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Brazil's INDC Restoration and Reforestation Target

Analysis of INDC Land-use Targets

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Abbreviations

ABC	Low Carbon Agriculture Program
APP	Area of Permanent Protection
AU	Animal Units (450Kg)
BLUM	Brazilian Land Use Model
BNDES	Brazilian Development Bank
CAR	Environmental Rural Cadastre
CDM	Clean Development Mechanism
CLFS	Crop-Livestock-Forest System
CLS	Crop-Livestock System
CMN	National Monetary Council
COP	Conference of the Parties
CRA	Environmental Reserve Quota
CREDD	Certified Emissions from Deforestation and Degradation
FAO	Food and Agriculture Organization of the United Nations
FLR	Forest landscape restoration
GDP	Gross Domestic Product
GHG	Greenhouse gas
Ha	Hectare
IBÁ	Brazilian Tree Industry
IBAMA	Institute for Environment and Renewable Natural Resources
IBGE	Brazilian Institute of Geography and Statistics
IDAF	Agroforestry and Forestry Defense Institute
IEMA	State Institute for Environment and Hydrological Resources
INDC	Intended Nationally Determined Contribution
INPE	National Institute for Space Research
IPÊ	Institute of Ecological Research
IRR	Internal rate of return
MAPA	Ministry of Agriculture, Livestock and Supply
MgC ha	Ton of carbon per hectare
Mha	Million hectares
MMA	Ministry of Environment
MPF	Federal Attorney
NDC	Nationally determined contribution
NGO	Non-government organization
NPCC	National Plan on Climate Change
NPV	Net present value
NVPL	Native Vegetation Protection Law or Forest Code
PAS	Sustainable Amazon Program
PDE	Decennial Energy Plan
PES	Payments for ecosystem services
PLANAVEG	National Plan for Restoration of Native Vegetation
PNDF	National Plan for the Development of Planted Forests
PPCDAm	Plan for Prevention and Control of Deforestation in the Legal Amazon
PRA	Environmental Compliance Program
PRONAF	National Program for the Strengthening of Family Farming (smallholders)
REDD+	Reducing Emissions from Deforestation and Forest Degradation

RL	Legal Reserve
RPPN	Private Natural Heritage Reserves
SDG	UN Sustainable Development Goals
SiCAR	Federal Rural Environmental Registry System
SME	Small and medium-sized enterprise
SNUC	National System of Conservation Units
toe	Ton of oil equivalent
UNCBD	UN Convention on Biological Diversity
UNFCCC	UN Framework Convention on Climate Change
UREDD	Reduction Units from Deforestation and Forest Degradation

Executive Summary

The Brazilian government announced at the 2015 UN climate conference in Paris (COP21) the country's Intended Nationally Determined Contribution (INDC) to the global effort of mitigating climate change. The INDC includes a combined target of restoration (return of ecosystem as close as possible to the original "reference" ecosystem) and reforestation (any process that returns complete or partial tree cover on forest land through planting or through natural or assisted regeneration processes) of 12 million hectares (Mha), along with zero net emissions from land-use change, zero illegal deforestation and other land-based targets by 2030. How this commitment relates to Brazilian policies and plans for environmental conservation, restoration and agricultural expansion remains poorly understood. This report assesses the restoration and reforestation target, in the context of other related INDC targets and ongoing policies that interact with them. The report then models future scenarios of land-use change, estimates the total cost needed to achieve the target, and offers policy recommendations to achieve the goals of Brazil's INDC.

The nearly 80% reduction in deforestation in the Brazilian Amazon since 2004 resulted from the implementation of specific policies designed to increase enforcement and punishment of environmental crimes, targeted by the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm). Deforestation in the Cerrado (savanna biome of central Brazil) has also decreased, but is again on the rise, and future projections for that biome indicate large-scale deforestation coupled with agricultural expansion.

The INDC goals reaffirm some prior Brazilian commitments and update others. Indeed, most of the Brazilian targets are already embedded in existing laws and national plans. Including them in the INDC is important in informing the international community about Brazil's ambitions to strengthen and consolidate these policies in domestic debates and to attract investment to meet the goals.

The INDC target refers to both reforestation and restoration, but does not specify the relative contributions of these two activities. According to the Forest Code, some set-aside areas (e.g. Legal Reserves, RLs) for conservation can be sustainably harvested and include the partial use of exotic species, such as pines and eucalyptus, interplanted with native species, which could mitigate the cost of restoration and even provide profits. There is a need for clarification in respect to these activities, particularly in relation to state-level legislation regarding the exploitation of native species and the consequences of different forms of reforestation for conservation of native biodiversity. Here we modeled the most ambitious version of considering the NDC target as restoration of native vegetation and including the extra target of expanding 7 Mha of planted forests.

The INDC's goal of restoring and reforesting 12 Mha (7 Mha of tree plantation plus 5 Mha of restoration) is laudable, but the analyses suggest that this target could be even more ambitious. For example, the INDC states that Brazil will comply with its Native Vegetation Protection Law (NVPL, or the "Forest Code"), and the latest estimate of the National Plan for Restoration of Native Vegetation (PLANAVEG) is for 20 Mha to be restored to comply with this law. Therefore, this report investigates the feasibility and costs of two scenarios: a) 12 Mha and b) 20 Mha of restoration, both alongside 7 Mha of tree plantations.

According to government officials, the central fixed target of the land-use change sector is to achieve zero net emissions by 2030, an ambitious but feasible target. The sub-targets under land-use change (12 Mha of restoration or reforestation and zero illegal deforestation by 2030) are preliminary estimates of how to achieve this overall zero net emissions target. It is crucial that this overall target is achieved and that the sub-targets are managed accordingly. One reason is that Brazil has approximately 88 Mha that could still be legally deforested in Brazil (half of this in the Cerrado), and if a significant fraction of this is deforested it would be very hard or impossible for restoration and reforestation to compensate for this by 2030. Deforestation emits most of the converted ecosystem carbon to the atmosphere very quickly, and restoration and reforestation take much longer to sequester similar CO_2 levels from the atmosphere. Thus, we focus here on modeling three further deforestation targets: a reduction of 80% from historical levels; a zero net deforestation target; and a zero absolute deforestation target.

Our results show that there is enough space in pastureland to accommodate the largest expansion of agriculture worldwide, while achieving zero deforestation, and expanding 7 Mha of planted forests and 20 Mha of restoration.

The effort required to improve the productivity of pastureland in order to accommodate these targets varies for each scenario and biome analyzed here. In the Amazon biome, for instance, meeting all agriculture, forestry production, deforestation and restoration targets means raising the level of productivity from the current level of 46% of the sustainable carrying capacity of pastureland to 63–75% over 15 years. In the Atlantic Forest biome, on the other hand, this means an increase in productivity from the current level of 24% of its sustainable carrying capacity to 30–34%.

The cost needed to restore 12 Mha would be US$ 13.7 billion[1] until 2030, or approximately US$ 900 million per year. This is equivalent to 1.6% of the annual public credit for agriculture, the Plano Safra. The restoration of 20 Mha would require US$ 24.3 billion, or 2.8% of the annual public credit for agriculture. Socioeconomic benefits such as the creation of 200,000 direct jobs annually and US$ 1.9 billion in taxes would accompany associated environmental benefits, such as conservation of rivers and soil. Moreover, climate change mitigation benefits associated with the Brazilian restoration target would be 1.4 billion tons of CO_2 for the 12 Mha scenario, and 2.3 billion tons of CO_2 in the 20 Mha scenario.

Although the estimated restoration expenses represent only a small percentage of total overall agriculture credit, the investments would be likely to have lower financial returns. Despite the positive social and environmental benefits, the revenues would be lower than the costs, suggesting a negative net present value (NPV) and internal rate of return (IRR). As a result, the immediate economic and fiscal cost would likely be greater than simply expanding agriculture credit for increased agricultural production, for example – with corresponding implications for Brazil's public expenditures and the need to explore additional sources of financing.

Among the related policies under implementation or development, PLANAVEG currently under development by the Ministry of Environment (MMA), is the most comprehensive plan relating to restoration in Brazil. It has eight core strategies ranging from the development of tree nurseries to financial mechanisms, market development and spatial planning.

To achieve its ambitions in the land-use sector, the Brazilian government should integrate the different sectoral plans and agencies. This would eliminate overlap and reduce ambiguity regarding

[1] Throughout the document consider US$ 1.00 = R$ 3.50 as of May 16th 2016.

responsibilities, resource allocation, implementation strategies and monitoring.

More specific recommendations for the government to accomplish the INDC targets are set out below. They are mostly aligned with those of the Brazilian Coalition on Climate, Forests and Agriculture, reflecting a broad discussion among government agencies, civil society organizations (CSO), and the forestry and agriculture sectors (Waack and Biderman 2016).

1. **Create the proper environment for investment in the native vegetation restoration supply chain.** This includes the regulation of the exploitation of native species and laws that encourage investment in creating new forest-tree nurseries to supply seedlings and training labor. Moreover, the government should move forward on land tenure regularization and land titling, since investments will not occur without tenure security.
2. **Validate the Rural Environmental Cadastre (CAR) and monitor compliance with the Forest Code.** Accurate data from the CAR are required to track the extent of RL and Areas of Permanent Protection (APPs) deficits; to define restoration or compensation demand of rural properties; and to establish the Environmental Reserve Quota (CRA) market, which has the potential to reduce the total cost of restoration and could include incentives to conserve and restore native vegetation in priority regions. CAR allows monitoring compliance with the Forest Code, directing incentives or disincentives to rural properties, and landscape-wide planning forest conservation.
3. **Establish priority areas for restoration.** Government should define priority areas for restoration based on multi-criteria analyses to maximize environmental benefits while minimizing conflict with agriculture. These spatial analyses can also help to achieve scale in restoration projects, which in turn would reduce costs per hectare and increase ecological benefits.
4. **Integrate restoration programs with actions for the agricultural sector to increase productivity.** Environmental agencies can develop actions and coordinated programs with the Ministry of Agriculture, Livestock and Supply (MAPA) and state agricultural secretariats and agencies to reduce institutional risk and compensate for the loss of productive area due to restoration.
5. **Expand incentive mechanisms for farmers to implement restoration.** Government may develop incentives for producers who want to invest in restoration programs, linking environmental conservation indicators, such as restoration priority areas and landscape connectivity. Incentives could include direct payment for ecosystem services schemes and subsidized credit.
6. **Establish a strategy for forestry credit under the Low Carbon Agriculture Program (ABC) and other financial mechanisms for restoration and Integrated Crop-Livestock-Forest Systems (CLFS).** Currently there are several lines of funding for restoration, CLFS and restoring regularity under environmental law. However, these resources are not sufficiently accessed. Farmer awareness and training of technicians are part of the actions planned by the ABC, but so far progress has been limited as regards restoration efforts.
7. **Expand incentive mechanisms for small- and medium-size enterprises (SMEs).** There is at present little information regarding the incentives and enabling environment for SMEs in the forest sector and their role in restoring lands at scale (e.g. in planting, management, etc.), the

credit and regulatory constraints, processing of the timber, options for vertical integration (wood and non-wood), as well as vertical integration of SMEs with larger enterprises.

8. **Develop a mechanism of transparency and establish community-based forest monitoring and restoration programs.** Federal agencies could provide greater transparency about certified forestry products and environmental compliance in the biomes. It would be useful, for instance, if financial agencies could better assess the environmental risk of investments via credit programs. Government could expand the "Terra Class Project" and similar initiatives to all biomes, producing high-resolution baseline maps of land use and land cover that are updated annually to monitor deforestation and different types of reforestation and changes in non-forest ecosystems.
9. **Include ecosystem services considerations within CAR, CRA and the Environmental Compliance Program (PRA).** Biodiversity conservation efficiency indicators (e.g. connectivity in landscape and priority areas) could be used in the valuation of RL forest surplus for compensation in the CRA market.
10. **Increase capacity building for silviculture of native Brazilian tree species and scale up research on these.** Create incentives for investments into the restoration supply chain, especially for tree nurseries for native species, technical assistance and training. Research initiatives on the genetics of native tree species, on improving their silviculture, and in addressing socioeconomic elements of restoration could help to decrease costs, increase benefits and better engage landowners.
11. **Clearly spell out the roles and accountabilities of different government agencies at the three levels of government (federal, state and municipal).** Current policies and programs such as the National Plan on Climate Change, ABC, and PLANAVEG are partially overlapping and create ambiguity regarding responsibilities, resource allocation, implementation strategies and monitoring. A comprehensive communications effort by government regarding its overarching INDC implementation strategy – including the expected modes of financing – would be recommended.

1. Introduction

1.1. Brazil's INDC: the role of the land-use sector

1.1.1. The context of deforestation and land-use change in Brazil

Brazil has 12% of the global forest area, being the second largest forest area in the world (4,935,380 km^2). Currently, forests cover 59% of the land area of Brazil (FAO 2015). In 2012, dense forests (>50% tree cover) covered 4,756,945 km^2, of which 65.2% were located in three states in the Amazon biome: Amazonas (31.7%), Pará (22.5%), and Mato Grosso (11.0%; INPE 2010). Deforestation rates have varied greatly over time and space; only 12% of the original forest cover remains in the Atlantic Forest biome, where most of the deforestation occurred between 1930 and 1993. In contrast, most of the deforestation in the Amazon has occurred since 1970. Over 70% of the forest loss in Brazil during the past 25 years occurred in the Amazon, primarily in the states of Pará and Mato Grosso. By 2015, 18.8% of the Brazilian Amazon forest was lost.

Robust efforts by multiple government agencies have contributed to the reduction of annual deforestation rates in the Amazon by nearly 80% since 2004, to the lowest levels recorded since annual recordkeeping began in the late 1980s. Despite these reductions, significant conversion of forest to agriculture continues, primarily in the Amazon and Cerrado biomes. From 1990 to 2011, 80% of Brazil's cropland expansion occurred in the Amazon and the Cerrado (Lapola et al. 2014). In the state of Mato Grosso, cropland expansion from 2001 to 2012 was evenly divided between Amazon and Cerrado. Agricultural lands cover 33% of the land area in Brazil today, of which around three-quarters are pastureland.

The Native Vegetation Protection Law (NVPL), or Forest Code, created in 1934 and last modified in 2012, was established to protect natural vegetation in forest and non-forest biomes, conserve biological diversity, protect water resources, and prevent soil erosion on private lands. The law established Areas of Permanent Protection (APP), and stipulates a minimum proportion of native vegetation to be conserved as a Legal Reserve (RL; see section 3.1). APPs are mandatory on hilltops, steep slopes, coastal shrublands, mangroves, wetlands, around springs, and along watercourses and reservoirs. Lack of compliance with this law has reached a high level, stimulating policymakers to make many changes in the Forest Code in an effort to ease compliance (Brancalion et al. 2016). The 1965 Forest Code lacked sufficient provisions for enforcement, monitoring, and rewards for compliance, particularly in remote areas and for both wealthy and poor landowners. Four institutional tools were developed to ensure comprehensive and integrated management of the NVPL, including implementation of the Environmental Rural Cadastre (CAR) and the Environmental Compliance Program (PRA, see section 3.1). In 2014, Brazil had an estimated deficit of 21 million hectares (Mha) of native vegetation, relative to the requirements of the NVPL, including 4.6 Mha in APP and 16.4 Mha in RLs (Soares-Filho et al. 2014). To comply with the NVPL, a massive reforestation effort is required, including establishing plantations of native species, and promoting natural regeneration and assisted natural regeneration. The National Plan for Restoration of Native Vegetation (PLANAVEG; MMA 2013; see section 3.4) contains a minimum goal of restoring 12.5 Mha of native vegetation within 20 years. An independent goal of the Atlantic Forest Restoration Pact is to restore 15 Mha by 2050 (Calmon 2011).

The legal mandate to reforest or recover natural non-forest vegetation in Brazil is closely aligned with several international conventions and commitments focusing on biodiversity conservation and climate change mitigation, especially the Aichi Target 15 of the UN Convention on Biological Diversity (UNCBD), and national climate mitigation commitments under the UN Framework Convention on Climate Change (UNFCCC). Land-use targets are an important component of Brazil's Intended Nationally Determined Contributions (INDC) under the recent (2015) Paris agreement under the UNFCCC.

1.1.2 Benefits and challenges of forest restoration in the Brazilian context

Recovery of forest vegetation provides many social, economic, and environmental benefits, even if all of the qualities and components of the original forests are ultimately not restored. Conversion of forest vegetation to agricultural land use creates a direct conflict between land available for biodiversity conservation and land available for production. But the restoration of degraded or unsustainably used land to forests or other forms of natural vegetation benefits both conservation and agricultural production and creates a new economic framework based on increased functionality and resilience of the land. A proper policy environment can create synergies between socioeconomic and environmental benefits, which is the only path toward achieving large-scale and long-lasting restoration and sustainable land use. In the case of forest areas, landowners initially converted natural vegetation to agricultural land to obtain economic benefits from either cattle raising or crop production. The landowners must now pay the cost of restoring forest cover on part of their land to be in compliance with the NVPL. This requires that landowners have the funds or can access financing to pay for restoration and forgo economic returns from agricultural land uses. Forest restoration must become a better land-use option than paying the penalties of non-compliance with the NVPL. The challenge in Brazil is to create synergies that make restoration the best land-use option for landowners, as it is clearly the best outcome for the environment and for sustaining Brazil's unique biological heritage. Ultimately, restoring natural vegetation is also the best outcome for ensuring sustainable land use.

A major economic benefit of forest restoration is the development of supply chains for tree-planting activities and plantation maintenance, which generates employment and business opportunities. Depending on the balance between restoration plantings and natural regeneration, restoration of 12 Mha of forest in Brazil is projected to generate between 112,270 and 190,696 jobs annually (MMA 2013). In addition, restored forests will provide sources of timber and non-timber products (Table 1) that may generate income for landowners and diversify local markets and livelihoods.

