel 2004.

has broad implications for global climate and the provision of a wide range of ecosystem services.[31]

Although 80 percent of deforestation in the Amazon is associated with cattle ranching,[32] its direct impact on deforestation is unknown. Only 13–18 percent of deforestation is caused by conversion to soy crops,[33] of which less than 6 percent can be attributed to biodiesel.[34] However, there is growing concern that soy expansion fuels deforestation elsewhere as it displaces cattle ranchers to inner Amazon frontiers,[35] where land is still cheap.[36] This increases land speculation and land concentration among larger-scale farmers with greater skills and capital, hence mobilizing deforesters who have capitalized on high rates of agricultural return at scale, and it spurs rural-urban migrations as land prices increase.[37]

The magnitude of these indirect impacts of agricultural expansion on Amazon deforestation are yet unknown, in spite of attempts to model the phenomena.[38] However, it is clear that high rates of return to agriculture increase the opportunity costs of conservation[39] as well as the costs of enforcement,[40] and they put more pressure on the Brazilian government to soften environmental laws, such as the bill passed to reform the Brazilian Forest Code. President Dilma Roussef has even issued a series of decrees decreasing the size of recently created protected areas.[41] These attacks on Brazilian environmental laws are a backlash against an environmental agenda that has advanced largely on the basis of laws that restrict land uses and sometimes vilify farmers and ranchers but that has failed to provide landowners with incentives for compliance or to recognize and reward land stewards.

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[31] Costanza et al. 1997; MA 2005; Turner et al. 2007; Stickler et al. 2009.
[32] Wassenaar et al. 2007.
[33] Morton et al. 2006; Lima et al. 2011.
[34] Lima et al. 2011.
[35] Nepstad et al. 2006; Arima et al. 2011.
[36] Bowman et al. 2012.
[37] Soares-Filho et al. 2005; Garcia et al. 2007.
[38] Lapola et al. 2010, 2011; Gouvello et al. 2010.
[39] Soares-Filho et al. 2010.
[40] Nepstad et al. 2009.
[41] Brasil 2011.

In light of these events, a full-speed reversal of the trend toward decreasing deforestation in Brazil looms large.[42] The profitability of deforestation is rising and could remain high for many years or decades, given the global outlook for continued growth in agricultural commodity prices.[43] As the demand for agricultural products increases, the commitment by commodity buyers to exclude illegal deforesters from supply chains may weaken. In addition, farmers and ranchers committed to sound land stewardship[44] have yet to realize economic benefits for their efforts and for the high cost of complying with international roundtable certification. Finally, diminishing prospects for an international REDD+ market may further discourage landowners from participating.[45]

3. FEEDBACKS BETWEEN CLIMATE CHANGE, DEFORESTATION, AND AGRICULTURE

Global forests remove 2.4 Pg (1 Petagram equals 1 billion tons) of carbon (1 kg of carbon equals 3.666 kg of CO_2) per year from the atmosphere[46]—equivalent to nearly a third of annual fossil fuel emissions.[47] In addition, regrowth of trees on previously deforested lands in the tropics absorbed a further 1.6 Pg of carbon annually between 1990 and 2007.[48] In this vein, as the world's largest tropical forest (5.4 million km^2), the Amazon plays a central role in maintaining the global carbon balance.[49]

The Amazon forest is home to about 20 percent of known terrestrial species,[50] contains one-tenth of the global carbon stored in land ecosystems (86±17 Pg of carbon),[51] and accounts for one-tenth of global net primary production,[52] sequestering 0.49±0.18 Pg of carbon in an average year.[53] The Amazon forest is also an important player in regional climate regimes; its forests cool the air by pumping about 7 trillion tons of water per year into the atmosphere via

[42] Metzger et al. 2010.
[43] Grantham 2011.
[44] Nepstad et al. 2009.
[45] Nepstad et al. 2011.
[46] Pan et al. 2011.
[47] Van der Werf et al. 2009.
[48] Pan et al. 2011.
[49] Malhi et al. 2008.
[50] Raven 1988.
[51] Saatchi et al. 2007.
[52] Melillo et al. 1993.
[53] Phillips et al. 2008.

evapotranspiration.[54] In essence, the forest functions as a giant air conditioner that keeps the regional climate humid and rainy by cycling atmospheric water in the form of aerial rivers to the southeast and center of the South American continent.[55] In addition, the Amazon forest influences the regional climate of areas such as the U.S. Midwest via climatic teleconnections.[56]

Despite these important roles of the Amazon, tropical deforestation has released significant amounts of carbon to atmosphere. During the 1990s, between 0.8 and 2.2 Pg of carbon were emitted per year from tropical deforestation, representing 10–35 percent of global GHGs.[57] Today this share has decreased to 12 percent, mainly due to increased fossil fuel emissions, but also due to declining global deforestation rates.[58] The Amazon carbon stocks are also sensitive to shifts in climate. In the severe drought of 2005, the Amazon forest lost about 1.2–1.6 Pg of carbon biomass,[59] and in 2010 a more extensive drought resulted in a loss of about 2.2 Pg of carbon.[60]

In addition to deforestation, forest fires also influence global warming. Alencar et al.[61] estimated that annual committed carbon emissions from fires in the Brazilian Amazon may amount to 0.094±0.070 Pg in El Niño–Southern Oscillation years. However, this figure can be far greater in extreme El Niño years, such as the event of 1997–1998, when emissions from forest fires in Mexico, the Amazon, and Indonesia totaled 1.6 Pg of carbon[62]—the equivalent of 18 percent of current fossil fuel emissions worldwide.[63] Not only do forest fires alter atmospheric composition, they also interrupt rain cloud formation,[64] thereby reducing rainfall[65] and increasing the average residence time of aerosols in the atmosphere.[66] These effects also have a significant negative impact on human health.[67] For example, during the extreme drought in the southwestern Amazon in 2005—probably associated with the abnormal warming of the tropical North

[54] Moutinho and Schwartzman 2005.
[55] Fearnside 2003.
[56] Avissar and Werth, 2003.
[57] Achard et al. 2002; DeFries et al. 2002; Houghton, 2005; IPCC 2007.
[58] Van der Werf et al. 2009.
[59] Phillips et al. 2009.
[60] Lewis et al. 2011.
[61] Alencar et al. 2006.
[62] Page et al. 2003; Cairns et al. 2000; Phulpin et al. 2002.
[63] JRC 2009.
[64] Ackerman et al. 2000.
[65] Andreae et al. 2004.
[66] Ramanathan et al. 2001.
[67] Mendonça et al. 2004.