Forest restoration also provides increased protection (insurance) against flooding, landslides and other extreme climate events, with incalculable benefits for human life and wellbeing. Restoration of forests in APPs is particularly critical for reducing risks of flooding and siltation of rivers and reservoirs, and protection of safe and reliable water supplies for both rural and urban populations. Heterogeneity of forest vegetation, due to different fallow ages, taxonomic and functional composition, also promotes deep infiltration of water to replenish ground water and reduce runoff (Klos et al. 2014).

TABLE 1: DIFFERENT TYPES OF NATIVE AND PLANTED FORESTS OFFER DIFFERENT BENEFITS AND AMOUNTS OF ECOSYSTEM GOODS AND SERVICES

	Natural forests with native species					Planted forests with native and non-native species			
Ecosystem goods and services provided by forests	Primary forest	Young SG forest	Old SG forest	Mixed species restoration plantation (with natural regeneration)	Mangrove restoration	Agro-forest	Protection plantation (no tree harvest)	Short-rotation monoculture plantation managed for pulp and charcoal	Long-rotation monoculture plantation managed for timber production
1. Food production (fruits, fungi, meat)	green	beige	light green	beige	light green	green	beige		
2. Timber production	green	beige	light green	light green	beige	beige			green
3. Firewood	beige	light green	beige	light green		beige	beige	light green	
4. Charcoal	beige	beige	beige	beige		beige		green	
5. Pulp, fiber		beige				beige		green	
6. Medicinal plants	green	green	green			light green			
7. Freshwater regulation	green	beige	light green	light green	light green	beige	light green		light green
8. Freshwater purification	green	beige	light green	light green	light green	beige	light green		
9. Flood regulation/storm protection	green	beige	light green	light green	green	beige	green		
10. Groundwater recharge	green	beige	light green	light green		beige	green		beige
11. Air purification	green	beige	light green	light green	beige	beige	light green		beige
12. Carbon sequestration	green	light green	light green	light green	light green	light green	light green	beige	light green
13. Climate regulation	green	light green	light green	light green	light green	beige	light green		light green
14. Disease regulation	green	beige	light green	light green	light green	light green	light green		
15. Pollination	green	light green	green	light green	light green	light green	light green		
16. Erosion prevention/soil stabilization	green	light green	green	green	green	light green	green	beige	light green
17. Habitat for species	green	light green	green	light green	green	light green	light green		beige
18. Reservoir for genetic diversity	green	light green	light green	light green	light green	beige	beige		
19. Recreation and ecotourism	green	beige	green	light green	light green	beige	beige		
20. Spiritual/religious	green	beige	light green	beige					

Source: MMA (2013)

Notes: Blank = not produced; beige = low level of production; light green = intermediate level production; green = high level of production.

Policies can create additional financial incentives for restoration through payments for ecosystem services (PES) to landowners. To date, PES programs in Brazil focus on hydrological services, carbon storage, and conservation of biodiversity (Guedes and Seehusen 2011). The Conservation of Water Program in Extrema, Minas Gerais, serves as an excellent example of how PES can work in Brazil (Richards et al. 2015). Over ten years, this program has coordinated restoration activities leading to increased cover of Atlantic Forest in 60% of the targeted sub-watersheds through contracts with 53 landowners. Collaboration among government agencies, civil society and landowners led to the program's success and prospects for long-term achievements. Across the Atlantic Forest, a total of 838 hydrological service providers participate in 40 PES projects, covering a total area of approximately 40,000 ha (Veiga and Gavaldão 2011). As of 2011, 15 PES carbon projects were being implemented across the Atlantic Forest and an additional 18 were being planned (May 2011).

Large-scale forest restoration generates multiple social benefits. In addition to increasing food security through agroforestry systems and reducing poverty through marketing of timber and non-timber products, restored forests create new spaces/areas for community activities, educational opportunities, cross-generational activities, and special events through community-based forest monitoring and mensuration activities. A new "culture of restoration" will invigorate and strengthen local communities and give them a renewed sense of identity, purpose and place.

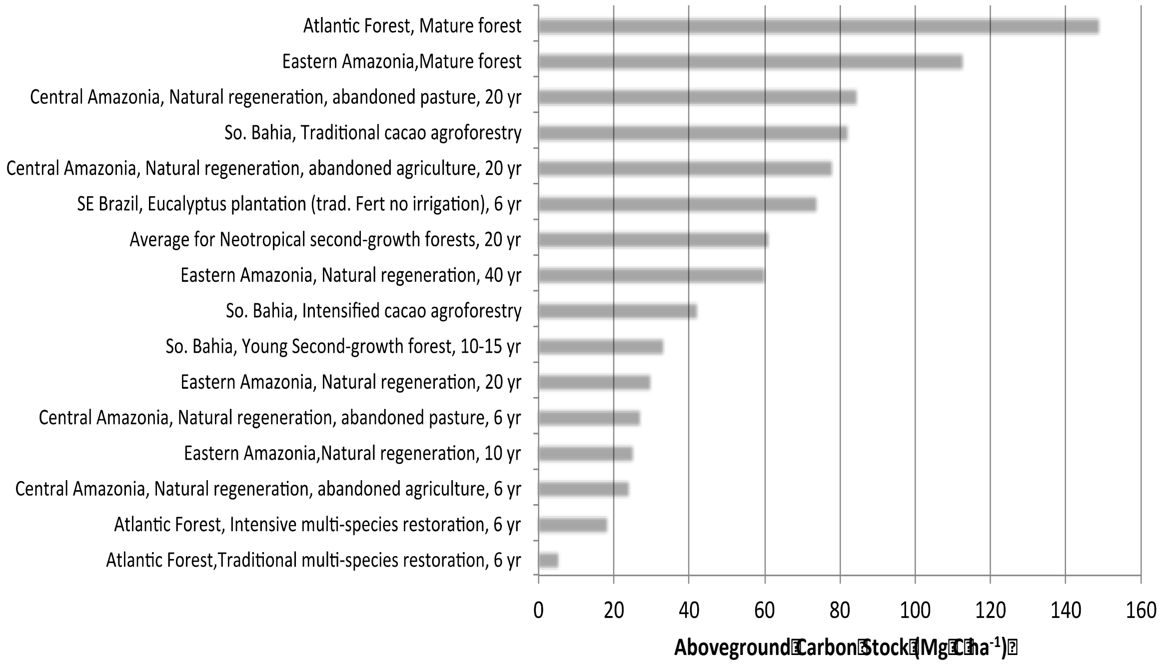
Forest ecosystems provide a long list of products and services that enhance human life materially and spiritually (Table 1). But the types and amounts of forest goods and services vary widely across different types of natural and planted forest systems. Primary forests offer the widest range and amounts of ecosystem services, including timber and non-timber products, regulation of air and water quality, carbon storage, buffering of climatic variation, and habitats for species. Naturally regenerating forests are the closest proxy to primary forests in terms of the diversity and quantity of ecosystem products and services offered. Protected forest plantings, such as those designed for APP, are next in line in terms of the overall goods and services provided. Plantations managed for pulp and charcoal (short-rotation) or for timber (long-rotation) also provide important products, but generate fewer ecosystem services than naturally regenerating forests or agroforests, and support lower levels of biological diversity (Table 1).

1.1.3 Carbon storage through avoided deforestation, reforestation and forest restoration in Brazil

Tropical forests contain approximately 40–60% of the carbon stored in the world's terrestrial vegetation (Baccini et al. 2012). In 2005, 77% of the total Brazilian CO_2 emissions that occurred that year (0.446 Pg, or gigaton, of carbon) were associated with the land-use change and forestry sectors (Brasil 2006). Leaving forest standing (avoided deforestation) is the most effective way to reduce carbon emissions. Tropical forest vegetation has tremendous potential for absorbing CO_2 from the atmosphere and storing it in plant tissues and in the soil. Carbon composes roughly 50% (range 42–52%) of woody plant biomass. Long-term carbon storage for climate mitigation is best accomplished in long-lived trees that will retain carbon stocks in their trunks, branches, and roots over many years. Biomass stocks in mature forests vary considerably within regions due to many factors. Annual rainfall and seasonality are two important predictors of the potential for carbon storage in regrowing forest vegetation in the Latin American tropics (Poorter et al. 2016). Aboveground biomass in coastal Atlantic Forest ranged from 166.3 to 283.2 tons of carbon per ha (MgC ha^{-1}) across an elevational gradient, equivalent to 83–142 MgC ha^{-1} (Figure 1, Alves et al. 2010). During forest regrowth in the Brazilian Amazon, prior land use and soil type strongly affect rates of basal area growth and biomass accumulation (Moran et al. 2000, Williamson et al. 2014).

During forest regrowth and restoration, carbon stocks in vegetation accumulate rapidly, although the losses due to deforestation take many decades to recover (Poorter et al. 2016). Natural regeneration of forests is the most cost-effective solution for increasing carbon storage on deforested land, with the goal of re-establishing natural forests that remain in the landscape for decades or more (Chazdon et al. 2016b). In areas that are favorable for natural regeneration, minimal costs are required for fencing or fire protection (Chazdon and Guariguata 2016). The report compares and contrasts biomass stocks and rates of aboveground carbon stocks in different types of natural and planted forests, based on studies conducted in Brazil (Figure 1). Below-ground carbon stocks in root biomass and soil carbon fractions are also important in carbon sequestration planning, as these can contribute at least an additional 25–30% of aboveground stocks (Marín-Spiotta and Sharma 2012).

FIGURE 1: ABOVEGROUND CARBON STOCKS (MgC ha^{-1}) IN DIFFERENT TYPES OF FOREST IN BRAZIL



Source: Alves et al. (2010)

Note: Areas include central and eastern Amazon and Atlantic Forest.

Short-rotation tree plantations

Because biomass accumulation is a direct outcome of tree growth rates, it is not surprising that rates of biomass accumulation in both natural vegetation and plantations are strongly affected by overall water availability, seasonality, and soil fertility. Plantations of clonally propagated eucalyptus in the Brazilian Atlantic Forest reach an average stem wood biomass of 147.5 Mg ha^{-1} at end of rotation (six years), with an average yearly increment of 25 MgC ha^{-1} (Stape et al. 2010), and can reach 200 tons per ha in the "Projeto Plantar". Biomass accumulation rates increased dramatically in response to irrigation and fertilization (Stape et al. 2010).

Natural regeneration

Naturally regenerating forests also show a strong effect of annual rainfall and seasonality on rates of biomass accumulated, as well as effects of soil fertility and intensity of prior land use (Mesquita et al. 2015, Poorter et al. 2016). Across 45 sites in lowland Latin America (including several regions of Brazil), aboveground biomass accumulation after 20 years of natural regeneration varied elevenfold. Average aboveground biomass growth after 20 years was 122 Mg ha^{-1} (Poorter et al. 2016). Wandelli and Fearnside (2015) compared aboveground carbon storage in 24 stands of second-growth vegetation from one to 15 years old in Central Amazonia. Age since abandonment was a strong predictor of aboveground biomass in former croplands, but not for former pastures. To predict carbon storage in former pastureland, it was necessary to account for the number of years of grazing. For six-year-old regrowth, aboveground carbon stocks were slightly higher on pastures used for three years as compared with cropland (Figure 1). Areas of regenerating pasture appear to have higher rates of carbon accumulation in aboveground biomass in the central Amazon compared with the eastern Amazon, which could be due to soil fertility or differences in prior land use. Moran et al. (2000) found strong effects of soil fertility on rates of forest regrowth, tree height, and biomass accumulation across the Amazon Basin.

Restoration plantations

Few comparative studies have been conducted on the rates of carbon storage in different types of forest restoration plantings. An experiment conducted at Anhemi Research Station in São Paulo compared the total carbon stock in restoration plantings of mixed native species (20 species) using traditional and intensive silviculture techniques. Six years after planting, aboveground forest carbon stock under intensive silviculture (additional fertilizer plus chemical weed suppression) reached 18.2 MgC ha^{-1} compared with only 5.2 MgC ha^{-1} under traditional silviculture (Férez et al. 2015; Figure 1). Rates of carbon sequestration ranged from 0.75 MgC ha^{-1} yr^{-1} in traditional silviculture to 2.68 MgC ha^{-1} yr^{-1} in intensive silviculture. These measures of carbon storage do not take into account additional carbon emissions from use of fertilizers or weed suppression or the production of other greenhouse gases (GHG), such as methane and nitrous oxide.

Agroforestry systems

Agroforestry systems are also effective for carbon sequestration. Using published allometric relationships and inventory data from 55 shaded cacao agroforests (known locally as cabrucas) in southern Bahia, Schroth et al. (2015) calculated aboveground carbon stocks and compared these with mature forests and second-growth forests (fallows). Traditional cacao agroforests contain greater carbon stocks than intensive agroforests because the trees are larger. Carbon stocks were higher in intensified cacao agroforests than in 10–15-year-old second-growth forests from the same study area (Figure 1).

1.1.4 Forest ecosystem restoration and forest landscape restoration

Within the context of the legal mandate, restoration of forest cover can take multiple forms, including agroforestry systems, commercial forestry plantations, natural regeneration, and ecological restoration plantations (forest ecosystem restoration). Note that neither PLANAVEG nor the NVPL provides a definition of "forest". For example, up to 50% of the RL can comprise exotic cultivated tree species. Further, the NVPL does not specify at what point during natural regeneration an abandoned field becomes a forest that is legally preserved. In the state of Pará, for example, approximately 25% of the deforested areas were in some form of secondary-forest regrowth in 2010 (Vieira et al. 2014). In 2014, Pará became the only state in the Amazon to establish legislation defining successional stages of second-growth forests and defining the stages where forest suppression is illegal (Vieira et al. 2014). The lack of clear legal definitions of what is a forest has impeded and will continue to impede forest restoration initiatives within Brazil.

Although legal mandates apply to areas within APPs and RLs of privately owned farms, forest vegetation can also be restored within the broad framework of landscape restoration in coordination with federal- and state-managed protected areas, wildlife reserves, and parks. For example, the creation of reforested buffer zones to protect the edges of protected areas from degradation due to harvesting, cattle grazing, or fire contributes to both conservation and restoration goals. Another example of landscape-scale restoration is the creation of forested corridors that provide connectivity between existing forest fragments or water sources and the establishment of "stepping stones" – isolated patches of forest vegetation that enhance movement of plants and animals and promote genetic diversity across the landscape. The percentage of areas to be restored in indigenous lands, protected areas and as APPs and RLs are presented in Table 6.

Forest landscape restoration (FLR) is a "process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded forest landscapes" (Maginnis and Jackson 2007, p. 10). A key feature of FLR is that it is based on a landscape approach, involving a combination of forest and non-forest ecosystems and a balance of land uses. Implementation of FLR requires strong stakeholder participation and integration in all aspects. A variety of restoration approaches (or methods) can be accommodated within a landscape to achieve sustainable food production, provisioning of ecosystem services, and to enhance biodiversity conservation. These approaches include ecological restoration of environmentally important areas, increasing agricultural productivity to create space for natural regeneration in marginal areas, and increasing tree cover through the implementation of native species forest plantations, natural regeneration, and agroforestry systems (Chazdon et al. 2015).

1.2 The need for integrated land-use planning for large-scale restoration

The need for integrated land-use planning has emerged in response to the need to mediate tradeoffs between environmental protection and development. On the one hand, agricultural output is expected to increase by 60% globally, compared with 2005–07 (Alexandratos and Bruinsma 2012), to meet the demands of 9.7 billion people by 2050 (United Nations 2015). Climate change is likely to reduce agricultural output in many regions. On the other hand, a number of global initiatives to protect and to restore degraded ecosystems have emerged. The Bonn Challenge aims to restore 150 Mha of deforested and degraded forests by 2020 (WRI 2012). Contributing to this effort, the initiative "20x20" launched at the 2014 COP20 in Peru aims to restore 20 Mha of forests by 2020 in some Latin American and Caribbean countries. In Brazil, the Atlantic Forest Restoration Pact, an initiative involving more than 250 members, including environmental organizations, research institutes, private companies, and government agencies, has a goal to restore 15 Mha of forest by 2050 (Melo et al. 2013). Although integrated approaches to land management are not new, the majority of the initiatives to protect natural resources target specific resources independently (e.g. water management versus forest management) (Denier et al. 2015). This lack of communication and coordination among sectors may lead to adverse impacts because different land uses often rely on the same resource base (Denier et al. 2015).

Integrated landscape management, or a "landscape approach" to land management, has gained prominence in the search for solutions to reconcile conservation and development tradeoffs (Sayer 2009); however, these terms encompass a wide variety of interpretations (Sayer et al. 2013). Although a universal definition for a "landscape approach" remains elusive, there is a broad consensus that such an approach focuses on tools and concepts for allocating and managing land to achieve a balance of social, economic, and environmental objectives in landscape mosaics where multiple land uses coexist, and where environmental goals often compete with agriculture and other land uses (Sayer et al. 2013).

In this respect, a landscape approach seeks to manage the increasingly complex and widespread environmental, social and political challenges within landscapes in a holistic, integrated fashion that transcends traditional management boundaries and incorporates multiple land uses within a single management process (Reed et al. 2014). Incorporating social aspects into environmental decision-making is what makes this approach different, and landscapes supposedly provide the setting where tradeoffs between different land uses and different stakeholders can be resolved (Reed et al. 2016). In addition, this approach signals a strong move away from a narrowly focused conservation-oriented approach to environment protection to achieve broad integration of poverty-alleviation goals. In other words, the concerns of people are placed center in a landscape approach – it is not just about the "land" or land management.

The landscape management approach considers unambiguous rights and responsibilities of stakeholders to be essential, especially in the case of local and indigenous populations whose cultures and livelihoods have historically depended on resources in the landscape. Rights to these resources by a range of stakeholders need to be clarified (even as institutional arrangements), and although not always possible, clarifying tenure rights and responsibilities is critical. However, as landscapes are a stage for a wide range of land uses and stakeholders, tenure systems can become even more complicated to manage. Inclusion of relevant stakeholders with some form of tenure right within the landscape may result in a sense of ownership of the management initiative (Denier et al. 2015). On the other hand, if stakeholders with tenure rights are excluded, their opposition may limit successful implementation of the landscape approach.

The landscape approach is also a key concept for the UN Sustainable Development Goals (SDG), which superseded the Millennium Development Goals, and which call for "holistic and integrated approaches to sustainable development that restore the health and integrity of the Earth's ecosystem" (UNOSD 2012). At least five of the key objectives of the SDGs (end hunger; secure water; promote strong, inclusive and sustainable economic growth; tackle climate change; and protect and promote terrestrial resources) overlap with the landscape approach (Reed et al. 2016). Although a number of integrated landscape initiatives are reported, to date there have been few well-documented cases of landscapes that can truly be called sustainable, due to, among other reasons, a lack of methods and metrics to fully assess the contribution of "sustainable" landscapes to sustainable development at multiple scales (Denier et al. 2015).

One successful case study is from the Brazilian municipality São Félix do Xingu in the state of Pará (Denier et al. 2015). The "Green Municipalities" program, a multi-stakeholder action to reduce illegal deforestation, resulted in a remarkable carbon emissions reduction by 85% (from a 1999–2008 average of 108,000 ha per year to 15,000 ha in 2014). In August 2011, as a part of a state-wide Green Municipalities program, a Pact for the End of Illegal Deforestation was signed by more than 40 entities in São Félix (local, state and national governments; producers unions; community associations; and non-government organizations, NGOs), to coordinate the land registration process, monitoring and reporting of deforestation, and sustainable development activities. Another key strategy was to register private land in the CAR. The state of Pará established a Green Value Added Tax in 2013 to incentivize the registration of properties.

An important part of the strategy was sustainable intensification of cattle ranching, which had previously been predominantly extensive, degraded, and of low productivity. Cattle ranchers received support to adopt better land management practices that maintain soil fertility and allow increased stocking rates on existing pastures, thereby reducing pressure to clear nearby forest. Beef supply chain stakeholders (such as Walmart and Marfrig) also played their part in promoting these practices and traceability of meat from non-deforested land. Among smallholders, the promotion of sustainable shade-grown cacao production boosted reforestation on the farms and provided an alternative to unsustainable cattle production (Denier et al. 2015).

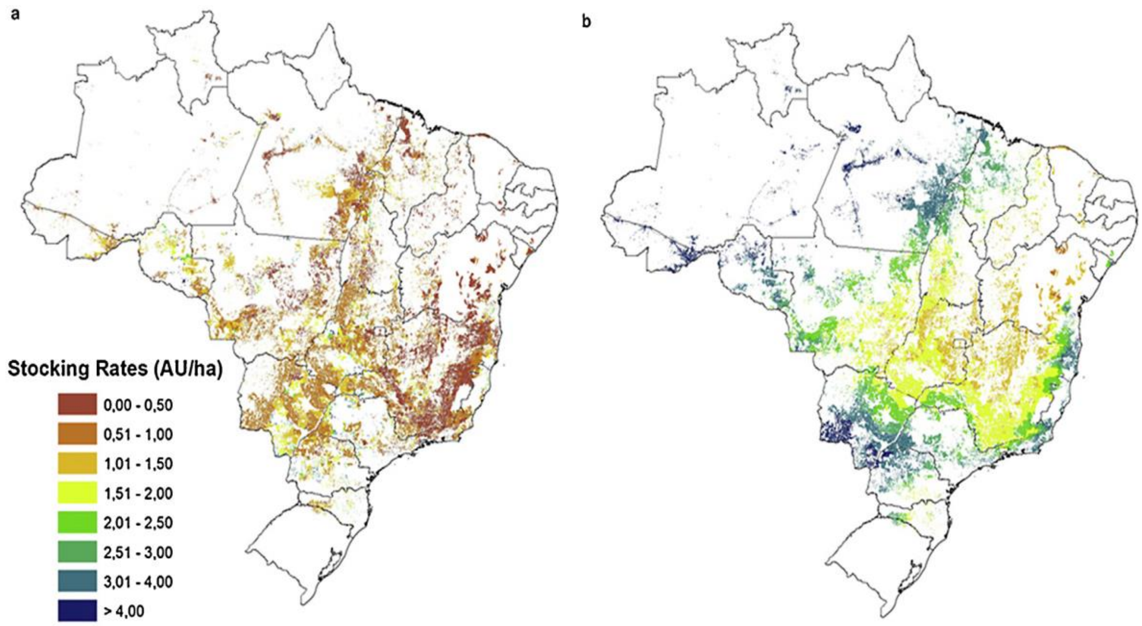
Sustainable intensification is also proposed as a key strategy in the Atlantic Forest, a highly threatened, deforested, and fragmented biome in Brazil. The development plan of the state of Espírito Santo in the Atlantic Forest region envisaged a 284,000 ha expansion of the areas devoted to agricultural crops and a 400,000 ha expansion of forest plantations (Estado do Espírito Santo 2008). At the same time, the state government, supported by both the State Institute for Environment and Hydrological Resources (IEMA) and the Agroforestry and Forestry Defense Institute (IDAF), has recently published the Reforest Program ("Reflorestar"), with the aim of restoring 236,000 ha of forest by 2025. By increasing cattle ranching productivity from 0.74 Animal Units (AU) per ha (1.42 million AU or 27% of the estimated capacity) to 2.77 AU ha^{-1} (5.29 million AU), it may be possible to spare land for restoration (Latawiec et al. 2015; Figure 2). This strategy, if implemented correctly, and if including all stakeholders, may be extrapolated across the entire country, given expected increases in agricultural production (Strassburg et al. 2014; Figures 3 and 4) and concurrent national plans for reforestation (see section 1.1 and Figure 4).

FIGURE 2: INCREASING PASTURE PRODUCTIVITY IN AREAS SUITABLE FOR CATTLE RANCHING

Source: Ricardo Rodrigues

Notes: An increase in pasture productivity in areas suitable for cattle ranching (left) allowed a farmer to set aside marginal areas with rocky soils (right) for forest restoration in the Atlantic Forest in Itú, São Paulo, southeastern Brazil.

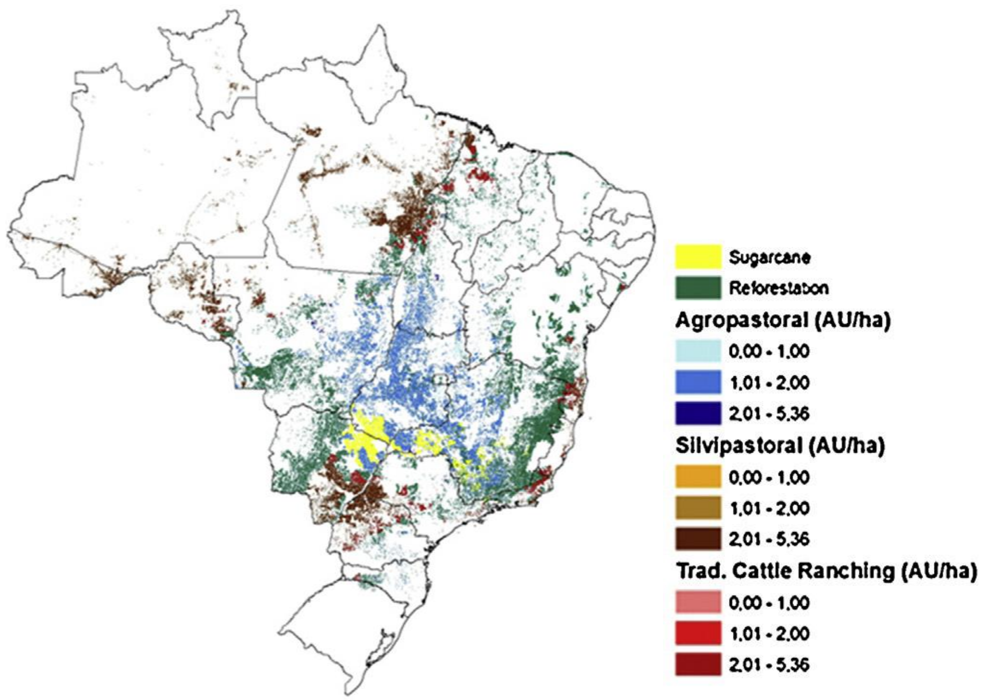
FIGURE 3: CURRENT PRODUCTIVITY AND SUSTAINABLE CARRYING CAPACITY OF CULTIVATED PASTURELAND IN BRAZIL



Source: Adapted from Strassburg et al. (2014).

Notes: (a) Current cattle ranching stocking rates in Brazil in AU ha^{-1}. (b) Potential sustainable carrying capacity for extensive systems in AU ha^{-1}. The color scale, with brown being low (0.00-0.50 AU ha–1) and blue being high (>4.00 AU ha–1), is the same for both maps.

FIGURE 4: POTENTIAL "LANDSCAPE APPROACH" TO LAND MANAGEMENT IN BRAZIL



Source: Adapted from Strassburg et al. (2014).

Notes: Alternative allocation of cattle, sugarcane, crop-livestock (for soybean and maize), silvopastoril (for wood production) and reforestation areas in 2040. It assumes that areas of low potential for cattle production and/or degraded areas will be recuperated for reforestation. Consequently, cattle required to meet demand in 2040 was allocated to pastures of high-carrying capacity. Yellow corresponds with sugarcane areas; green to reforestation; shades of blue correspond with mixed cattle-crop systems; shades of brown correspond with mixed cattle-timber systems; and shades of red correspond with pure cattle systems. Light shades correspond with low carrying capacity of pastures (0.00–1.00 AU ha^{-1}); medium shades reflect medium carrying capacity (1.01–2.00 AU ha^{-1}); and dark shades reflect high carrying capacity (>2.00 AU ha^{-1}).

Increasing agricultural productivity can also occur within an "agroecological matrix" through a land-sharing approach (Perfecto et al. 2009). For example, the Rural Landless Workers' Movement, which now includes more than one million people throughout Brazil, resettled more than 3,000 families in the Pontal do Paranapanema in the state of São Paulo, part of the Atlantic Forest biome, and formed the Agrarian Reform Settlers' Cooperative in the Pontal (Valladares-Padua et al. 2002). This occurred (in the mid-1990s) in the areas surrounding Morro do Diabo State Park, an area designated to protect the highly threatened Atlantic Forest ecosystem and the endangered endemic black lion tamarin (Hart et al. 2016).

This area was also characterized by deforestation for timber and for pasture and by conflicts of landownership. Although the settlements were located in buffer zones of the Park and remaining forest fragments to reduce conflicts with "latifundios" under intensive agriculture this also generated concerns in the conservation community that land reform has ''diminished the priority of nature conservation'' (Valladares-Padua et al. 2002). The Institute of Ecological Research (IPÊ), an NGO concerned with conservation, mounted a concerted effort with a range of stakeholders, including the members of the Rural Landless Workers' Movement, local NGOs and public agencies in the Pontal, to take the opportunity afforded by land reform to support rural livelihoods through landscape-level coordination. Diversified agroforestry, incorporating endangered native species, a range of forest species including fruit, timber and fuel wood species into the system of maize, beans and cassava, created a buffer for wildlife reserves (Cullen et al. 2005). Importantly it also improved productivity and provided income for local communities (Cullen et al. 2005, Rodrigues et al. 2007). This case study of a landscape approach demonstrates how different stakeholders were able to engage in a participatory approach to environmental conservation and restoration within a matrix of agricultural land use.

The few examples of a landscape approach to land management including multiple sectors and diverse stakeholders show that it can generate solutions that achieve multiple objectives and cost efficiencies at many levels, and help empower communities. These multifunctional landscapes are inherently people-centered and may therefore be, at least in theory, increasingly recognized by a range of stakeholders (Laven et al. 2005, Sayer 2009) to generate multiple outputs in a sustainable manner with the least trade-off costs and with maximized synergies. Arguably, the landscape approach is the only way to ensure long-term (multi-generational) environmental change, landscape-scale restoration and/or improved land management. Sayer et al. (2013) set out ten principles of an integrated landscape approach that reflect the prevailing views in recent literature, which may guide landscape approaches to best practice in environmental management (Table 2).

TABLE 2: THE PRINCIPLES OF THE LANDSCAPE APPROACH TO LAND

Principle 1: Continuous learning and adaptive management
Principle 2: Common concern entry point
Principle 3: Multiple scales
Principle 4: Multifunctionality
Principle 5: Multiple stakeholders
Principle 6: Negotiated and transparent change logic
Principle 7: Clarification of rights and responsibilities
Principle 8: Participatory and user-friendly monitoring
Principle 9: Resilience
Principle 10: Strengthened stakeholder capacity

Source: Sayer et al. 2013

Furthermore, adaptive management is critical to the long-term effectiveness of landscape approaches, requiring robust monitoring programs that encompass environmental, social, and governance response variables. Ultimately, new institutions may need to be formed that take responsibility for implementing, reporting, tracking, and adaptively managing landscape-scale restoration programs (Chazdon et al. 2015).

2. Unpacking Brazil's INDC Reforestation/Restoration Target

The INDC target of 12 Mha of restoration and reforestation does not specify\ how many hectares will be reforested using commercial forestry approaches with exotic species, such as eucalyptus, and how many hectares will be reforested using native species plantings or natural regeneration. These systems provide very different ecological and socioeconomic outcomes, and greater clarity is need for planning and implementing this target. PLANAVEG proposes at least five different restoration methods that vary in cost, extent, and quality of vegetation restoration (section 5.4).

The choice of the restoration method depends on soil conditions, the surrounding ecosystem and forest fragments, intensity and historical land use and natural regeneration potential of the area (TNC 2013, Brancalion et al. 2015). For example, total planting of native tree species should occur in areas with no potential for natural regeneration of the forest (low resilience). This usually occurs in an area with a long history of agricultural or grazing use and extensive clearance of forests in the landscape. The enrichment options occur in areas with some resilience, but low stem density and species diversity and low need for weed control. Finally, the natural regeneration of vegetation is suitable for areas with high capacity of natural regeneration, high resilience, and where the isolation of the area is necessary only to prevent grazing or fires. The proximity of the area to forest fragments is another important landscape factor that influences the dispersal and diversity of seeds, increases the resilience of the restored area, and lowers the cost of restoration.

Despite the high cost of restoration on a large scale, there are social gains such as the creation of approximately 200,000 direct jobs (MMA 2013, Instituto Escolhas 2015) and US$ 1.9 billion in tax revenues. Additional environmental benefits include carbon storage, nutrient cycling, regulation of rainfall, improved water quality and flows, habitat provision, and conservation of rivers (Table 1).

2.1 Rural credit could enable reforestation and restoration

Of the total US$ 44.5 billion of rural credit available in 2014, at least US$ 1.4 billion was offered for the restoration of degraded and reforested areas, including for the Low Carbon Agriculture Plan (ABC), the Climate Fund, Constitutional Funds and other programs of the Brazilian Development Bank (BNDES), such as the BNDES-Forest. The main barriers to the credit taken for forest restoration are: low supply of qualified technicians for the development of forestry projects; high initial investment/cost; and low liquidity of the restoration when compared with other agricultural activities. The appeal of most of these credit lines is the interest rate below inflation, ranging from 5.5% to about 12% per year (Table 3) and complementary funding for research related to enhanced reforestation practices.

TABLE 3: CREDIT LINES FOR REFORESTATION FUNDING

Credit line	Who can apply?	Investment/ operational cost	Limit	Purpose of funding	Eligible items	Interest	Payback and grace
Climate Fund – Native Forests	Public bodies and companies	Up to 90% of the investment	Minimum US$ 1.4 million	Forest management, forest planting with native species, supporting the supply chain of timber and non-timber	Research and development, fire prevention, implementation of seedling nurseries, purchase of seeds and seedlings	Approximately 5.5% for public institutions and 8.1% for private sector[1]	12 years for technological development; 20 years to support the supply chain; and 25 years for forest restoration
BNDES Forest – Support Reforestation, Sustainable Recovery and Use of Forests	Individual entrepreneurs, associations, and foundations	100% of the investment	Minimum of US$ 285,700	Environmental regulation, recovery of degraded areas, reforestation and forest management[2]	Implementation of seedling nurseries, purchase of seeds and seedlings, technical assistance for environmental compliance	Approximately 12.6%	15 years
Low Carbon Agriculture Program (ABC)	Producers and cooperatives	100% of the investment, and up to 35% of the financed amount for funding	US$ 571,000 to US$ 5 million, depending on the property size	environmental regulation of farms, forest management and forest of palm oil	Eligible items	7.5% to 8% annually	3–15 years depending on the purpose

Notes: [1] Considering: 0.1% financial cost; 0.9% of the basic remuneration of BNDES; 1% risk assessment for public bodies or to 3.6% for the private sector; at least 0.5% of the net interest margin; and 3% of the accredited financial institution spread. The final amount may increase depending on the risk analysis of each accredited financial institution. [2] Does not fund forest management in the Atlantic Forest. [3] Considering: 7% of the long-term interest rate; 1.5% of the basic remuneration of BNDES; at least 0.1% of the net interest margin; and 4% of the compensation of the accredited financial institution spread. The final amount may increase depending on changes in the long-term interest rate and accredited financial institution spread.

2.2 National Plan for the Development of Planted Forests

The National Plan for the Development of Planted Forests (PNDF) intends to expand the area of Brazilian forestry by 3 Mha by 2025. The goals are to increase the production of logs and lumber to 50,000,000 m³/year, anticipating an increase in wood furniture consumption to 600 million pieces; stimulate growth of 67% in domestic consumption of pulp and 90% in consumer packaging; double per-capita paper consumption; increase the sustainable production and consumption of charcoal by 170% to 60 million m³ by 2025; and achieve export revenues of at least US$ 5.7 billion.