Atlantic[68]—more than 40,000 people in the State of Acre sought medical care due to a persistent smoke plume, which stemmed from multiple fires that burned 300,000 hectares of forest in the region.[69] Moreover, direct economic losses from widespread fires in 2005 amounted to US$50 million.[70]

In sum, fires in tropical forests release globally significant amounts of carbon to the atmosphere and may increase in importance as a result of climate change. Among the Intergovernmental Panel on Climate Change (IPCC) scenarios that do not consider mitigation efforts, the A2 scenario is currently considered very plausible, given the steady increase in anthropogenic carbon emissions.[71] Under this scenario, temperatures are expected to rise between 2° and 5.4°C.[72] As a result, climate models predict a replacement of a large portion of the Amazon forest with savanna-like ecosystems by the end of the twenty-first century, turning the standing Amazon forests from a net sink to a source of atmospheric carbon.[73] In addition, extensive deforestation may reduce rainfall over the Amazon[74] and increase the length of the dry season,[75] augmenting the risk of loss of a large portion of the forest to climate change–induced fires by as soon as 2020.[76]

Therefore, the synergy among deforestation, which may be exacerbated by growing global demands for agricultural products and biofuels,[77] and infrastructure investments in the Amazon,[78] forest degradation by logging and fire, land management practices associated with fire, and an increasingly drier climate may serve to boost fire activity in the Amazon, leading the remaining forests toward a vicious cycle of impoverishment[79]—a tipping point that may be reached within the next two decades.[80] The degree to which this process will affect the Amazon forest is still uncertain and depends on other joint effects of climate change, such as the potential

[68] Marengo et al. 2008.
[69] Brown et al. 2006; Aragão et al. 2007.
[70] Brown et al. 2006.
[71] Van der Werf et al. 2009.
[72] IPCC 2007.
[73] Cox et al. 2000, 2004; Botta and Foley 2002; Oyama and Nobre 2003; Collins 2005; Li et al. 2006; Salazar et al. 2007; Nobre et al. 2010.
[74] Sampaio et al. 2007; Ramos da Silva et al. 2008.
[75] Costa and Pires 2010.
[76] Golding and Betts 2008; Silvestrini et al. 2011.
[77] Nepstad et al. 2006.
[78] Soares-Filho et al. 2006.
[79] Nepstad et al. 2001.
[80] Nepstad et al. 2008; Golding and Betts 2008.

fertilization of vegetation from higher atmospheric CO_2 concentrations[81] and the level of resilience of remaining forests.[82]

In the Bali map, the 13th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) proposed to drastically diminish tropical deforestation in order to keep the atmospheric CO_2 concentration below 450 ppm (currently it is at 389 ppm (climate.nasa.gov/keyIndicators) and to reduce global emissions by 2–3 percent a year beginning in 2010. This would constrain the rise in global temperatures within 2°C until 2100, aiming to avoid a dangerous disruption in global climate.[83] Brazil plays a leading role in this global effort, given its large extent of native vegetation (it contains 60 percent of Amazon forest), which stores a total of 92 Pg of carbon.[84]

Brazil has already showed success in both committing to and achieving carbon emission reductions from deforestation. However, it risks losing these important gains in forest conservation through drought cycles and forest fires. The extreme drought of 2005 was eclipsed by a more severe drought episode in 2010 in which vast tracts of forest burned in Brazil, Peru, and Bolivia.[85] The climate-driven Amazon forest dieback that is predicted to begin by midcentury may have already begun through positive feedbacks between drought, fire-dependent land uses, and forest fires.[86] A comprehensive conservation strategy for the Amazon therefore requires careful consideration of the interactions between climate change, deforestation, and fire and relies heavily on international efforts to mitigate global warming.

Current predictions of the impacts of climate change in the northeast of Brazil are dramatic. In this semiarid region where it rains less than 600 millimeters per year, climate change may produce a desert[87] and provoke economic loss, unemployment, and vulnerability to vector-borne disease.[88] Such a change would also prompt a flow of migrants from low-income

[81] Rammig et al. 2010.
[82] Soares-Filho et al. in review.
[83] O'Neill and Oppenheimer, 2002; Elzen and Meinshausen 2005.
[84] Leite et al. in review.
[85] Lewis et al. 2011.
[86] Nepstad et al. 2011.
[87] CEDEPLAR and FIOCRUZ 2008.
[88] Domingues et al. 2008.

rural areas to other parts of Brazil by as early as 2035.[89] Thus environmental trends of climate change threaten global progress for the poor.[90]

With respect to agriculture, climate change can cause large geographic shifts in productivity, thereby reducing the productive area of grains (especially soy, due to the expected increased frequency of water stress events) in central and southeast Brazil by up to 40 percent.[91] In addition, cassava—a staple crop of rural subsistence farmers—may disappear from the northeast, and coffee plantations will be greatly impaired throughout the southeast. On the other hand, southern Brazil will become more suitable for tropical crops, such as cassava and sugarcane. A net gain in cropland due to climate change in Brazil is likely to occur only for sugarcane, whose suitable lands are expected to increase by 100 percent. In general, considering nine crops evaluated by Assad et al.,[92] the economic losses from climate change are expected to be about US$4 billion by 2020 and could reach US$14 billion by 2070 under the IPCC-A2 scenario.[93] They could be even higher, as more frequent and extreme weather events will impose a heavy burden on food security and may result in further cropland expansion.