The National Agricultural Policy on forestry is even more ambitious. Decree 8,375/2014 transferred the public management of forest actions of MMA to the Ministry of Agriculture, Livestock and Supply (MAPA). The goal is to almost double the internal supply of forest products, by doubling the area of planted forests to reach a target of 14 Mha. Unlike the case of the livestock industry, where current levels of productivity are well below potential capacity, the forest sector is highly efficient. The Brazilian Forestry Industry points out that the average productivity of *Eucalyptus* and *Pinus* is about 39 m³/ha and 31 m³/ha per year, or

77% and 93% higher than the productivity in Australia, the geographic home of most species used commercially in Brazil. The industry believes that productivity gains should be about 0.3% per year, so the increase in production is expected to come largely from area expansion. If this expansion occurs, it would represent about 7 Mha, accounting for 58% of the INDC “reforestation and restoration” target.

It is likely that tension over land competition will intensify. Currently, 85% of planted forests are in those states with the greatest expansion of sugarcane and soybeans: Minas Gerais, São Paulo, Parana, Mato Grosso do Sul, Bahia, and Rio Grande do Sul. Commercial production goals set by agricultural expansion targets for biofuels, food, and forestry products can compete directly with requirements for restoration of APPs and RLs to comply with the NVPL. These competing land uses are likely, since the states generally do not allow environmental compensation outside of their administrative boundaries, in order to keep these types of investments in-state.

Despite the divergence of goals between forest plantations and restoration of native vegetation, both can and already do co-exist. According to the Brazilian Tree Industry (IBÁ), the Brazilian forestry sector is responsible for the protection of at least 5.43 Mha of native forests, of which 3.36 Mha are in RLs, 1.88 Mha in APPs, 0.15 Mha in Private Natural Heritage Reserves (RPPN, Reserva Particular do Patrimônio Natural), and 40,000 ha in restoration. This means that each hectare of commercial forest with exotic species is matched by 0.65 ha of native vegetation under varying degrees of protection. In the agricultural sector, on average, the ratio is 0.07 ha.

Improved performance in production and restoration requires some structural changes, such as consolidating environmental legislation, encouraging research and development, and supporting a low-carbon economy. Others are more cyclical and useful to support restoration regardless of the industry and agent that leads it, such as an institutional credit policy compatible with the long-term reality of forestry.

2.3 What is new in INDC?

Only one of the goals (“Compensate GHG emissions from deforestation”) included in Brazil´s INDC is entirely new, although this goal raises the ambition for the land-use sector as a whole. The other goals have already been articulated in previous Brazilian policies and commitments, beginning in 2007, and in some cases remained the same while in others the ambition was raised (Table 4).

TABLE 4: GOALS CITED IN NDC, LEGAL BASIS FOR SUCH GOALS AND LAUNCH YEAR TARGETS

INDC target	Legal base	Additionality of NDC to the previous laws or goals	Year of release
Increase the participation of bioenergy by 18% in the Brazilian energy matrix	National Plan on Climate Change (Brasil 2010, Decree 7,390), decennial energy plan (PDE)	Originally predicted 11.4%, and in the INDC this value had risen to 18%	2008
Compliance with the National Vegetation Protection Law	Law nº 12.651 (Brasil 2012a)	None	2012
Zero illegal deforestation until 2030 in the Amazon biome	National Plan on Climate Change (Brasil 2010, Decree 7,390), Plan for Prevention and Control of Deforestation in the Legal Amazon (Portuguese acronym PPCDAm)	None	2008, 2010
Compensate GHG emissions from deforestation	Nothing found	Fully additional, and becomes the overarching goal for the land-use sector	-
Restoration of 12 Mha	National Plan on Climate Change (Brasil 2010, Decree 7,390)	Originally, the National Plan on Climate Change promised 11 Mha by 2020, 2 Mha of native species. In INDC this value had risen to 12 Mha but postponed to 2030; it does not specify the fraction related to native species	2008
Expand sustainable forest management	Decree 3,420 (Brasil 2000); Decree 6,101 (Brasil 2007b)	None	2000; 2007
45% of renewable energy in the energy matrix	Decennial Energy Plan (PDE)	The 2007 Decennial Energy Plan states that Brazil already has 45% of the energy matrix from renewable sources	2007
Low Carbon Agriculture Plan	ABC	None	2010
Restore 15 Mha of pastures	ABC	None	2012
5 Mha of integrated systems (i.e. crop-livestock system)	ABC	ABC originally predicted 4 Mha of integrated systems, and in the INDC this value had risen to 5 Mha	2012
In the industrial sector, promoting new standards of clean technologies and expand energy efficiency measures and low-carbon infrastructure	National Plan on Climate Change (Brasil 2010, Decree 7,390), decennial energy plan (PDE)	None	2008
In the transport sector, to promote efficiency measures, improvements in transport infrastructure and public transport in urban areas.	National Plan on Climate Change (Brasil 2010, Decree 7,390), Decennial Energy Plan (PDE)	None	2008

3. Key Related Policies and Laws

3.1 The Native Vegetation Protection Law, or Forest Code (NVPL)

Brazil's Native Vegetation Protection Law (12.651/2012; NVPL), also known as the Forest Code (Código Florestal), is the main national environmental law that protects and regulates the use of native vegetation in rural private lands (Brancalion et al. 2016). The law requires landowners to conserve native vegetation on their rural properties, setting aside APPs and RLs. The APPs are environmentally sensitive areas that must be protected or restored, especially for water supply and prevention of soil erosion. These areas include riparian vegetation adjacent to streams and rivers, around springs, on hilltops, high elevations and on steep slopes. The size of the riparian areas to be protected or restored depends on the size of the rural property (Table 5). The RLs within rural properties can be used: i) for economic use in a sustainable way; ii) to help conservation and rehabilitation of ecological processes; and iii) to promote biodiversity conservation. They occupy different percentages of the property area according to the biome in which they are located: 50–80% in the Amazon (depending on the deforestation year and regional law), 35% in Cerrado lands in the Legal Amazon, and 20% in the Atlantic Forest, Cerrado, Pampa and Pantanal. However, the area of APPs on the property count towards the required RL. The NVPL exempts small rural properties (≤ 4 "fiscal module" units) from maintaining the RLs. The fiscal module is the minimum size of an economically viable rural property and varies from 5 to 110 ha, according to the location of the municipality. For example, in Paragominas (in the state of Pará), the fiscal module is 75, and therefore properties of less than 300 ha are exempt.

TABLE 5: NATIVE VEGETATION AREA TO BE PRESERVED AS ENVIRONMENTAL PROTECTED AREAS (APP, SUCH AS RIPARIAN AREAS) ACCORDING TO THE NVPL, DEPENDING ON THE SIZE OF THE RURAL PROPERTY

Fiscal module units	Riparian area (meters)
Up to 1	5
1 to 2	8
2 to 4	15
4 to 10	20
Above 10	30

The NVPL emphasizes that portions of the RLs can be used to generate economic benefits from sustainable forest management. Specific recommendations are that: i) up to half of the RLs may be used for economic benefits; ii) when using exotic species (up to 50%), these species need to be interspersed with native species; iii) when using exotic species, management should promote the regeneration of native species; iv) the holding must follow the principles of sustainable forest management; and v) the species diversity needs to be maintained. However, there is a lack of specification on some aspects, such as the required value to maintain species diversity. APPs may not be used to provide economic benefits, although small rural properties (≤ 4 fiscal module units) can use them for sustainable agroforestry.

It is critical to distinguish between restoration, recovery and reforestation. "Restoration" means the return of a degraded ecosystem as close as possible to the original "reference" ecosystem (e.g. old-growth forest). Ecosystem restoration at smaller spatial scales can be a component of landscape restoration. "Recovery" signals the return of a degraded ecosystem to a non-degraded condition that may differ substantially from the reference ecosystem. Recovery of ecosystem functions and services, however, can be accomplished without strict fidelity to the original species composition of the vegetation, and in some cases exotic species can be useful in this process. "Reforestation" is a broad term for any process that returns complete or partial tree cover on forestland through planting or through natural or assisted regeneration processes, and can also include agroforestry, commercial plantations, restoration plantations, or small woodlots. The restoration process gradually leads to increasing functional, structural, and compositional similarity of vegetation with the prior (undisturbed) vegetation, and is driven by native species.

These terms remain poorly defined within the reforestation policy framework in Brazil, creating confusion and conflicts regarding the types of forest that should be prioritized under particular circumstances and spatial scales. The interests of the forestry, agriculture, and energy industries tend to support reforestation as a market-based commercial activity, whereas conservation biologists and ecologists view the major purpose of restoration as sustaining biological diversity and ecosystem services (Chazdon et al. 2016a).

Several features of the new NVPL weaken its effectiveness in promoting native vegetation recovery in the different biomes of Brazil. These include: i) amnesty from fines for those who illegally deforested before 2008; ii) amnesty from the obligation to restore RL for small landowners (≤ 4 fiscal modules) who illegally deforested before 2008 (around 90% of Brazilian rural properties; Soares-Filho et al. 2014); iii) reduction of the required width of forest to be planted in riparian areas (APP) (Table 5); and iv) authorization to plant exotic woody species in up to 50% of the RL (Brancalion et al. 2016). These changes can lead to perverse outcomes, such as a potential increase in deforestation of up to 22 Mha (Sparovek et al. 2010), a decrease in the total native vegetation area to be restored by around 29 Mha (Soares-Filho et al. 2014), and increased carbon emissions by around. 1.1 billion tons of CO_2 (Nazareno et al. 2012).

Although part of the native vegetation is in public protected areas defined by the National System of Conservation Units (SNUC), the extent of this protection is insufficient to maintain Brazil's rich biodiversity and to sustain the provision of ecosystem services. In the Amazon, 46% of the native vegetation is in protected areas, but such levels of protection are much lower in other Brazilian biomes: 9% in the Atlantic Forest; 8% in the Cerrado; 7% in the Caatinga; 5% in the Pantanal; and 3% in the Pampa. Thus, it is crucial to preserve and restore natural vegetation in APPs and RLs. Brazil's Ministry of Environment (MMA) estimates that 19 Mha (53%) of native vegetation are in private lands. Thus, by excluding the Amazon biome for example, the APPs and RLs (87.6 Mha) are approximately two-and-a-half times larger than the sum of protected areas under the SNUC (34.4 Mha) and the protected indigenous lands (Table 6). If properly managed and integrated into the landscape, these APPs and RLs can provide crucial connectivity as corridors and stepping stones between larger fragments; provide buffer zones for public protected areas; and provide crucial ecosystem services that will improve the sustainability and productivity of the landscape (Fagan et al. 2016).

TABLE 6: THE POTENTIAL ROLE OF APPS AND RLS IN FIVE BRAZILIAN BIOMES

Biomes	Indigenous lands	Protected areas	LRs and APPs with native vegetation cover
Cerrado	9,440,000	16,819,900	49,018,770
Atlantic Forest	682,900	10,088,100	14,234,207
Caatinga	267,800	6,269,700	18,028,834
Pampa	2,623	483,000	3,061,732
Pantanal	266,900	694,800	3,307,551
Amazon	101,471,500	111,750,900	109,287,140
Total	**112,131,723**	**137,026,900**	**200,119,214**

Source: Indigenous lands: www.funai.gov.br; protected areas: www.mma.gov.br/areas-protegidas/sistema-nacional-de-ucs-snuc; LRs and APPs with native vegetation cover from Soares-Filho et al. (2014).

3.1.1 Environmental Rural Cadastre (CAR)

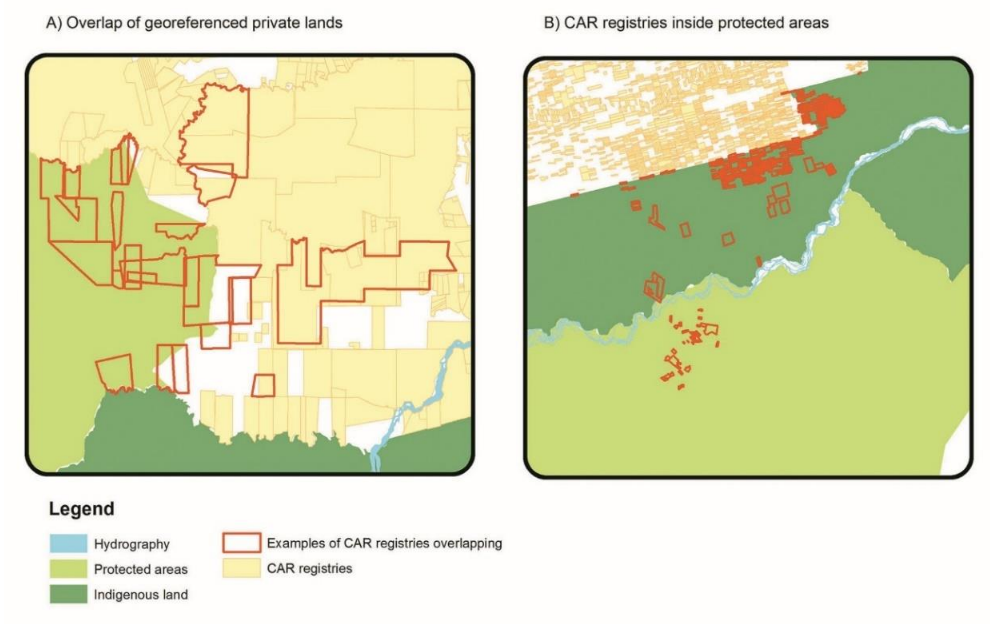
The Environmental Rural Cadastre (CAR) emerged as the instrument of the new NVPL to regulate and manage land use on rural private lands (Silva et al. 2012). The CAR constitutes a strategic database for controlling, monitoring and combating deforestation in Brazil, and for the economic planning of rural private lands (http://www.car.gov.br).

According to the NVPL, all landowners must register their property and identify, in a spatially explicit way, the precise limits of their APPs and RLs in the Federal Rural Environmental Registry System (SiCAR). This system provides georeferenced maps and images, enabling documentation of more than five million rural properties. Registration under SiCAR is required for the concession of rural credit, environmental compliance through restoration and compensation of illegally deforested areas, and may facilitate the market for payments for ecosystem services. Thus, the registry provides federal and state governments the power to regulate and manage accurately the amount of land allocated in private properties for both environmental conservation and agricultural production.

To date, a total of R$ 183 million (US$ 52.28 million; US$ 1.00 = R$ 3.50 as of May 16th 2016) have been invested in SiCAR. This investment includes satellite image acquisition, software development, training, and analysis, but does not include the costs of human resources from the Brazilian Forest Service and MMA. By February 2016, 269 Mha had been registered under SiCAR (67.6% of the total rural properties area), referring to about 2.5 million rural properties. In May 2016 the federal government extended the deadline for registration to May 2017.

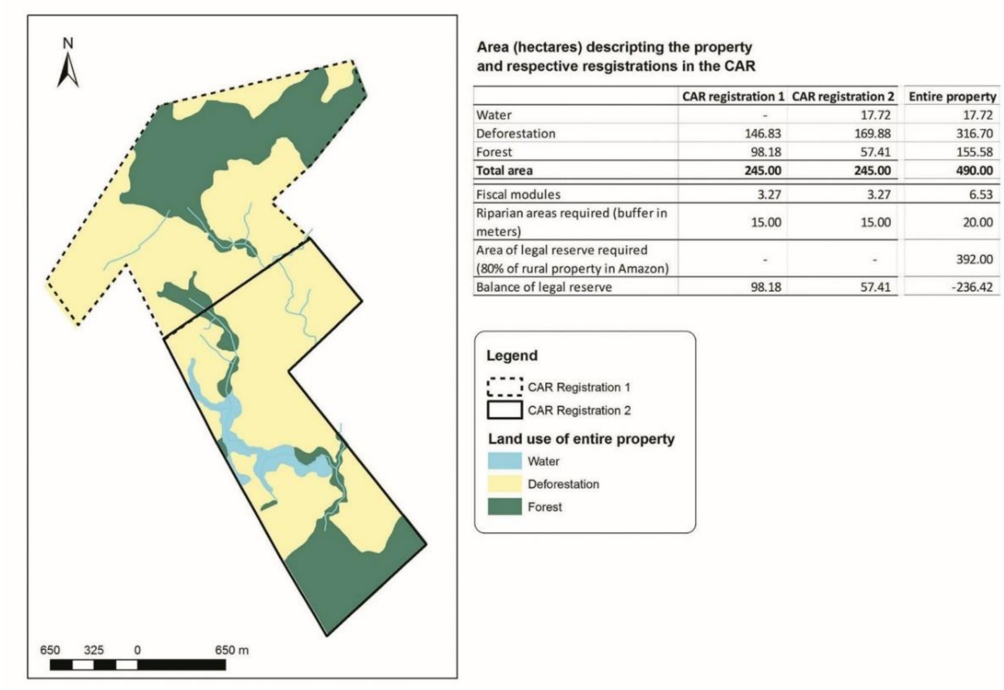
The state-level efforts revealed three flaws that can affect the environmental conservation and regulation/management of rural private lands (Silva et al. 2012). These are: i) overlap of georeferenced private lands (Figure 5A). Georeferenced data without overlaps are required to estimate accurately the environmental "debt" in RLs; ii) registration of private land inside protected areas (Figure 5B). Several registrations appear partially or totally inside areas where agricultural production is not allowed (e.g. indigenous lands and protected areas); and iii) registry of lands as multiple properties by landowners (Figure 6). Thus, one of the major risks to environmental regulation lies in the possibility that producers register a single large property as multiple small properties, such that each property is below the threshold for environmental compliance in APPs (e.g. Table 6) and RLs (≤ 4 fiscal modules).