The agricultural sector is responsible for 15 percent of global GHG emissions, mainly due to emissions of methane and nitrous oxide.[94] If the trend of global consumption growth continues, there will be a significant increase of non-CO_2 GHG emissions, which will also increase due to shifting global consumption patterns toward high-value foods such as meat and milk.[95] Therefore, a positive feedback exists between climate change, decreasing crop yields, additional deforestation needed to accommodate those geographic shifts, and crop expansion due to improved levels and patterns of global food consumption. To counteract this trend, agriculture intensification has been suggested. For example, Burney et al.[96] investigated the effect of agricultural intensification on historic carbon emissions between 1961 and 2005 and concluded that the emissions related to fertilizer application have increased, but the net effect of applying technologies for agricultural intensification avoided emissions of up to 161 Pg of carbon since

[89] CEDEPLAR and FIOCRUZ 2008.
[90] UNDP 2011.
[91] Assad et al. 2008.
[92] Ibid.
[93] Ibid.
[94] Popp et al. 2010.
[95] Ibid.
[96] Burney et al. 2010.

1961. According to their estimates, each dollar invested in agricultural yields has resulted in 68 fewer Kg of carbon emissions in comparison to 1961 technology.

Thus, to reach the objectives of food production and climate mitigation, agricultural intensification appears to be a key factor. But local and regional realities require specific strategies[97] as well as large investments.[98] Agricultural intensification also comes at a cost to the environment, as croplands release significant amounts of nitrogen and phosphorus from fertilizers and organic matter, and they pollute local and regional ecosystems via the release of nitrites, nitrates, and pesticides into waterways, which can cause eutrophication of freshwater ecosystems and an associated loss of aquatic biodiversity as well as groundwater contamination.[99] In addition, irrigated agriculture accounts for around 70 percent of the world's freshwater use, of which 15–35 percent is considered unsustainable.[100]

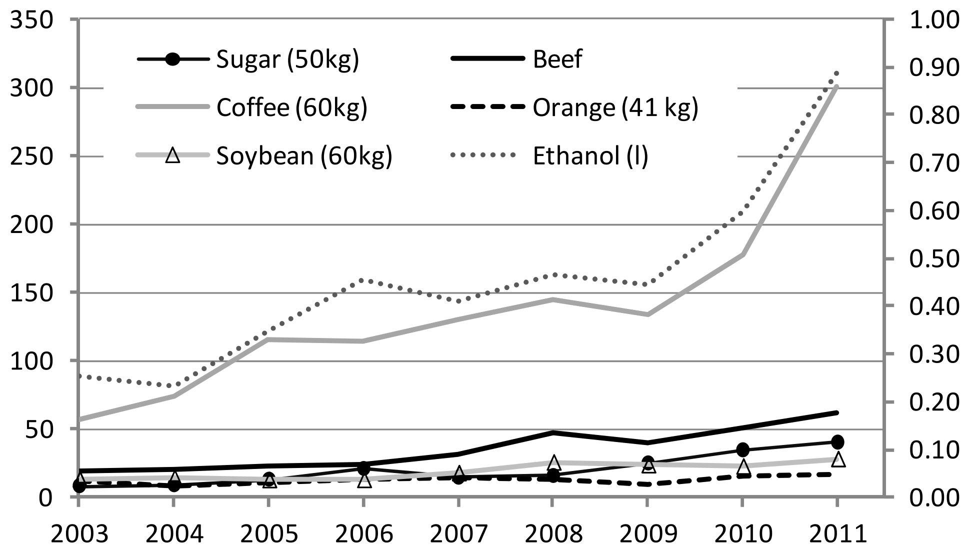
4. SCENARIOS OF POTENTIAL AGRICULTURAL EXPANSION IN BRAZIL TO MEET BIOFUEL AND CROP DEMANDS

If, in practice, improving the productivity of ranching will allow Brazil to reconcile forest conservation with crop expansion, yielding land to agricultural production as demand increases for food and biofuels produced domestically (see Figure 1), this strategy is not straightforward. Rather than large investments in cattle intensification, as suggested by Gouvello et al.,[101] this strategy will require application of the best science to develop sound solutions that satisfy the principles or goals of a low-carbon rural development strategy. The technical, institutional, and policy solutions can be addressed in the context of a national strategy that includes a carefully planned expansion of sugarcane, soy, and other crops and forest plantation onto land that has already been cleared for cattle pasture as well as land titling at the forest margin.[102] This must be accompanied by a low-carbon program that emphasizes investments in designing and implementing solutions both to develop best practices for land use and to maintain or recover

[97] DeFries and Rosenzweig 2010; Foley et al. 2011.
[98] Leite et al. 2009; Gouvello et al. 2010.
[99] Tilman 1999.
[100] Rosegrant et al. 2009.
[101] Gouvello et al. 2010.
[102] Bowman et al. 2012.

forests in order to maintain climate stability and all the environmental services that forest ecosystems provide.

Figure 1. Price trend of Brazil's major agricultural commodities



Source: CEPEA (2011).

Thus, science must be the basis for a process that establishes a comprehensive low-emission land use strategy aimed at informing and effectively engaging a broad spectrum of stakeholders. A scientific platform named SimBrasil does this (www.csr.ufmg.br/simbrasil); it includes the best data and knowledge on land use, cropping, ranching, and forestry as well as forest carbon biomass and land cover change and land use emissions to serve as a tool to explore a range of national strategies aimed at reconciling crop expansion and forest conservation in Brazil

SimBrasil was originally developed for the World Bank's Low Carbon Country Case Study for Brazil.[103] This study encompasses the four major emission sectors in Brazil: energy, transport, waste, and land use and land use change and forestry (LULUCF). For the latter, the study developed two scenarios: a reference and an alternative low-carbon scenario. In the reference scenario, 20 million ha of additional land are required to accommodate the expansion of all activities by 2030, increasing the total area in agriculture by 7 percent (from the current

[103] Gouvello et al. 2010.