FIGURE 5: EXAMPLES OF OVERLAP BETWEEN A) PRIVATE LANDS AND B) PRIVATE LANDS AND EITHER PROTECTED AREAS OR INDIGENOUS LANDS IN THE STATE OF PARÁ, BRAZILIAN AMAZON



Source: Adapted from Silva et al. (submitted)

FIGURE 6: EXAMPLE OF A RURAL PROPERTY SPLIT INTO TWO REGISTERS IN THE CAR OF SÃO FÉLIX DO XINGU, BRAZILIAN AMAZON



Area (hectares) descripting the property and respective resgistrations in the CAR

	CAR registration 1	CAR registration 2	Entire property
Water	-	17.72	17.72
Deforestation	146.83	169.88	316.70
Forest	98.18	57.41	155.58
Total area	**245.00**	**245.00**	**490.00**
Fiscal modules	3.27	3.27	6.53
Riparian areas required (buffer in meters)	15.00	15.00	20.00
Area of legal reserve required (80% of rural property in Amazon)	-	-	392.00
Balance of legal reserve	98.18	57.41	-236.42

Source: Adapted from Silva et al. (submitted).

Notes: The former registration is in the name of the landowner, while the latter was completed on behalf of others. The fiscal module is 75 ha in the São Félix do Xingu.

Another important question concerns the CAR registrations in agrarian reform settlements. It is currently unclear if these properties will consider the settlement as one or more individually registered lots. These flaws and ambiguities can reduce valid registrations in Brazil, potentially undermining the CAR as an instrument to regulate and manage land use on private lands. The federal government is aware of these flaws and is planning an extensive effort to validate not only state-level registrations, but also all other new registrations. An effective and reliable CAR has the potential to be a central pillar for national and global ambitions of sustainable development by conciliating environmental conservation and rural development (Silva et al. submitted).

3.1.2 Environmental Compliance Programs (PRA)

Rural landowners with a deficit of natural vegetation and protective forests on their properties are required to carry out a PRA. The PRA establishes criteria for the definition of the areas in APPs and RLs that need to be recovered. PRAs will be planned, developed and monitored at the state level. The PRA carries a potential risk of insufficient enforcement and monitoring by state governments.

3.1.3 Environmental Reserve Quota (CRA)

The NVPL provides the opportunity for landowners to "compensate" or "offset" their RL debts (the difference between the actual RL and RL mandated by law) by purchasing surplus from properties that have native vegetation in excess of the minimum RL requirements. This opportunity extends to landowners who, as of July 22nd 2008, did not meet the area-based preservation requirements of the law. Such surplus occurs in rural properties that have either more native vegetation area than required, or have approved plans to restore/reforest sites that would permit them to exceed the minimum legal requirements in the future. The compensation instrument is the Environmental Reserve Quota (CRA), a tradable legal title for landowners with i) an intact or regenerating native vegetation exceeding the NVPL requirement; and ii) a land title. The CRA (surplus) on one property may be used to offset an RL debt on another property within the same biome and, preferably, the same state. Implementing the CRA could create a market for forested lands, adding monetary value to native vegetation. Given the high costs of restoration/reforestation in some regions, exchange of CRAs could become an effective way to facilitate NVPL compliance, and the option with the highest cost–benefit ratio for avoiding legal deforestation of surplus native vegetation.

Compensation of RL debts can be implemented in several ways in a CRA market. These are: i) acquisition of a CRA; ii) lease arrangements for areas under environmental easement or RLs; iii) donation to government of properties located within public protected areas requiring land regularization; and iv) registration of an equivalent surplus area to the RL, in a property of the same landowner or acquired in a third property, with established native vegetation or in regeneration/reforestation, located within the same biome.

The SiCAR will facilitate the market for CRAs and payments for ecosystem services. State plans and CRA trade clearinghouses are intended to regulate and track trading of surplus reserves between landowners, while commercial exchanges are emerging to grease the wheels of the trading mechanism. The legislation allows for trading at biome scale – i.e. beyond state boundaries. To ensure that purchasing a CRA results in additional native vegetation conservation (i.e. a greater environmental benefit than would have otherwise occurred under "business as usual"), higher-priority properties should receive additional compensation per unit area. Funding for such complementary programs could come from the government as well as from philanthropic sources, but could, in principle, also come from carbon and/or other environmental service markets. A balanced use of CRAs should focus on improving functional and ecological attributes of native vegetation at the landscape level – e.g. habitat integrity (and thus biodiversity), carbon stocks, and water balance regulation – crucial for maintaining hydroelectric power generation in Brazil. These compensation markets could involve exchanges worth US$ 2.2 billion (Observatório do Código Florestal 2015), but require an accurate CAR.

The CRA market has a risk of low levels of trading as a consequence of weak monitoring and enforcement of areas demarcated for protection, and demand exceeding supply. Advances in remote sensing technology have improved the feasibility of monitoring; the CAR system works with Rapid Eye satellite images with a resolution of 5 meters. Demand could be higher if CRAs were issued not only to compensate RL, but also to compensate biodiversity conservation and ecosystem services provision. CRA trading could be more effective for biodiversity conservation if higher-priority properties were to receive additional compensation per unit area, funding of which would come from carbon and/or other environmental services markets. The interest of private companies in ensuring zero-deforestation agricultural supply chains could create private sector pressure for native vegetation conservation and legislative compliance (as was the case under the soybean moratorium). Other issues should be considered, such as:

1. How much does it cost to create and operationalize this market?
2. How much is needed to validate the contracts? and
3. What is the transaction cost?

3.2 Legal deficits, total area to be restored, and the benefits of restoration

In June 2015 Brazil stated that its main targets would be presented at the COP21 in Paris (December 2015). The Brazilian government proposed to end illegal deforestation by 2030; increase the generation of clean electric (except hydroelectric) power to 20% in relation to the current situation; and restore or reforest 12 Mha. The striking target was that relating to restoration/reforestation, based on the new NVPL. Depending on the share of native vegetation restoration, this target has the potential to establish Brazil as a global environmental leader on climate change mitigation and ecosystem-based adaptation initiatives.

A study by Soares-Filho et al. (2014) estimated the area that is currently not covered by natural vegetation, but would need to be in order to comply with the new NVPL – the environmental deficit or liability. The estimate was used in the first version of the National Plan for Restoration of Native Vegetation (see section 3.5). The total environmental liability would be 21 Mha, but 9.2 Mha and 1.5 Mha could be compensated via CRA markets and by potential purchase of properties illegally established in federal protected areas, respectively, while 2.2 Mha could be restored or reforested opportunistically beyond RLs and APPs. Thus, there is a net total 12.5 Mha of environmental liabilities under the NVPL.

More recent (unpublished) government estimates put the environmental liability of rural landowners in complying with the NVPL at about 20 Mha (Table 7). Such estimates include deficits of RLs and APPs and opportunistic areas for restoration beyond RLs and APPs, but exclude the amount of area to be compensated via CRA markets and by potential purchase of properties illegally established in federal protected areas (Table 7). Thus, the latest estimates of vegetation recovery needed to comply with the NVPL have increased from 12 to 20 Mha. These data are detailed per biome (Tables 8 and 9). The RL liability (18,873,543 ha) is about 3.8 times larger than the APP liability (4,997,310 ha). Furthermore, the NVPL allows additional legal deforestation of 88 Mha (Soares-Filho et al. 2014).

Table 7: Overall estimated environmental debit to comply with the NVPL in Brazil: APP and CRA

a) RL deficit	18,873,543
b) APP deficit	4,997,310
c) Potential for CRA market	4,674,185
d) Potential purchase in federal protected areas	1,500,000
e) Opportunity for restoration beyond RLs and APPs	2,387,085
Target deficit (a + b - c - d + e)	**20,083,753**

Source: Data made available by the PLANAVEG team (unpublished)

Table 8: Potential purchase of properties illegally established in federal protected areas

	Total (ha)	**Areas with ownership (subject to purchase)**
Amazon	2,970,000	-
Caatinga	103,000	-
Cerrado	1,677,000	-
Atlantic Forest	656,000	-
Pampas	-	-
Pantanal	-	-
Total	**5,406,000**	**1,500,000**

Source: Data made available by the PLANAVEG team

Table 9: Total net restoration target per biome (ha)

Biome	**Target (ha)**
Amazon	7,222,518
Caatinga	1,163,146
Cerrado	5,133,618
Atlantic Forest	5,840,495
Pampas	596,187
Pantanal	127,787
Total	**20,083,751**

Source: Data made available by the PLANAVEG team

3.3 The environmental and social impacts of restoration

If deficits are restored to natural vegetation on private holdings in order to comply with the NVPL, restoration has the potential to become the second-largest driver of land-use change in Brazil. As discussed in section 1.1, restoration would bring significant social and environmental benefits, such as job creation, training and increased labor skills, as well as increased on-farm income through the exploitation of timber and non-timber products. Encouraging native vegetation restoration as a productive activity will also contribute to the reduction of inequality between rural and urban municipalities and the transformation of Brazil into a country with higher levels of human development and ecosystem services.

There is an intense debate about the need for human intervention (active restoration) to accelerate and influence the restoration process (Holl and Aide 2011; Chazdon 2014), fueled by the wide variation in spontaneous restoration capacity (resilience) through natural regeneration (Guariguata and Ostertag 2001, Chazdon 2014). Some studies show that degraded areas can recover in a few decades (e.g. Jones and Schmitz 2009), while others show the opposite trend (e.g. Liebsch et al. 2008). Thus, active restoration is indicated for areas with low potential for natural regeneration or that would take a long time to recover. These differences motivate the need to develop models for planning the most cost-effective restoration approaches for different areas (e.g. Holl and Aide 2011, Brancalion et al. 2012, Wortley et al. 2013). Natural regeneration has been shown to be the most cost-effective option for increasing native vegetation cover at a large scale (Chazdon 2014).

With proper planning and implementation, it is possible to restore natural vegetation at the required scale without compromising agricultural production. One of the main arguments of the agribusiness sector against forest restoration through natural regeneration is that it competes for land with agricultural production (Soares-Filho et al. 2014). Increasing the productivity of cattle ranching in a sustainable manner has been proposed as a potential solution to reconcile increasing demand for forest restoration (Smith et al. 2010, Lambin and Meyfroidt 2011, Bustamante et al. 2012, Cohn et al. 2014, Latawiec et al. 2015). Sustainable intensification means increasing production from current agricultural lands that are being used below their potential sustainable capacity, while respecting biophysical constraints to avoid adverse impacts from over-intensification (Foresight 2011). The current productivity of Brazilian pastureland is only about 30% of their sustainable potential. Increasing productivity to 70% of the sustainable potential could accommodate production of key products (meat, soybean, sugarcane and maize), even for exports, and release 36 Mha for restoration of natural systems (Strassburg et al. 2014). This will be discussed in more detail in section 6.2.

Nevertheless, if not implemented correctly, sustainable intensification can have negative environmental, economic and social effects. For example, a rebound effect may follow whereby further deforestation occurs since more productive systems can also be more profitable (Lambin and Meyfroidt 2011). Indirect deforestation (Arima et al. 2011, Lambin and Meyfroidt 2011, Cohn et al. 2014) and displacement of less capital-intensive smallholders (Bustamante et al. 2012) are other examples of unintended adverse effects. Thus, intensification may not result in less deforestation in the absence of effective regulations that would prevent unintended consequences.

Restoration of native vegetation faces several challenges. These include a lack of experiments, especially in the long term, to assess the effectiveness of different restoration methods, which compromises scientific validation of restoration recommendations and legal instruments (Rodrigues et al. 2009 and 2011, Brancalion et al. 2012), and a lack of knowledge about the economic benefits of ecological restoration for landowners (Calmon et al. 2011, Brancalion et al. 2012).

The Brazilian economy is heavily dependent on land-based products for its agricultural exports, and on natural resources like hydropower which accounts for 68% of Brazil's energy matrix. Therefore, sustainable land management is of crucial importance for the economy. Restoration is a green solution that can alleviate poverty and improve human well-being, mainly through job creation and higher incomes, payment for ecosystem services, exploration of timber, and generation of carbon credits (Calmon et al. 2011, Brancalion et al. 2012, Melo et al. 2013), reducing inequality in terms of income and land-ownership distribution within rural municipalities. However, the socioeconomic effects of forest restoration on the local and global society are still largely unexplored.

Up-scaling restoration initiatives can involve and benefit a range of stakeholders. Examples include the public sector, which stands to gain from the increased socioeconomic benefits of the restored areas; landowners, who are interested in having a forest area that is compliant with the NVPL; producers in the restoration supply chain, which benefits from the increased demand caused by a successful showcase of viable restoration; and civil society, which benefits from the lessons learned and the strengthened supply chain.

Restoration may be one of the best green options for achieving effective sustainable development. Restoration contributes to: i) socio-environmental resilience by improving water regulation, increasing biodiversity, improving soil properties, restoring microclimates, and increasing livelihoods; ii) creation of jobs and building capacity; iii) increasing incomes, for example, through payment for ecosystem services; iv) improved restoration chains by identifying bottlenecks and creating demand and stimulating supply. Once the whole chain is robust and each of its parts is well connected, current and future restoration projects will more likely continue and be scaled up more easily. Synergies with other initiatives and policies developed countrywide may contribute to scaling up restoration in Brazil.

Deforestation, fragmentation and degradation of Brazilian native vegetation cover reduce biodiversity conservation and provision of ecosystem services. Despite the remarkable success in reducing deforestation in the Amazon, deforestation and land degradation in other biomes – in particular the Cerrado and Caatinga – continue at alarming rates. Fragmentation is a serious threat for biodiversity conservation in heavily deforested biomes, particularly for Brazil's two global biodiversity hotspots (high biodiversity areas under critical threat): the Atlantic Forest and the Cerrado.

3.4 The national policy for planted forests and its targets

The responsibility for the plantation forestry policy was transferred to MAPA in 2014. The growth of this sector will be based on a national strategy, supported by the National Development Plan for Planted Forests being prepared by MAPA, and guided by the National Policy for Planted Forests. Both production and consumption in the domestic market are to be strengthened. For instance, paper production for packages is to be increased by 50%, and national consumption of cellulose is to be raised from 6 million to 10 million tons per year. To achieve this, planted forest area is to be scaled up from 7.3 to 10.6 Mha between 2015 and 2025.

The National Policy for Planted Forests (Agriculture Policy for Planted Forests) was created by Decree 8,375 in December 2014 (Brasil 2014b). It defines planted forests as comprising species grown for economic and market returns. Through the National Policy for Planted Forests, Brazil could achieve a lead position in the international market, aligning environmental management, restoration of degraded areas and opportunities in the carbon market. The instruments of the policy are, among others, those set out in the aforementioned Agricultural Policy (Law 8,171 of 1991).

3.4.1 Planted forests in Brazil

Land cover

The area of planted forest increased by 1.8% from 2013 to 2014, reaching 7.7 Mha, or 0.9% of the national territory (IBÁ 2016). Only the Pampas (grasslands) and Pantanal (wetlands) biomes have no plantations. Most plantations are in the Southeast region. Eucalyptus plantations cover 5.56 Mha (71.9% of total area) and are located mainly in the states of Minas Gerais (25.2%), and São Paulo (17.6%).

Planted forests may grow to 16 Mha in the next ten years due to high potential productivity in Brazil. Expanding plantations would require an investment of US$ 20 billion. This expansion can happen through sustainable intensification of cattle ranching, sparing land for reforestation. On the other hand, such spared land could also be used for other types of restoration favoring native species and providing greater social benefits, multiple ecosystem services, and habitats for biodiversity (Table 1).

Market, production and demand

Globally, the forestry sector would need an additional 210 Mha of plantations to supply the projected demand. The UN Food and Agriculture Organization (FAO) estimates a world with 9.5 billion inhabitants by 2050, demanding a 70% increase in food production (FAO 2012). As stated in section 2, Brazil aims to increase the planted forests under its draft National Development Plan for Planted Forests by 3.3 Mha. The industries responsible for current planted forests are primarily pulp and paper (34%), followed by independent forest producers (27%); whereas steel mills and charcoal account for 15%.

Planted forests represent a gross revenue of US$ 60 million, and create 4.4 million jobs and approximately 6.5% of industrial Gross Domestic Product (GDP). Every hectare of planted forest contributed around US$ 2,228 to GDP in 2014. Planted forest GDP grew by 1.7% in 2014 (reaching 39 m^3/ha/year for eucalyptus, and 31 m^3/ha/year for pine), being the leader in terms of global productivity (IBÁ, 2015). The growth of planted forests is exceptional when compared with the growth of cattle ranching and industry (0.4% and 0.7% respectively). Considering the contribution of planted forest to environmental mitigation and its potential growth, the sector is a key actor in achieving the INDC.

Despite the potential of the planted forest sector in achieving the Brazilian INDC, the sector must overcome some challenges. Pulp production increased in the first months of 2016 compared with 2015 (IBÁ 2016). However, timber production in Brazil will have to address increasing costs. In the last 14 years, forestry production costs in Brazil increased: the National Index of Forestry Activity was 7.9% while inflation over the same period was 6.4% (IBÁ 2015). This is due to increases in wages combined with stagnant labor productivity and inflation. Apart from the production costs, concentration in the forest plantation sector may pose another challenge for the INDC. A few big companies control most of the market while most of the companies are small or medium-sized producers (SMEs).

Carbon sequestration and carbon market

Forest plantations can store high levels of CO_2, averaging 7.5–15 tons/ha/year, depending on the species (pine and eucalyptus) and the management regime. In 35 years, eucalyptus can sequester 1.400 tons/ha of CO_2 (IBÁ 2015). In 2014, the 7.7 Mha of planted forests in Brazil were responsible for storing 1.69 billion tons of CO_2, an increase of 1.2% over 2013 – equivalent to one year of national emissions. The forest plantation sector could be part of the carbon market, in which carbon credits could be used for financing the high timber production costs.

However, there is still debate about whether this carbon storage is only temporary, or if every planted tree ensures the maintenance of carbon stock. Overcoming this doubt is essential in ensuring the potential of the forestry sector in environmental compensation. In addition, according to the Kyoto Protocol, only forest planted after December 31st 1989 can be considered for the Clean Development Mechanism (CDM). This cut-off point seems arbitrary as it disregards the possibility of renewing and intensively managing already existing forestry plantations that were established before this date.

Furthermore, there are other risks associated with the carbon market, such as the exposure of plantations to fire, floods and other natural disasters. This calls for a precise monitoring and verification process, with accurate measurement of CO_2 storage above and below ground. There is a need for lines of forestry insurance to mitigate the escape of CO_2 and guarantee sequestering and storing an equivalent amount in the event of such disasters. Another risk is in the substitution of native forest for planted trees. The high productivity and fast growth of pine and eucalyptus changes the relative viability and market value of native species products. This risk increases with the lack of policies for sustainable native forest management.

Certification

Despite its central importance for reforestation and climate mitigation policies, the actual practices of the forestry sector need to be aligned with environmental standards. The sector comprises companies with high standards that follow strict protocols under certification schemes (from the 7.7 Mha of planted forests in Brazil, 4.8 Mha (63%) are certified by independent organizations; IBÁ 2015). However, there are also companies that contribute to illegal deforestation and/or adopt unsustainable practices. Although the exploitation of native forest for timber and non-timber products is allowed by law, after authorization by public agencies, there is a growing concern about sustainability in sector practices and the sourcing of forest products from planted forests.

3.5 National Plan for Restoration of Native Vegetation (PLANAVEG)

PLANAVEG is an ambitious initiative of the MMA in collaboration with various NGOs. It seeks to restore 12.5 Mha of native vegetation by 2034, primarily in APPs and RLs, but also in degraded or low-productivity areas. Such a strategy would allow Brazil to fulfill some of its major national and international commitments regarding environmental conservation. It was included in the Brazilian Multi-year Plan (2012-2015, Program 2036 – objective 0229), which highlights the importance of promoting the recovery of native cover in degraded lands, mainly APPs and RLs.

3.5.1 Content

PLANAVEG proposes three main lines of action to help the recovery process of native vegetation: motivate, facilitate, and implement the restoration of native vegetation (Table 10). These three lines of action are developed into nine strategic initiatives: i) awareness; ii) seed and seedlings; iii) markets; iv) institutions; v) financial mechanisms; vi) rural extension; vii) spatial prioritization and monitoring; viii) research and development; and ix) human resources. Three existing programs and policies complement these strategic initiatives and, in their own way, create important motivating and enabling conditions for recovery of native vegetation: sustainable agriculture intensification to increase the productivity of pastures and croplands through efforts such as the ABC program, the Forest Code itself;

follow-through with the implementation of the provisions of Law Nº. 12.651/2012; and land tenure regularization.

TABLE 10: THE PLANAVEG THREE MAIN LINES OF ACTION

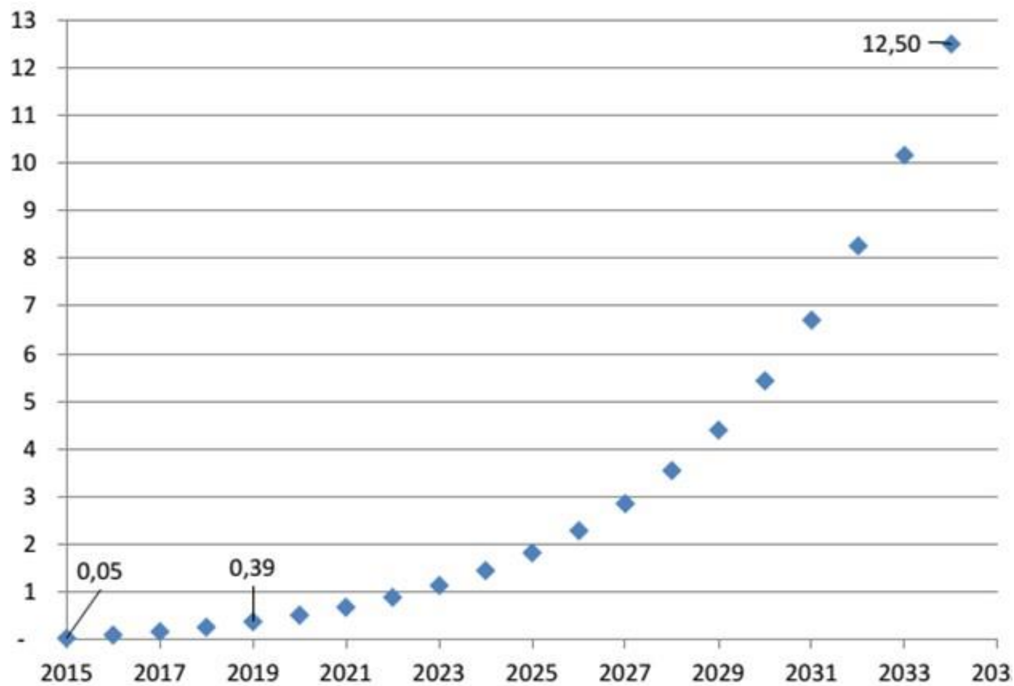
Line of action	Aspects	Key factors of success
1) Motivate	a) Benefits	Existence of social and environmental benefits from recovery
		Economic viability of recovery
	b) Awareness	Communication of the benefits of recovery
		Identification of opportunities for recovery
	c) Extreme events or crises	Extreme events transformation or crises into opportunities
	d) Legal mechanisms	Existence of legislation for the recovery of native vegetation
		Understanding and enforcement to recover the native vegetation
	e) Culture	Existence of a cultural link between society and the different types of vegetation
2) Facilitate	a) Ecological conditions	Soil, water and climate conditions suitable for recovery
		Default of plants, animals and fire that might prevent recovery
		Availability of seeds, seedlings, seed bank and seedlings
	b) Market conditions	Little existence of competing demands (e.g. production of food, fuel, fiber) in degraded or altered areas
		Existence of markets for products from reclaimed areas
	c) Conditions of public policy	Land tenure guarantee and its natural resources by owners
		Alignment and coherence between public policies that influence the recovery of native vegetation
		Existence of restrictions on the conversion and degradation of native vegetation
		Application of restrictions and penalties for causing the illegal conversion of native vegetation
	d) Social conditions	Engagement and empowerment of local communities in decision-making about recovery
		Local people benefit from the recovery of native vegetation
	e) Institutional conditions	Clear definition of roles and responsibilities of key actors for recovery
		Arrangement of existence and effective institutional coordination (governance)
3) Implement	a) Leaders	Existence of leaders in national and / or local level
		Existence political commitment of long term
	b) Knowledge	Existence of knowledge on the recovery of ecosystems
		Knowledge transfer on recovery through networks of experts and technical assistance and rural extension
	c) Techniques and methodologies	Techniques and methodologies for recovery based on scientific knowledge and that take into account climate change
	d) Financing and incentives	Positive incentives and resources for recovery outweigh the negatives
		Incentives and financial resources readily accessible
	e) Monitoring	Existence of an effective system of monitoring and evaluation of results
		Wide dissemination of good examples and recognition of them by society

Source: PLANAVEG

3.5.2 Time horizon and cost

PLANAVEG covers 20 years since the recovery of native vegetation is a long-term process. Figure 7 provides estimates of the recovery of native vegetation projected over the next 20 years.

FIGURE 7: RECOVERY OF NATIVE VEGETATION (MHA), CUMULATIVE, OVER THE NEXT 20 YEARS



Source: PLANAVEG

In the first five years, this plan will cost around US$ 51.7 million, to be funded by government, financial institutions, international funds (e.g. Global Environmental Facility), the private sector and foundations (Table 11). It is important to note that this value refers to the costs of developing the strategies outlined below, not the costs of actual restoration.

TABLE 11: ESTIMATED BUDGET OF PLANAVEG IN THE FIRST FIVE YEARS

Strategic initiatives	Budget (US$ million)
1) Awareness	14.3
2) Seeds and seedlings	6.4
3) Markets	0.7
4) Institutions	2.8
5) Financial mechanisms	0.6
6) Rural extension	11.3
7) Spatial planning and monitoring	6.1
8) Research and development	8.1
9) Additional human resources	1.5
Total	**51.7**

Source: PLANAVEG

Note: Figures may not sum due to rounding.

The restoration/reforestation cost will vary with the method used to recover native vegetation. PLANAVEG describes five commonly used methods to promote recovery of native vegetation, with different costs per ha (Table 12), ranging from natural regeneration (low cost) to complete planting (high cost). Three scenarios use each method to different extents. These preliminary estimates were based on expert opinion (see section 6.2). Their costs over the first five years are presented in Table 12. Recovery costs for an area of 390,000 ha in the first five years range from of US$ 371 to US$ 542.8 million.

TABLE 12: COSTS OF RECOVERING NATIVE VEGETATION IN THREE SCENARIOS THAT ADOPT FIVE METHODS USED TO RECOVER THE NATIVE VEGETATION ON-THE-GROUND

Approach	Description	Total cost (US$/ha)	Restoration scenarios			Restoration cost of 390,000 ha of native vegetation, by scenario, over five years (US$ million)		
			A	B	C	A	B	C
1. Total planting	Total planting (1,666 seedlings/ ha)	2,857	30%	20%	10%	334	223	111
2. High enrichment and high density	Enrichment planting, filling open forest areas (800 seedlings/ha)	1,429	15%	15%	15%	84	84	84
3. Low enrichment and low density	Enrichment planting, filling open forest areas (400 seedlings/ha)	971	15%	15%	15%	57	57	57
4. Natural regeneration (with fencing)	Fencing areas and *Brachiaria spp*. Control[1]	686	20%	25%	30%	53	67	80
5. Natural regeneration (abandoned pasture)	Sparing areas of low agriculture potential or low productivity	400	20%	25%	30%	31	39	47
Total 5 years						**559**	**469**	**379**

Source: PLANAVEG

Note: [1] *Brachiaria spp* are grasses grown to feed cattle.

3.5.3 Benefits

The implementation of PLANAVEG will generate many socioeconomic and environmental benefits. These include: i) reduced cost of compliance with the NVPL due to economies of scale and consolidation of the restoration/reforestation chain; ii) increased farmer access to capital and markets; iii) creation of 112,000–191,000 jobs (based on PLANAVEG); iv) diversifying farmer income from new sources of revenue such as timber, non-timber forest products, and payments for environmental services; v) reduced risk associated with natural disasters; vi) drinking water supply to urban areas; vii) contribution to biodiversity conservation; and viii) carbon sequestration.

PLANAVEG is an important element in accelerating the process of bringing rural properties into compliance with environmental law. It does this by: identifying current obstacles, factors that affect restoration success, and priority areas for restoration; enabling landowners to access technical assistance and financial mechanisms; increasing seed and seedlings supply; reducing cost per ha; and generating income for small, medium and large landowners.

Need for restoration: the example of the Atlantic Forest

The Brazilian Atlantic Forest is one of the world's most threatened biodiversity hotspots (Myers et al. 2000). It now covers only 12–16% of its original 150 Mha and is in urgent need of restoration (Ribeiro et al. 2009, Crouzeilles et al. 2015). Overgrazing of pastureland has led to extensive land degradation, including soil erosion, sedimentation of rivers and nutrient loss. As a result, severe droughts, landslides and flooding have affected 60.5 million people in Brazil, with 1,668 deaths. Total economic damage has been estimated at US$ 10.66 billion (CRED 2016), with just the economic losses alone from the disaster in the municipality of Teresópolis totaling more than US$ 121.4 million. Table 13 presents an assessment of disaster costs compared with the costs of appropriate APP management. According to a report by the MMA, 92% of the landslides occurred in areas with some kind of ecosystem change (MMA 2011). In addition, water shortages are increasing in many states of the Atlantic Forest biome, such as in the most populated of Brazil – São Paulo – and have been associated with the loss of native vegetation.

TABLE 13: DISASTER COSTS COMPARED WITH COSTS OF PROPERLY RESTORED APPS IN TWO NEIGHBORHOODS IN THE MUNICIPALITY OF TERESÓPOLIS, RIO DE JANEIRO

APP: River bank	**Campo Grande[1] (US$ 1,000)**		**Bonsucesso[1] (US$ 1,000)**	
	Low	**High**	**Low**	**High**
Total structural, non-structural and emergency costs	4,240	12,213	1,189	3,039
Externalities (mortality and morbidity)	32,082	109,307	4,149	14,138
Disaster total costs	***36,323***	***121,520***	***5,338***	***17,192***
Relocation and settlement urbanization costs; opportunity costs of agriculture	2,188	6,036	1,724	4,869
Restoration costs	11	22	42	82
Total costs of the sound management of APP	***2,200***	***6,058***	***2,051***	***5,530***
Avoided costs = disaster costs - sound management costs	**3,412**	**115,462**	**5,133**	**11,662**

Source: MMA (2011)

Note: [1] Neighborhoods in the city of Teresópolis, Rio de Janeiro.

4. Other Land-based Targets Related to Brazil's INDC

A critical and often misunderstood element of the Brazilian NDC is the target of achieving zero net emissions from land-use change by 2030. According to governmental officials, this is the only "fixed" goal related to land-use change, whereas the stated goals for deforestation and restoration are initial estimates of how to achieve this, and these could be changed.

4.1 The INDC zero illegal deforestation target

In the National Plan on Climate Change (NPCC), Brazil stated the goal of reducing annual rates of deforestation by 80% in the Amazon, relative to the average rate of 19,625 km^2 per year between 1996 and 2005 (INPE 2014). According to the NPCC, the deforestation rate is expected to decrease to about 3,800 km^2 by 2020 (Brasil 2009a). Public policies have succeeded in reducing the rate to around 5,500 km^2 in recent years. In order to achieve its goal, Brazil still needs to step up its efforts and improve policies such as the Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm).

The 80% reduction in deforestation rate since 2004 has been a consequence of the implementation of policies aimed at increased enforcement and punishment of environmental crimes. An innovative approach was the focus of PPCDAm on a sub-set of municipalities with high deforestation rates, and the annual publication of a "black list" of municipalities. The list has guided actions of the Institute for Environment and Renewable Natural Resources (IBAMA) in recent years. Rural producers in these municipalities have faced restrictions of access to rural credit. The penalties for illegal deforestation vary from fines to the embargo of the area. However, the effectiveness of the sanctions is being questioned due to the low levels of collection of fines – less than 5% according to the Federal Audit Court's report (document TC 024.101/2009-2) – and to failures in controlling animal transport, which ultimately allowed the sale of embargoed livestock.

The PPCDAm currently focuses on three areas: promoting sustainable productive activities; land-use planning; and monitoring and control of deforestation. Implementation of these lines of action is uneven, with monitoring being the most effective, and the only action covering several municipalities (IPEA 2011). Increased monitoring has generated an effective demand for legalization of land titles – a challenge that states cannot meet. Identifying appropriate economic incentives has proven to be the biggest challenge of the PPCDAm because sustainable activities (i.e. gathering non-timber products such as fruits) have shown lower economic returns than economic activities linked to deforestation, such as soybeans and livestock.

In addition to more effective enforcement in the last decade, the beef and soy supply chains signed agreements with federal prosecutors and NGOs to boycott products from illegally deforested areas. For soybeans, such a boycott has been effective since July 24th 2006. Known as the Soy Moratorium, the agreement requires environmental legal compliance by producers and zero deforestation. Participants of the Moratorium established the Soy Working Group to implement the agreement. In 2009, the Federal Attorney (MPF) and IBAMA brought lawsuits against ranchers who had been fined for environmental offenses, and against slaughterhouses that purchased cattle from these farms. Moreover, the MPF published a list of 69 supermarket chains and industries that do not acquire products originating from farms or slaughterhouses involved in environmental crimes. This resulted in agreements (called Terms of Adjustment of Conduct) with various actors in the supply chain, pledging not to purchase cattle from illegally deforested areas, to abide by environmental laws, and to monitor suppliers.

The Sustainable Amazon Plan (Plano Amazônia Sustentável) proposes guidelines for sustainable development of the Amazon region. It seeks to promote socio-cultural and ecological diversity and the creation and adjustment of rural credit lines such as for ABC, the National Program for the Strengthening of Family Farming (PRONAF), and others. In total, the government estimated a financial contribution of US$ 400 million for the implementation of various actions to combat deforestation in the years 2012–2015 (Brasil 2012b).

While deforestation by medium and large producers is under more effective control, deforestation by small producers has increased significantly. The small polygons of cleared forest accounted for 20% of deforestation in 2002, but more than 60% in 2009 (Maia et al. 2011). The more sophisticated actions focused mainly on medium and large producers, with less attention to smallholders linked to smaller regional markets, which are subject to much weaker law enforcement. However, in order for Brazil to meet the goal of 80% reduction of deforestation by 2020, it will have to address the issue of deforestation on small properties. Barreto and Araújo (2012) make a simple estimate that illustrates the point: in 2006 (IBGE 2006), there were around 460,000 small farmers in the Amazon; if each cleared just one hectare, annual deforestation would reach 4,600 km^2 – 21% above the 2020 target.

4.1.1 Recent history and actions against deforestation and its consequences

The MPF and IBAMA were the key protagonists in the execution of legal actions and operations in the field to combat illegal deforestation, especially between 2007 and 2009. In December 2007, federal Law 6321/07 (Brasil 2007a) provided for the embargo of illegally deforested areas, except in subsistence activities. Embargoed areas must be geo-referenced to facilitate the monitoring and penalizing of potential buyers of products from those areas. The Normative Instruction 001 of 2008 (Brasil 2008) regulated the economic embargo of activities in illegally deforested areas. The embargo has become one of the most effective tools in the fight against deforestation. The requirement of re-registration with geo-referencing of rural properties ultimately led to what is now the CAR.