257 million ha to 276 million ha). Most of this expansion is expected to occur in the Amazon region (24 percent), and secondarily in the states of Maranhão, Piauí, Tocantins, and Bahia. Pastures are expected to occupy most of these areas (207 million ha by 2030), and further deforestation will be needed to accommodate this expansion. (See Table 1).

Table 1. Comparison of land use results for the reference and low-carbon scenarios

Land Use	2008	Reference Scenario in 2030	Low-Carbon Scenario in 2030	Difference in 2030
	(million hectares)			
Grains (harvest)	37.79	47.92	47.86	–0.57
Sugarcane	8.24	12.70	19.19	6.49
Forest plantation	5.87	8.45	11.17	2.72
Pasture	205.38	207.06	137.82	–69.24
Total area for agriculture and livestock	257.28	276.13	216.04	–60.08
Regrowth	–	–	44.34	44.34
	(per 1000 heads)			
Herd	201,410	234,460	208,000	–26.460

Source: Gouvello et al. (2010).

In the low-carbon scenario, cropland for grains is expected to expand by 26 percent. In addition, sugarcane crops are projected to expand by 6.4 million ha so that Brazil will replace 80 percent of its gasoline consumption with ethanol and still meet 10 percent of estimated global demand for ethanol to achieve an average worldwide gasoline mixture of 20 percent ethanol by 2030. This scenario also assumes the expansion of commercial forest plantations by 2.7 million ha to eliminate deforestation due to charcoal production by 2017 and offset 46 percent of coal used for iron and steel production by 2030. Finally, under the low-carbon scenario, a countrywide forest restoration of 44 million ha would take place by 2030 to bring illegally deforested riparian zones and legal reserves into compliance with the Forest Code.

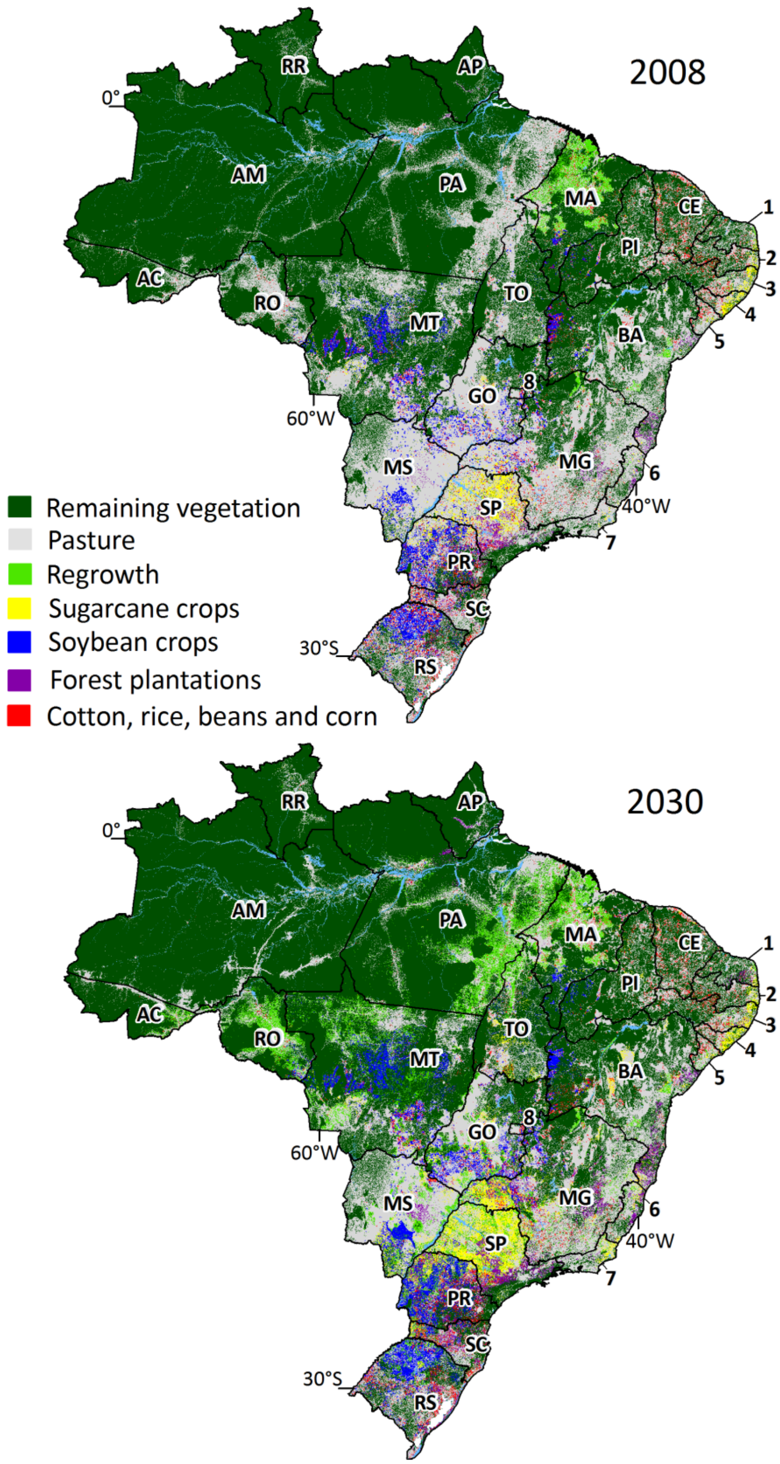
All this will amount to 70.4 million ha, but in contrast to the reference scenario no direct deforestation will take place, because a portion of arable pasturelands that cover over 90 million ha in the cerrado and Atlantic forest alone will be used to accommodate agricultural expansion, and degraded or low productivity pastures will be used for reforestation. Although pastureland decreases from 208 million to 137 million ha in the low-carbon scenario, herd size still increases slightly from 205 million to 208 million head. Thus, the main assumption of the low-carbon scenario is that it is possible to free up pasture for crop expansion by increasing livestock productivity, and that simultaneous expansion of cropland and forest plantations by 50 percent and restoration of 44 million ha of forest would be feasible if cattle ranching in Brazil could be intensified from the current of 1.1 head to 1.5 head per hectare. (See Figure 2).