Based on the recent actions of MPF and IBAMA, the National Monetary Council (CMN) issued Resolution Nº 3,545/08 (BACEN 2008) prohibiting the concession of public or private credit to properties that do not possess a valid rural register (this differs from the CAR) or evidence of compliance with environmental regulations by the environmental authority. Furthermore, financing contracts must not be extended, or must be suspended if the rural property is to be subject to an embargo, until the environmental regularization of the property. Concerns on the part of agricultural interests about increased enforcement and punishment to combat deforestation resulted in major changes in the Forest Code in 2012, which included the establishment of the CAR as the main tool for monitoring deforestation and land-use planning (Law 12,651/2000).

4.2 INDC agricultural targets: recovery of pastureland

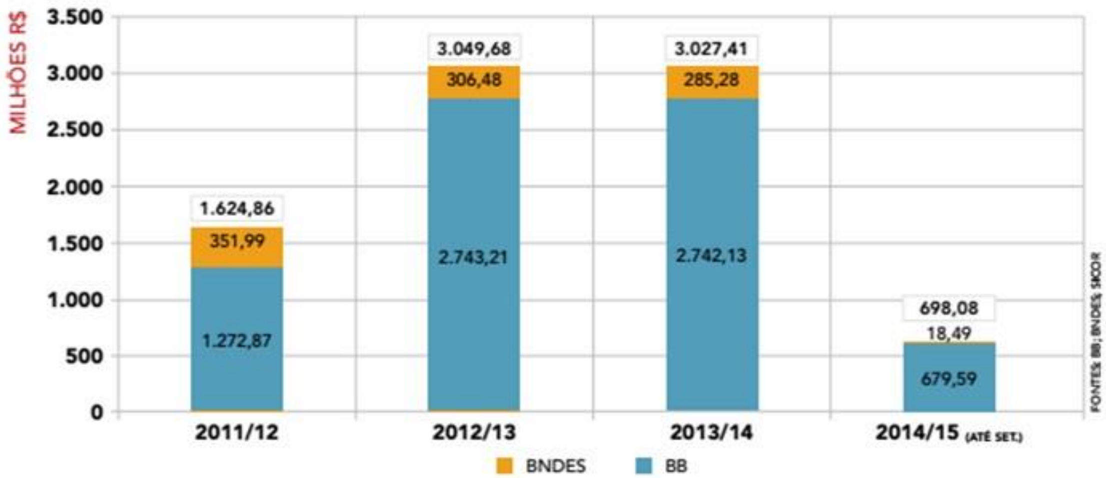
In the agricultural sector, the main strategy is the Low Carbon Agriculture Plan (ABC), which includes the restoration of 15 Mha of degraded pastureland and an increase of 5 Mha of integrated crop-livestock-forest systems by 2030 (Brasil 2015b). The government estimates the total pastureland area in Brazil to be 176–220 Mha (Brasil 2014a), but 25–30% of this area is natural grassland – that is, native vegetation, especially in the Cerrado, Pantanal, Pampas and Caatinga biomes. These areas should be excluded from the forest restoration goal. In the Amazon, an estimated 9 Mha of pastureland with some degree of degradation were classified as "dirty pastures" and "pastures with regeneration" by the Terra

Class project (INPE 2014). It is estimated that 27–42% of the total planted pasture is degraded (Brasil 2014a). The Brazilian government launched a line of credit as part of the ABC as the main incentive to farmers to restore this degraded pastureland.

The ABC estimates that US$ 12 billion (R$ 44 billion) will have been invested in adapting the agricultural sector to climate change by 2020, and 99% of this investment will be funded by rural credit, especially the ABC credit line (Table 14). The ABC Funding Program has so far disbursed about US$ 1 billion (R$ 3.5 billion) per year since 2010, and the government estimates that US$ 10.5 billion (R$ 37 billion) will be invested by 2020. In spite of significant increases since 2011 (Figure 8), ABC still represents only 2% of rural credit in Brazil. In a recent report, the ABC Observatory (Observatório ABC 2015) listed some of the barriers to scaling up ABC credit:

1. **Technical training for the preparation of projects**. Technicians and rural extension agents are used to design projects for the conventional credit lines and need learning to develop projects that incorporate ABC techniques.
2. **Financing limits**. The ABC funding limits are too low compared with those of the Constitutional Funds that can reach R$ 2 million (US$ 571,000) for smallholders and R$ 9 million (US$ 2.5 million) for small and medium producers.
3. **Documentation requirements and environmental licensing**. Small producers have difficulties in obtaining documentation, such as the Credit Aptitude Statement to Smallholder. In addition, state-level agencies have advanced little in the environmental licensing of rural properties, a prerequisite for funding projects.
4. **Little progress in state plans for ABC**. The federal government has delegated to the states the responsibility for implementing and monitoring the program at the state-level, but state finances are in bad shape and coordination is weak between the federal government and states.
5. **Lack of certification**. There is a lack of certification systems that guarantee the origin of products and that assess the risk associated with deforestation and carbon emissions. Without certification, more efficient producers have the same conditions than producers without low-carbon practices.
6. **Cultural barriers**. Producers traditionally resist adopting innovative practices and this is related to cultural habits and behaviors.

FIGURE 8: TOTAL CONTRACT VALUE FOR THE ABC PROGRAM



Source: Adapted from Observatório ABC (2014)

TABLE 14: ESTIMATED FINANCIAL RESOURCE TO BE INVESTED BY THE ABC UNTIL 2020

Action	US$ million	%
Publicity	0.09	0.001%
Training for technicians and producers	3.56	0.028%
Awareness events	2.14	0.017%
Mapping of priority areas	0.60	0.005%
Purchase of inputs (limestone, fertilizer)	39.37	0.312%
Rural credit	12,565.55	99.637%
of which: ABC funding	*10,586.71*	
-PRONAF financing (smallholders)	*1,978.83*	
Total	**12,611.31**	

Source: Adapted from the Sector Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture

4.3 INDC agricultural targets: crop-livestock-forest systems

Integrated production systems are models of productive land use characterized by crop rotation or a mosaic of agricultural activities and/or environmental restoration. Among them, the best known are the so-called Crop-Livestock System (CLS) and the Crop-Livestock-Forest System (CLFS). They were officially recognized as a public policy instrument in Brazil in 2013 through the National Policy Law CLFS (Law 12.805 /2013), but have been in place since the early 1980s as part of EMBRAPA activities. Their advantages over conventional systems include: i) non-use of pesticides by breaking the pest cycles and recycling of mineral and organic nutrients; b) optimizing rural land use, such as breaking the idle fallow periods between harvests of temporary crops; c) restoration of degraded pastures opportunities with additional revenues;

and d) the need for environmental compliance, especially the Forest Code, convergent with opportunities for new CRA markets and certified wood-products (Balbino et al. 2011).

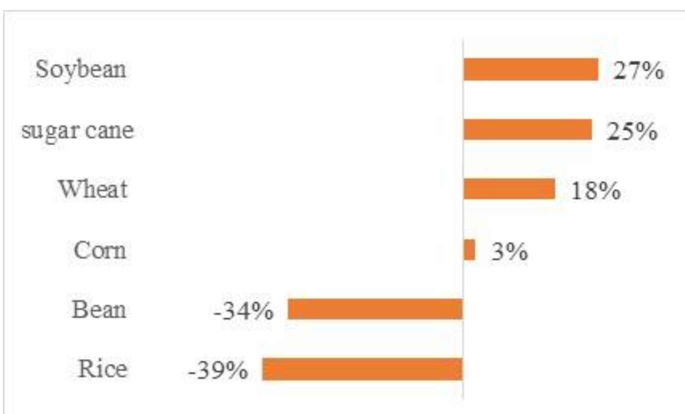
Important barriers, however, impede a wider adoption of CLS and CLFS systems. These include agricultural policy encouraging specialization as a way of optimizing production, at the expense of diversification, cultural resistance to innovation and lack of alternative technical knowledge by specialized producers, high initial investments, and lack of credit at competitive interest rates (Reis et al. 2016).

Brazil currently has around 3.5 Mha of integrated systems, of which 96% are crop-livestock. That is to say that there are just over 140,000 ha of CLFS in the country (Eduardo Assad, personal communication). The challenge of achieving 5 Mha as indicated in Brazil's INDC is therefore to implement the system at average annual growth rates of 25% between 2014 and 2030. The main financial instrument in implementing CLFS is the ABC Credit Program which funded US$ 2.6 million in 2015 (BACEN 2016).

MAPA projects that agricultural growth will affect at least 8.5 Mha (Brasil 2015b), but does not say how this growth will impact the restoration target. The growth of 29.4% in grain production will occur by increasing productivity and area increase. The government estimates a 15% increase in 2014 agricultural area until 2024, or 8.5 Mha. Livestock production is estimated to increase by 23% (beef), 35% (pork), and 35% (chicken) until 2024. However, there is no information on where, geographically, this growth is expected to occur.

Nevertheless, current trends indicate that the largest expansion is likely to occur in the area known as MATOPIBA (formed of parts of the states of Maranhão, Tocantins, Piauí and Bahia), which by 2014 increased its agricultural area by 2.7 Mha, or 31% of Brazil's total agricultural growth. Figure 9 shows the projected area expansion of Brazil's most important agricultural products: soybeans, sugarcane, wheat, corn, bean, and rice. Government expects further export-demand-driven growth. However, China's economy (the main buyer) has recently slowed down, which may affect the trend.

FIGURE 9: GROWTH PROJECTION FOR THE AREA OF MAIN AGRICULTURAL CROPS FROM 2014 TO 2024



Source: Brasil (2015b), adapted from MAPA

Will agribusiness growth influence future deforestation? MAPA projections (Brasil 2015b) do not indicate how the 23–35% growth in livestock will affect land-use change, or how the 9 Mha of agricultural growth will interact with the target of 12 Mha forest restoration. While prices, productivity, and land use are the main factors that will determine growth of the agricultural GDP in the coming years, they may also influence the connection between GDP and deforestation. From 1999 to 2006, the value of production from agriculture and ranching in the Amazon biome was correlated with deforestation rates – meaning, they either rose or fell together. However, from 2007 the value of agricultural and ranching production began increasing again while deforestation rates fell.

An increase in land for agriculture has lower financial risks but creates more pressure for deforestation, whereas an increase in productivity reduces demand for area, but depends on large investments. The main drivers that affect the tradeoff between area increase and or productivity increases are as follows.

1. **Commodity prices**. A rise in prices will not sustain the increase in production value in the coming years; soy has undergone changes in supply and demand, while beef has competition from poultry and pork. For example, with the price increases for beef, the per capita consumption of poultry meat has increased and consumption of beef fell from 40 to 32 kg/person/year. Poultry still has a competitive advantage with cheaper costs due to a recent reduction in corn prices. Therefore, with the high prices of calves and limits on consumer willingness to pay, producers must invest in efficiency (pasture intensification) or in economies of scale by increasing the area (thus mitigating the fixed costs of labor and infrastructure by increasing cattle herd). As for soybean prices, there was a downward trend in 2015 due to increased supply from record harvests. The high dollar exchange rate currently compensates for the drop in international prices. Furthermore, China is experiencing a slowdown of growth, also leading to reduced demand.
2. **Productivity**. Productivity increases can sustain economic performance of agriculture, even during a crisis. However, during the period of high prices, Brazil did not reinvest its gains significantly in technology – in particular, the average stocking rate is far below the potential carrying capacity of most pastures.
3. **Land use**. In a crisis, the option of owning land becomes more attractive because it is a store of value, whereas investing in productivity improvements implies more costs with uncertain gains. Moreover, the cost of land is lower than investing in intensification in several regions of the Amazon and Cerrado biomes. For example, the price of land in the municipality of Alta Floresta (Amazon) was US$ 428.5/ha in 2014, while the cost of pasture intensification in that same region was US$ 685.7/ha (IIS 2015).

5. Towards Reconciling Agriculture, Conservation and Restoration

5.1 What can be learned from existing land-use modeling studies?

Brazil´s expanding agricultural frontier, environmental conservation, climate change, and changing public policies present a complex context for modeling land-use change and its environmental and social consequences. Several studies have examined potential trajectories of land-use change, using a variety of scenarios and assumptions. Part of the complexity of modeling land-use change arises from the multidirectional nature of these trajectories: policy changes influence land use, with impacts on agricultural and forestry sectors in Brazil, which in turn have local and global environmental impacts. Literature on land-use change in Brazil employs different methodological approaches and different scenarios, based on a range of premises and for a range of land uses (different crops, livestock, forestry or natural regeneration) at different scales. Although most studies focus on regional cases, few comprehensive studies examine impacts of dynamic changes in the landscape, considering both future agricultural demand and reforestation targets for all biomes of Brazil.

In analyzing impacts of the Forest Code on competition for land with agriculture in Brazil, Soares Filho et al. (2014) show that of the 4.5 Mha of riparian preservation areas (APPs) planned for restoration, only 0.6 Mha are occupied by crops. Soares-Filho et al. (2014) estimated the extent of pastureland suitable for crops, including areas with slopes below 15% (for use with heavy machinery) and excluding highly unsuitable soils for agriculture (ultisols, lithosols, dysthropic podzols, sands, and hydromorphic soils). In order to estimate the potential savings of land they deducted approximately 70 Mha of existing croplands (IBGE 2006) from about 290 Mha of productive land. They estimated, accounting for climate restrictions, that of the remaining 220 Mha of pastures, approximately 60% could be utilized for crops. Such a conversion would require significant increases in cattle stocking rates, if restoration of the remaining deficit of RL (after compensation through CRA) was to occur in pastureland unsuitable for crop production. In this case, only 550,000 ha of required restoration would remain in arable lands. Others (such as AGROICONE) estimate that in 2030 Brazil will release 19 Mha of pastures (out of 176 Mha in 2014/15) for other types of production and for compliance with the NVPL.

An estimated 148 Mha of native vegetation on private lands could enter the CRA market (1 CRA = 1 ha), where 92 Mha of native vegetation could be legally deforested because they exceed the requirements of the law and 55.5 Mha are within small properties (Soares-Filho et al. 2016). The Cerrado and Caatinga biomes hold the largest surpluses, while the Amazon biome holds the largest source of CRAs of small landholders. An investment of US$ 8.4 ± 2.0 billion to purchase low-cost CRAs could cut legal deforestation (19 Mha) in half by 2030 and would reduce CO_2 emissions by as much as 3.8 ± 0.8 billion tons (Soares-Filho et al. 2016).

In a recently published study, the Escolhas Institute estimated how much it costs per hectare to restore RLs by 2030 in Brazil (Instituto Escolhas 2015). Using a range of existing data (e.g. from the Brazilian Institute of Geography and Statistics (IBGE) and the National Institute for Space Research (INPE)) it estimates the RL deficit and finds that reforestation would cost a total of US$ 14.9 billion in present value. It would create 215,000 jobs, raise US$ 1.9 billion in tax revenue, and implement forest recovery to fulfill the environmental obligations of agribusiness.

A number of recent modeling studies analyze changes in the NVPL (Brancalion et al. 2016). For example, Rodrigues-Filho et al. (2015) analyzed three scenarios of the impacts of different ranges of preservation areas (scenario 1: with 30-meter-wide permanent preservation areas along the shore of water bodies and a 50-meter-radius in springs; scenario 2: with 100-meter-wide permanent preservation areas along water bodies; and scenario 3, with the substitution of 20% of natural forest by agricultural activities) on nutrients outflow in the Lobo Stream Watershed. A suppression of 20% of forest cover would cause a reduction of ecosystem services due to losses in water quality and quantity from an increase in nutrient loads in the basin (Rodrigues-Filho et al. 2015). Based on expert opinion (n = 9) and literature review, Sparovek et al. (2015) analyze how two main legal frameworks – the NVPL and Conservation Areas (SNUC) influence the expansion of Brazilian agriculture. They clarify how different agendas relate to each other and how to derive an agenda for sustainable agricultural development providing food, biofuels, and other bioproducts. They concluded that the expected future trends reflect interventions and ambitions to reconcile production and conservation. However, public opinion and thus decision-making for agriculture and conservation is governed by a perceived conflict between these objectives, leaving the debate an end in itself (Sparovek et al. 2015).

Most of the land-use change studies are conducted for the Amazon region with some models showing future risks of large-scale biodiversity loss and irreversible change in vegetation structure (Cox et al. 2004, Malhi et al. 2008). In this heterogeneous and complex landscape, multiple forces contribute to land-use change; global markets exert pressure on land for food and biofuels (Lapola et al. 2010, Foley et al. 2011, Lambin and Meyfroidt 2011); and new transportation and energy infrastructure projects (Brasil 2011) also play their parts. Malhi et al. (2008) projected the loss of Amazon forest by 2050 from impacts of climate change on land-use change. They found a high threat of significant deforestation and a medium threat of significant drying.

An example of a study based on stakeholder consultation is a paper by Gómez and Nagatani et al. (2009), which develops four scenarios for the Amazon Basin from 2006 to 2026. Their scenarios showed that, in addition to climatic variables and external demand, internal factors such as new roads or protected areas significantly influence land-use change in the region. Concurrently, Soares-Filho et al. (2006) analyzed protected areas and the impact of new paved roads in eight scenarios for the Amazon biome until the year 2050. The "business-as-usual" scenario would result in a reduction from 5.3 to 3.2 million km^2 of closed-canopy forest, while the "governance" scenario (improved implementation of environmental legislation) would reduce closed-canopy forest to 4.5 million km^2. The contribution of protected areas to reducing deforestation is also addressed by Soares-Filho et al. (2010), where five land-cover scenarios with different distributions of protected areas are combined with two socioeconomic scenarios (moderate and high agricultural growth). When exclusion of all protected areas was assumed, the risk of deforestation increases; four other scenarios show the progressive contribution of protected areas to a reduction in deforestation.