In the Brazil Low Carbon Country Case Study, SimBrasil is loosely coupled to BLUM (Brazilian Land Use Model; iconebrasil.org.br), which estimates the demand for cropland based on competition between major crops. In this way, BLUM calculates the amount of land area allocated to each of a basket of six crops: soy, sugarcane, corn, cotton, beans, and rice, plus forest plantation and pasture for each Brazilian microregion. And it passes on those quantities to SimBrasil. SimBrasil, operating at a spatial resolution of 1 km^2, then spatially explicitly allocates those lands taking into account potential rents of crops based on specific agrozoning,[104] terrain suitability, and logistics. If a microregion does not contain sufficient arable pasture for expansion, either SimBrasil deforests available native vegetation or it “exports” residual demand to neighboring microregions, creating a cross-country cascade of land use changes. SimBrasil also simulates Amazon deforestation resulting indirectly from cropland and herd expansion by using an econometric model.[105]

Under the low-carbon scenario, SimBrasil results indicate that deforestation throughout Brazil could decrease by 68 percent by 2030 compared with the reference scenario. In the Atlantic Forest, this reduction would amount to 90 percent, in the Amazon to 68 percent, and in cerrado to 64 percent. Moreover, Amazon deforestation would fall steeply to 17 percent of the historical annual average of 19,500 km^2 from 1996 to 2005, complying, therefore, with the NPCC target of 20 percent of the baseline by 2020.

[104] Assad et al. 2008.
[105] Soares-Filho et al. 2010.

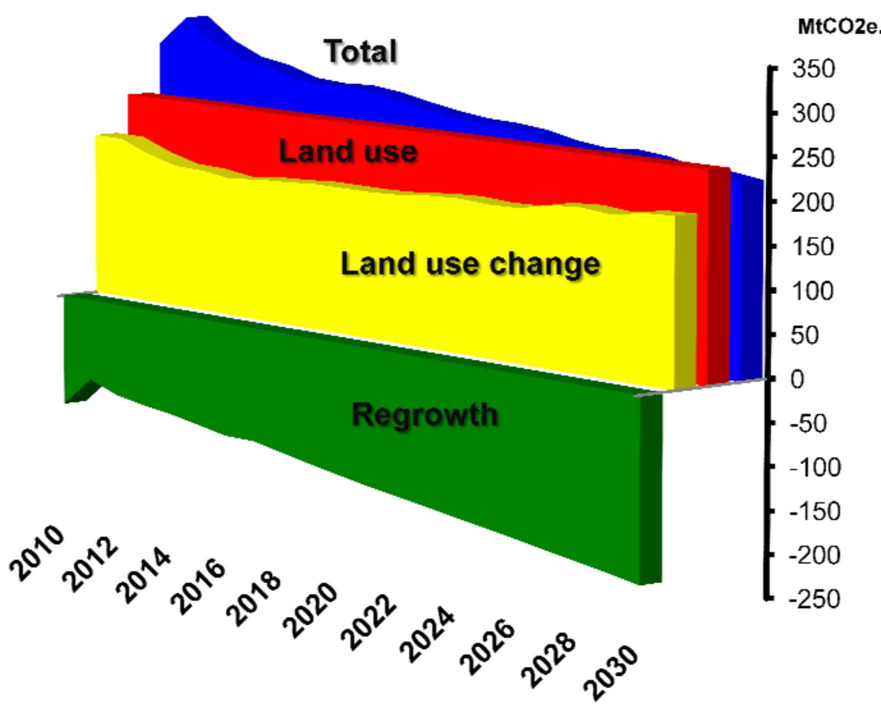
Figure 2. Land use in Brazil in 2008 and in 2030 under the low-carbon scenario.



Key to states: 1 - Rio Grande do Norte, 2 - Paraíba, 3 - Pernambuco, 4 - Alagoas, 5 - Sergipe, 6 - Espírito Santo, 7 - Rio de Janeiro, 8 - Distrito Federal, AC - Acre, AM - Amazonas, AP - Amapá, BA - Bahia, CE - Ceará, GO - Goiás, MA - Maranhão, MG - Minas Gerais, MS - Mato Grosso do Sul, MT - Mato Grosso, PA - Pará, PI - Piauí, PR - Paraná, RO - Rondônia, RR - Roraima, RS - Rio Grande do Sul, SP - São Paulo, SC - Santa Catarina, TO - Tocantins.

Figure 3 depicts total CO_2 emissions from LULUCF as well as the total balance for the low-carbon scenario from 2010 to 2030. Brazil's annual emissions from LULUCF, which already account for the 68 percent reduction in Amazon deforestation that took place since 2004, are approximately 350 M tons of CO_2. If a low-carbon scenario prevails, further reductions may result in a drop in Brazil's annual emissions from LULUCF to only ≈ 200 M tons of CO_2 by 2030. Over this period, emissions from livestock under this scenario will eventually surpass the ones from land use change, thus highlighting the need to improve the productivity of cattle ranching in order to reduce enteric methane emissions.

Figure 3. Total and sector balances for land use, land use change, and forestry under the low-carbon scenario



Source: Gouvello et al. (2010).

Model results reveal, therefore, that Brazil has a unique opportunity to meet its goals of agricultural expansion by 2030 while undertaking a large forest restoration program that would recuperate 44 M ha of forests and potentially sequester ≈5 Pg of carbon. But to harvest the full range of opportunities to mitigate GHG emissions, it is essential that Brazil coordinate policies and measures across environmental and agricultural sectors simultaneously, reconciling the goal of the Ministério de Agricultura, Pecuária e Abastecimento of increasing agricultural production with the targets of NCCP and compliance with the Forest Code.

5. PATHWAYS FOR LOW-CARBON AGRICULTURE

In light of the results presented in the previous section, it is clear that Brazil has the potential to make a substantial contribution to climate change mitigation while developing a low-carbon rural economy. Nevertheless, this effort is not trivial and will demand diverse policy initiatives and financial incentives. For example, the cornerstone proposal of the low-carbon study—intensification of the Brazilian cattle herd—may be viable in terms of land availability, but it will be difficult to implement. According to Gouvello et al.,[106] it will be necessary to subsidize cattle ranchers with US$280 billion (net present value between 2010 and 2030) in order to intensify production to 1.5 head per hectare by 2030. This is the Achilles' heel of this plan, as cattle ranching provides, in general, very low rates of return.[107] Many cattle ranchers in areas where intensification would be required have invested little in capital or new technologies. Thus it is expected that this undertaking would be led by agribusiness and would only take place in regions where conditions are highly favorable for intensification. These regions might be characterized by proximity to markets and supply of agricultural inputs (such as fertilizers and lime), proximity to high-productivity grain production zones, and availability of arable land that is not suitable for cultivation of higher-rent crops such as soy or sugarcane. Therefore, understanding the geography of intensification will be key to its success.[108]

[106] Gouvello et al. 2010.
[107] Bowman et al. 2012.
[108] Ibid.

Among initiatives aimed at intensifying beef production, pasture restoration is cited as central.[109] According to Gouvello et al.,[110] 60 percent of pastures in the cerrado region are degraded. Pasture restoration increases yields, hence carrying capacity, as well as fixes soil carbon and prevents erosion. However, not all degraded pasture can or must be recuperated due to marginal suitability; such areas must be set aside for forest restoration or used for forest or oil palm plantations. In addition to the challenges posed by high input and transportation costs, pasture restoration may be prohibitively costly due to a steep yield decline after three to five years of use (Alysson Paulinelli, personal communication).

With this in mind, adopting integrated crop-livestock systems, whether associated or not with feedlot systems, may be a more feasible option. However, such systems demand upfront investments, thus capital—in addition to agricultural knowledge and business skills—and arable land. If these conditions are met, such systems may attain sustainable stocking densities of 3 animals/ha or more,[111] while at the same time providing carbon fixation through, for example, rotation of Brachiaria and maize.

Additional efforts include improving fodder quality, which is still relatively unexplored, and genetic improvement of the herd. The latter is particularly important for Brazil, as its herd is double the size of the U.S. herd but produces less meat. Part of this difference is due to production systems, which are extensive in Brazil and extensive/intensive in the United States, where most of the animals are kept in feedlots. Furthermore, the Brazilian herd has a longer lifecycle, which limits productivity and adds to the methane emissions per unit of meat produced. Shortening the cattle lifecycle through productivity improvements seems to be a promising way to substantially reduce enteric methane emissions from Brazil's large cattle herd, since the emissions factor of intensive systems is only ≈13 percent lower than that of extensive systems (1.0 versus 1.15 ton of CO_2 equivalent per head per year).[112]

Complementary measures to achieve a low-carbon land use sector should also focus on a number of other initiatives: zero tillage cultivation, which can help control soil temperature,

[109] Sá et al. 2010.
[110] Gouvello et al. 2010.
[111] Sá et al. 2010.
[112] Bustamante et al. 2009.

improve soil structure, increase soil water-storage capacity, reduce soil loss, and enhance the nutrient retention of plants; promotion of the use of sugarcane waste to generate energy at ethanol and sugar plants; expansion of commercial forest plantations to replace charcoal from deforestation, for example through integrated livestock-forestry systems;[113] organic agriculture techniques that improve soil nutrients;[114] and an end to deforestation[115] while undertaking a countrywide forest restoration project to comply with Brazil's Forest Code.[116] (The low-carbon agriculture program included the mixed livestock-forestry system as an alternative for the reduction of GHG emissions;[117] the program expects to increase the area of this mixed system by 4 million hectares by 2020.) The forest restoration project constitutes a major potential carbon sink that could sequester ≈5 Pg of carbon.

6. MEETING THE GOALS OF LOW-CARBON AGRICULTURE AND COMPREHENSIVE ENVIRONMENTAL CONSERVATION

By and large, reducing emissions from deforestation offers the lowest-cost option to mitigate global warming in Brazil.[118] Although the low-carbon study showed that agricultural expansion can take place in Brazil without further deforestation, this may not be a win-win game due to the indirect impacts on deforestation of the growth in the agricultural sector, as it capitalizes deforesters and increases land prices. Therefore, additional measures are needed to reduce deforestation in Brazil. These include protected area (PA) consolidation in the Amazon, mainly through support for the ARPA program[119] as well as creation of new PAs along the active deforestation frontier.[120]

In addition, it is necessary to put PAs to work by upgrading extractive production chains in sustainable use reserves in order to lower production costs and stabilize a market floor price. International certification schemes and improvements in supply chains are also needed to provide

[113] Oliveira et al. 2010.
[114] Pimentel et al. 2005.
[115] Nepstad et al. 2009.
[116] Gouvello et al. 2010.
[117] MAPA and MDA 2011.
[118] Nepstad et al. 2009.
[119] Soares-Filho et al. 2008b.
[120] Soares-Filho et al. 2010.

a price premium for sustainable activities such as Brazil nut collection[121] and rubber extraction in Acre (www.csr.ufmg.br/map/publication/folder_borracha_eng.pdf) and elsewhere in the Amazon. Other measures include promoting ecotourism in more-accessible PAs[122] and supporting the role of forest concessions in supplying certified timber through reduced-impact logging.[123] In support of this goal, Law 11.284 enacted in 2006 established the Brazilian Forest Service and the National Fund for Forest Development. Although the PA network covers 46 percent of the Brazilian Amazon, PAs in the other Brazilian biomes are still scant, covering, respectively, only 7 percent and 2.6 percent of cerrado and Atlantic biome, which is well below the 15 percent recommend by the Tenth Conference of the Parties to the Biological Diversity treaty.

Enforcement initiatives include the Plan of Action for the Prevention and Control of Deforestation in the Amazon (PPCDAM), which focuses on land titling, monitoring, and field enforcement campaigns involving collaboration between federal and state agencies, and the PRODES and DETER programs that aim, respectively, to monitor annual deforestation and detect deforestation in close to real time.[124] These systems are now been expanded, improved, and applied to the cerrado (e.g., SIAD; see www.lapig.iesa.ufg.br) and Mata Atlantica biomes.[125] In addition, a system of fire detection allows near real-time detection of fires across the country (sigma.cptec.inpe.br/queimadas). Still, fire prevention and active fire brigades (e.g., www.aliancadaterra.org.br) must be expanded to a great extent to tame forest fires that contribute to carbon emissions and forest degradation in Brazil.[126] This is particularly important for climate change mitigation programs, given that the loss of forest carbon to the atmosphere through fire represents a threat to the "permanence" of reductions in carbon emissions from deforestation.

Moreover, programs for sustainable use of natural resources, such as PAS (Sustainable Amazon Program)[127] and state land use zoning initiatives[128] represent complementary efforts that must be expanded and consolidated in order to harness sustainable development with

[121] Nunes et al. in press.
[122] Kirby et al. 2011.
[123] Merry et al. 2009.
[124] INPE 2011a, b.
[125] SOS MA 2011.
[126] Silvestrini et al. 2011.
[127] Government of Brazil undated.
[128] Government of the State of Acre 2006; Government of the States of Amazonas undated.

conservation of natural resources. In this respect, it is crucial to effectively engage the drivers of deforestation in a low-emission rural development strategy. Commodity roundtables for palm oil, soy, and sugar/ethanol have developed international standards and criteria for certification of supply chains that are attracting producers and industry participation. Certification criteria include prohibition of production on illegally deforested lands and compliance with local laws. As a result, farmers and ranchers are coming together to form voluntary property registries whose owners are committed to improving their socio-environmental performance (see an example of the Registry of Social-Environmental Responsibility at www.whrc.org/ecosystem/registry.html).

There are many project-level initiatives under way that attempt to harness market mechanisms or implement payments for ecosystem services[129] in order to place economic value on standing forests. Perhaps the most important initiative being considered is REDD+—Reducing Emissions from Deforestation and Forest Degradation in developing countries and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks. REDD+ focuses on creating both an institutional framework and the necessary economic incentives for developing countries to reduce CO_2 emissions from deforestation and forest degradation.

Despite the sluggish progress in structuring REDD+ within the UNFCCC, the program has thus far triggered a multitude of individual projects, often supported by nongovernmental organizations, which represent REDD "early initiatives."[130] Among those projects, the Juma was a pioneer project in Brazil,[131] and a collection of 12 individual projects in Madre de Dios, Peru, is worthy of mention.[132] Projects' design documents seek to demonstrate the project-based effect on lowering deforestation. Most of them adopt simulation models (e.g., csr.ufmg.br/dinamica) to establish forward-looking baselines in order to measure the additionality of the project in reducing future deforestation. To this end, various methodologies for measuring, reporting, and verifying (MRV) carbon stocks and reductions as well as standards for international certification have been developed (e.g., the Standard CCBA – Climate Community, at climate-standards.org).

[129] Wunder, 2008.
[130] Cerbu et al. 2009.
[131] CCBA 2008.
[132] Hajek et al. 2011.

Nevertheless, the criteria for establishing baselines for crediting purposes are fuzzy and do not take into account that forward-looking baselines are questionable because deforestation trajectories can alter drastically in response to changes in a complex set of circumstances.[133] Furthermore, it is very difficult to isolate the local effect of a project from the overall trajectory of deforestation as well as to assess leakage arising from the establishment of projects,[134] and none of those projects have attempted to perform such analyses. Therefore, REDD+ and associated payment schemes must be negotiated and implemented under a broader nation-state framework rather than on a project-by-project basis if REDD+ is to succeed.[135] Under this view, REDD+ should be part of a comprehensive rural planning strategy that supports the sustainable development of rural livelihoods.

In this vein, it is worth highlighting initiatives that seek to create national and international funds to conserve forests, such as the Amazon fund, to which Norway has already committed US$1 billion if Brazil succeeds in reducing deforestation.[136][137] Also, as a result of PPCDAM, states in Brazil (principally in the Amazon) are establishing their own programs for climate change mitigation that include specific plans for deforestation prevention. Such programs allow Amazon states to participate and deliberate as part of the steering committee for the Amazon fund. Currently, the Amazon states are in different stages of building their state programs. Amazonas, Pará, Mato Grosso, Acre, Amapá, and Rondônia have already concluded their plans; only Tocantins has not published its plan yet. Amazonas, Pará, Mato Grosso, and Acre have already established voluntary reduction targets within the context of the National Climate Change Plan, and Acre and Amazonas are the first states to have received resources from the Amazon Fund.[138] Hence, resources from the Amazon fund will enable states to consolidate REDD+ by developing a series of initiatives that include property registering, stakeholder consultation, policy analysis, institutional restructuring, development of a MRV system that incorporates remote sensing monitoring and carbon biomass mapping systems, schemes for payments for ecosystem services, and funding for civil society to convene, support, and participate in the "Reddiness" process.

[133] Soares-Filho et al. 2010.
[134] Ibid.
[135] Nepstad et al. 2009.
[136]
[137] Soares-Filho et al. 2010.
[138] CGEE 2011.

Examples of ecosystem payment systems include Bolsa Floresta—a forest allowance established by a state law (number 3135 of 05/06/2007)[139]—in Amazonas that delivers monthly payments of R$50 (US$30) to registered families who live in the state conservation units, in which communities have signed a collective agreement to halt deforestation. A similar program, Proambiente (Program for the Socio-Environmental Development of Rural Family Production in the Amazon), harnesses rural credit to environmental performance of small landholders.[140]

Aside from the Amazon region, the Bolsa Verde (Green Allowance) program carried out by the state of Minas Gerais represents a pioneer initiative for payments for ecosystem services (ief.mg.gov.br/bolsa-verde). This program aims to support the conservation of the state native vegetation through regular payments to landowners who preserve or have committed to recover native vegetation on their land. The priority of the program is small landholders and properties inside conservation units. The program began in 2011, when it invested US$3 million in payments of US$100 per year per hectare of preserved vegetation.

Finally, a whole series of other initiatives could also be placed under the umbrella of payments for ecosystem services. These include environmental compensation to private properties with a surplus of forest from those that have deforested beyond the limit established by the Forest Code and payments and other incentives to undertake forest restoration. While the first could stir up a market of forested lands, thus valuing standing forests, the second could encourage land owners to comply with Brazil's Forest Code, which is far more advanced than Brazil's rural reality. Nevertheless, whereas programmatic costs of forest conservation are low (US$21–54 per ha within a 20 year period),[141] forest restoration will require at least 20 times more investment.[142] (The costs of forest restoration can go from US$750 per hectare (minimum intervention) to US$4,000 per hectare.)[143] In this respect, a carbon market paying as low as US$10 per ton of CO_2 sequestered through forest regrowth would provide ≈ US$4,000 per ha to fund a countrywide forest restoration effort, thereby triggering multiple socioeconomic and environmental benefits. As a new rural development model, REDD+ and other payments for ecosystem services must therefore be integrated into a low-carbon agriculture program to enable

139 Amazonas Sustainable Foundation undated.
140 MMA 2004.
141 Nepstad et al. 2009.
142 Gouvello et al. 2010.
143 Ibid.

Brazil to develop a culture of forest stewardship and environmental responsibility that equals its prominence as an agricultural commodity exporter.

7. ROLE OF BILATERAL ACCORDS

To date, most of the progress within the UNFCCC negotiations has focused on structuring the REDD+ regime as part of a new climate protocol that will succeed Kyoto. However, the Conference of the Parties held in Durban in December 2011 postponed the enactment of a new climate protocol until 2015, with responsibilities to be effective in 2020. Although this accord will be an important step forward in that it will represent a binding commitment for all nations, it also represents a lost decade for climate change mitigation.

In light of this, there are currently only two options left for advancing with REDD+: individual projects and state or federal initiatives. REDD+ individual projects have played a critical role in providing lessons for state and federal REDD+ programs, but they must be viewed as pilots. Conversely, the progress in Brazilian states' climate change mitigation programs has been especially important for REDD+.[144] In particular, the Governors' Climate & Forest Task Force (GCF) has made headway in developing policies and accords to conserve forests through REDD+ projects, which eventually could generate credits to offset part of the industrial and other sectors' emissions within a cap-and-trade system.[145]

Launched in November 2008 by the state of California, the GCF integrates five Brazilian Amazon states (Mato Grosso, Acre, Amazonas, Pará, and Amapá), four Indonesian provinces (Aceh, Papua, East Kalimantan, and West Kalimantan), three American states (California, Illinois, and Wisconsin), one Mexican state (Chiapas), and one Nigerian state (Cross River). The prospects of Californian offsets flowing to Amazon states has driven a process of convergence among those states to design a REDD+ architecture that will link the Brazilian state-level programs with the offset regulations and forest carbon accounting protocol of California and other states in the United States, which are still evolving. This innovative framework will, for

[144] Boyd et al. 2010.
[145] CGEE 2011.

example, allow electricity companies in the United States and even in Brazil faced with a mandate to lower their greenhouse gas emissions to offset part of their emissions via credits from REDD+ programs of the Amazon states and elsewhere.[146] As a result, this policy alignment and innovation will allow a carbon market to develop from interactions between environmental, agricultural, and industrial sectors, among others, and across states and countries.

It is important to secure political momentum by supporting the development of federal and state REDD+ programs through which tropical countries will achieve large reductions in deforestation and forest degradation. In this regard, Brazil is well situated, given its technical, political, and social conditions, its industrial and energy contexts, its environmental policies, and its growing governance in forest frontier regions. Nevertheless, Brazil needs not only to actively participate in the global REDD+ arena but to be a leader, lest it lose a great opportunity to reward its formidable efforts to reduce deforestation. Brazil must seize the opportunity to develop intranational and international bilateral accords that secure the operations of payments for ecosystem services, especially REDD+. This will be crucial in helping Brazil—a country with pressing social and development needs—to meet the goal of reconciling agricultural expansion with countrywide forest conservation and restoration.

The challenges presented here are common to many countries in Latin America and the Caribbean, especially those with great potential for the expansion of commercial agriculture, such as Argentina, Bolivia, Peru, Chile, Mexico, and Paraguay. This article therefore provides an example for these countries as they design their own national plans to reconcile agricultural production with environmental conservation.

[146] Nepstad et al. 2009.

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