The model by Rosa et al (2015) further corroborates these results. They found that clearing of primary forest tends to occur along roads (included in 95% of models) and outside protected areas (included in all models), while natural regeneration tends to occur away from roads (included in 78% of the models) and inside protected areas (included in 38% of the models) following land abandonment.

A dynamic spatial model used by Aguiar (2006) considers access to markets to build five different explorative scenarios of land-use change until 2020. This model demonstrated that the connection to national markets is the most important factor for predicting deforestation frontiers and that intraregional dynamics are influenced by the connectivity to local and national markets and other factors, such as agrarian structure. Rosa et al. (2015) draw attention to temporal changes in drivers and calibration issues for the modeling of the future of the Amazon. Using a large historical database they ran several model simulations to quantify how freezing parameters in time influences the model outputs. The degree to which the model correctly predicts observed change is dependent (statistically significant) on the year used for calibration.

A number of future projections are restricted to particular sectors, such as biofuels (Lapola et al. 2010, Verstegen et al. 2016). Lapola et al. (2010) shows a displacement of pastureland and cattle production due to biofuel production in the Southeast and Center-West regions of Brazil, showing an expansion of 121,970 km^2 in the Amazon by 2020.

As stated above, few studies comprehensively analyze land-use change in Brazil in a way that incorporates and addresses competing land uses in the future. A study by MAPA projects an increase of 70,000 km^2 in crop production area, mainly beans (47,000 km^2) and sugarcane (19,000 km^2) until 2022, given growth in internal and external demand (Brasil 2012b). The REDD-PAC (REDD-PAC 2015) project analyzes land-use policies in Brazil using the IIASA-developed GLOBIOM partial equilibrium model. It projects future land use of agriculture, forestry and bioenergy considering both internal policies and external trade. As with Soares-Filho et al. (2014), the model reveals that Brazil has the potential to reconcile environmental protection (as outlined in the NVPL) and expansion of food and biofuels production. The model uses the IBGE vegetation map and statistics for crop, livestock and planted forests, and remote-sensing land-cover maps. It considers a range of scenarios developed on the basis of the stakeholder meetings at the MMA: the base scenario (NVPL is implemented as planned); the "business-as-usual" scenario (no NVPL); the scenario where crop farmers buy environmental reserve quotas; the scenario where the NVPL does not include the environmental reserve quotas; and the scenario where small farms are not exempt from recovering their legal reserve deficits.

In the NVPL scenario, the model shows a total forest cover (mature forest, managed forest and forest regrowth) for the country of 430 Mha in 2030 and 425 Mha in 2050, avoiding the clearing of 42 Mha of mature forest. Forest area (regrowth and legally selectively harvested mature forest) will stabilize at 328 Mha in the Amazon, and 45 Mha in the Cerrado. The projected forest area increases or stabilizes in Amazônia, Cerrado and Atlantic Forest, but decreases in Caatinga (11 Mha of forest lost in this biome from 2010 to 2050). Total forest regrowth for the entire country will cover 10 Mha by 2030. Considering different scenarios, forest regrowth increases to 20 Mha if crop farmers are the only ones who buy quotas (as the livestock farmers will have to restore more forest). However, this scenario also predicts that a further 7 Mha of mature forest are lost in Amazônia. The beneficial impact of the NVPL would be even greater without exemptions for small farms and without CRA, which would lead to the highest total forest area with 17 Mha more forest regrowth in 2030 and 33 Mha more in 2050, with the gains largest in the Amazon (6 Mha), in the Cerrado (9 Mha), and in Atlantic Forest (4 Mha). In the case of Atlantic Forest, the removal of the exemption would increase total forest area by 38% compared with the NVPL scenario in 2050, as the Atlantic Forest has a high number of smallholder farmers. Furthermore, without the CRA, total forest regrowth would increase by 25 Mha in 2050, with the effect most pronounced in Cerrado (13 Mha) and the Amazon (9 Mha).

In the scenario in which cattle ranchers need to restore their forest, 14 Mha more forest regrowth would occur as compared with the NVPL scenario (but 11 Mha less than in the scenarios where there is no CRA allowed). Projections of the area of planted forest were similar in all scenarios, suggesting that environmental laws do not limit plantation expansion (16 Mha in 2050 in the Forest Code scenario). Concurrently with Strassburg et al. (2014) and Soares-Filho et al. (2014), the model also projects increases in cattle ranching productivity and a consequent significant decrease in pastureland by 10 Mha in 2030

(230 million heads of cattle) and 20 Mha by 2050. Croplands will more than double as compared with 2010 increase in all scenarios from 56 Mha in 2010 to 92 Mha in 2030, and 114 Mha in 2050. Although NVPL does not prevent crop expansion, it may lead to a major decrease in GHG emissions. According to the projections, emissions from deforestation are 110 Mt CO_2e in 2030 – a 92% decrease compared with 2000 with zero forest-related emissions after 2030, due to reduced deforestation and forest regrowth.

Another model that looks into future land-use change is the Brazilian Land Use Model (BLUM), a multi-market, partial equilibrium economic model developed by the Institute for International Trade Negotiations (ICONE s.d) and the Food and Agricultural Policy Research Institute of the Iowa University in the US. The model considers land allocation for six regions:

1. South (states of Paraná, Santa Catarina, and Rio Grande do Sul);
2. Southeast (states of São Paulo, Rio de Janeiro, Espírito Santo, and Minas Gerais);
3. Center-West Cerrado (states of Mato Grosso do Sul, Goiás and part of the state of Mato Grosso inside the Cerrado and Pantanal biomes);
4. Northern Amazon (part of the state of Mato Grosso inside the Amazon biome, Amazonas, Pará, Acre, Amapá, Rondônia, and Roraima);
5. Northeast Coast (Alagoas, Ceará, Paraíba, Pernambuco, Rio Grande do Norte, and Sergipe);
6. Northeast Cerrado (Maranhão, Piauí, Tocantins, and Bahia).

BLUM not only calculates land allocation but also identifies the area exchanged for each activity, considering the amount of total allocated agricultural area. BLUM projections show that the agriculture sector in Brazil will continue to expand into land occupied by native vegetation due to food and feed demand, but not due to biofuel production. In accordance with other studies, pasture intensification can help to reduce demand for additional agricultural land, but without implementation of policies to stimulate stronger intensification, the market alone will not be sufficient to cause the intensification. As with other models, BLUM projects strong pressure to convert native vegetation in the Cerrado biome.

The Brazil Low Carbon Study (World Bank 2010) estimates future demand for land and CO_2 emissions based on BLUM and Simulate Brazil (SIM Brazil). SIM Brazil, developed by the Remote Sensing Center of the Federal University of Minas Gerais is a geo-referenced spatial model that estimates future land use over time under various scenarios. It operates at two spatial levels: IBGE micro-region and raster at a definition level of 1 km^2. The BLUM study projected land use and land-use change until 2030, whereas SIM Brazil attributed land use and land-use change to specific locations and years. Land allocation is performed using regional profitability of the considered crop and regional profitability of competing crops. The model then creates favorability maps for crop allocation given agricultural aptitude (Assad and Pinto 2008), declivity, cost of transport to ports, urban attraction, distance to roads, and distance to converted areas.

The study reports that under the reference scenario, approximately 17 Mha of additional land are required to accommodate the expansion of all activities over the 2006–30 period. The Amazon is projected to accommodate the highest growth rate (24%), largely for pastureland. The total area in Brazil allocated to productive uses is expected to be around 276 Mha in 2030. Pastures are expected to occupy most of this area (205 Mha in 2008 and 207 Mha in 2030). The annual rate of deforestation in the reference scenario is about 14,500–15,500 km^2, on average, for the period 2010–30. Deforestation would cause emissions to go up to 533 $MtCO_2$e by 2030. Total emissions from all land uses will increase to 916 $MtCO_2$e by 2030, and the difference between land use and carbon uptake reaches about 895 $MtCO_2$e annually by 2030. Given the low-carbon scenario that considers compliance with the law regarding APPs and RLs, 2.9 Gt CO_2e over the 20-year period, or around 140 $MtCO_2e$ per year, could be stored by native forest restoration.

Other models have focused on how changes in forest land use affect the potential for carbon sequestration. Based on a 2008 biomass map of the tropics (Baccini et al. 2012), Chazdon et al (2016b) estimated that areas of young, naturally regenerating forest (aged 1–60 years) covered 1.7 Mha across moist and dry tropical forest biomes of Brazil. If permitted to regrow, these forests could potentially store 22.15 Pg (gigatons) of CO_2 from 2008 to 2048, demonstrating the significant potential of regrowth forests in mitigating carbon emissions from fossil fuels and deforestation.

Complementing the discussion over the relationship between land use and climate change, Féres et al (2009) showed how climate changes may impact agricultural patterns of land use throughout the whole country, according to three types of land use: tillage, pasture, and forest. Simulation data are based on temperature average values and future precipitation (for the periods 2010–40, 2040–70 and 2070-2100) according to the 'PRECIS' regional climate model projections, for both scenarios (A2 and B2) defined by the Intergovernmental Panel for Climatic Change. The results show that, due to spatial heterogeneity in climate change, each region suffers different effects. In the North, simulations showed a significant reduction of agricultural establishment of forest and woodland areas, due to forest area conversion for livestock. In the South, the tillage area increased, mostly due to better climate adaptation of agricultural production compared with forest and pasture areas. In the Midwest, pasture areas increase whereas tillage decreases due to climate change. Given this context, monitoring and land-use planning are required in order to avoid loss of agricultural productivity, and to achieve deforestation reduction goals defined by the Brazilian government.

Faria and Haddad (2013) developed a general computable balance model to analyze how 13 land uses respond to temperature and precipitation variations during the periods 1975–2005, 2010–39, 2040–69, and 2070–99. Climatic changes are correlated to economic effects, integrating the model with an econometric model for two scenarios, A2 and B2. Results show increased land scarcity due to climatic changes, resulting in increased competition for land among diverse land uses. Climate change is also projected to shift the spatial distribution of agricultural productivity according to Faria and Haddad (2013).

Soares-Filho and Hissa (2010), simulated land-use change for the period 2010–30 based on a "reference" scenario and a "low-carbon" scenario. Results showed that with the decrease in demand for pastureland, it is not yet possible to reach zero deforestation in the low-carbon scenario. This result confirms the need to adopt measures and policies to support avoided deforestation, such as: PRODES – Brazilian Amazon Satellite Monitoring; PPCDAM – Action Plan for Prevention and Deforestation Control in Amazon; the Sustainable Amazon Program (PAS); Public Forests Management; Forest Grant; and the Social Environmental Register, among others.

Correia et al (2008) conducted a regional modeling study of the impacts of climate change on land use in the Amazon Basin, incorporating changes in water balance due to deforestation, urbanization, and agricultural activities, and climatic changes due to increasing atmospheric CO_2 concentration. Their model results show a disturbing scenario, involving a feedback mechanism where alterations in humidity and evapotranspiration alter the rainfall regime in the Amazon, creating instability of the precipitation system and breakdown of natural ecosystems.

The majority of the published studies focus on regional analyses and modeling of land-use change impacts. However, they do not investigate comprehensively the different agricultural demands from land as well as targets for restoration for Brazil. Strassburg et al. (2014) modeled scenarios that demonstrated future alternatives, until 2040, for the allocation of different agricultural demands and restoration scenarios. The next section updates this work and shows how these earlier projections have now been complemented with and incorporate the targets for restoration as committed by Brazil at the 2015 COP21 in Paris. The analyses assess whether Brazil has already converted enough land to agriculture to accommodate future increases of both agricultural production as well as to meet the INDC restoration goals set by the Brazilian government.

6. Productivity Increases to Reconcile INDC and Agricultural Production Targets

This section analyzes the interplay between the targets for agricultural and biofuels expansion, deforestation control, restoration and tree plantation expansion, and models what level of effort in improving the use of existing land is necessary for each scenario combination. Here we also present the cost estimates for achieving the restoration targets and an associated mitigation estimate.

6.1 Productivity increases to reconcile NDC and agricultural production targets

This section analyzes how future demand for land for agriculture and the INDC targets for restoration and reforestation, deforestation, crops and biofuels interact, and whether it is possible to reach those targets simultaneously. We modeled two scenarios for restoration (12 Mha, or NDC target, and 20 Mha, or NVPL target) considering three different deforestation control targets (zero absolute deforestation, zero net deforestation, and 80% reduction in deforestation).

6.1.1 Agricultural expansion by biome

In the case of soybean, the distribution allocates 2.6 Mha in the Amazon, 6.4 in the Cerrado, 6.000 ha in Caatinga, 3 Mha in Atlantic Forest, 26.000 ha in Pantanal and 2 Mha in the Pampa. The total area of expansion is approximately 14 Mha for the entire country (Table 15).

TABLE 15: PROJECTION OF ADDITIONAL LAND FOR SOYBEAN IN EACH BIOME THROUGH 2030 (HA)

	2000	2014	Share 2000	Share 2014	Estimated share 2030	Total projected 2030	Additional land needed
Amazon	405.67	3,636.65	2.93%	12.51%	14.41%	6,266,766.66	2,630,116
Cerrado	6,736.00	13,865.64	48.67%	47.68%	46.57%	20,261,350.78	6,395,715
Caatinga	0.00	4.53	0.00%	0.02%	0.02%	10,807.73	6,280
Atlantic Forest	5,993.50	9,479.19	43.30%	32.60%	29.63%	12,891,117.41	3,411,928
Pantanal	5.46	27.38	0.04%	0.09%	0.12%	53,501.18	26,117
Pampa	700.05	2,067.32	5.06%	7.11%	9.24%	4,019,194.98	1,951,873
Total	**13,840.68**	**29,080.71**			**100.00%**	**43,502,738.74**	**14,422,030**

Note: Figures may not sum due to rounding.

6.1.2 Biofuel

In 2030, the additional area for biofuels for all of Brazil will be approximately 6.5 Mha (Table 16). The highest increase is projected for the Cerrado biome with just over 4 Mha needed, followed by the Atlantic Forest with 2.5 Mha. The Amazon, Caatinga, Pantanal and Pampa will undergo an increase in sugarcane area of 36,000 ha, 25,000 ha, 8,000 ha, and 903 ha, respectively.

TABLE 16: PROJECTION OF ADDITIONAL LAND FOR SUGARCANE IN EACH BIOME THROUGH 2030 (HA)

	2000	2014	Share 2000	Share 2014	Estimated share 2030	Total projected 2030	Additional land needed
Amazon	94.15	156.32	1.90%	1.51%	1.14%	192,997.96	36,680
Cerrado	1,975.16	4,683.93	39.89%	45.34%	51.45%	8,691,482.17	4,007,551
Caatinga	103.93	115.31	2.10%	1.12%	0.53%	89,809.63	-25,495
Atlantic Forest	2,764.06	5,361.35	55.83%	51.89%	46.81%	7,906,888.30	2,545,542
Pantanal	9.68	10.06	0.20%	0.10%	0.04%	7,266.48	-2,792
Pampa	4.08	4.66	0.08%	0.05%	0.02%	3,756.71	-903
Total	**4,951.06**	**10,331.62**		**100.00%**	**100.00%**	**16,892,201.25**	**6,560,583**

Note: Figures may not sum due to rounding.

6.1.3 Restoration scenarios

Two targets for restoration in Brazil were considered in the analyses: 12 and 20 Mha. The former was based on the INDC targets, while the latter was based on recent government estimates (unpublished data, PLANAVEG; Table 9). These values were distributed across the seven Brazilian biomes to comply with the NVPL (unpublished data, PLANAVEG) (Table 17). Such an estimate was not available for the INDC target, so it was calculated proportionally against the PLANAVEG estimate (Table 18). The analysis also divided the total amount in each biome by the share of each of three restoration/reforestation methods that could occur in each biome (unpublished data, PLANAVEG) (Table 19). The four restoration/reforestation methods were: natural regeneration, low/high enrichment and complete planting.

TABLE 17: DISTRIBUTION OF REFORESTATION TARGETS BY BIOME (NVPL TARGET) (HA)

	Brazil	Amazon	Cerrado	Atlantic Forest	Caatinga	Pantanal	Pampa
Updated PLANAVEG	20,083,754	7,222,519	5,133,618	5,840,495	1,163,147	127,788	596,187
Area to be recovered (planting)	4,844,663	201,508	1,143,770	2,686,044	619,957	24,484	168,900
Area to be recovered (low/high enrichment)	7,092,554	1,617,844	2,392,266	2,792,925	0	22,964	266,555
Area to be recovered (natural regeneration)	8,146,537	5,403,166	1,597,582	361,527	543,190	80,340	160,732

TABLE 18: DISTRIBUTION OF REFORESTATION TARGETS BY BIOME CONSIDERING NDC TARGET (HA)

INDC: target 12 Mha	Brazil	Amazon	Cerrado	Atlantic Forest	Caatinga	Pantanal	Pampa
Sum	12,000,000	4,315,440	3,067,326	3,489,683	694,978	76,353	356,220
Area to be recovered (planting)	2,894,675	120,401	683,400	1,604,905	370,423	14,629	100,917
Area to be recovered (low/high enrichment)	4,237,785	966,658	1,429,374	1,668,767	0	13,720	159,266
Area to be recovered (natural regeneration)	4,867,538	3,228,380	954,552	216,011	324,555	48,003	96,037

TABLE 19: DISTRIBUTION OF REFORESTATION METHODS IN EACH BIOME

	Brazil	Amazon	Cerrado	Atlantic Forest	Caatinga	Pantanal	Pampa
% total planting	172	2.79	22.28	45.99	53.3	19.16	28.33
% low/high enrichment	180	22.4	46.6	47.82	0	17.97	44.71
% natural regeneration	249	74.81	31.12	6.19	46.7	62.87	26.96

For forestry and pastures, we used the same proportional distribution method as for soybean (Annex A). The total area occupied by planted forest by 2030 will be 14 Mha, with a projected increase in the area of approximately 7 Mha compared with 2014 (Table 20). The highest increase will occur in the Atlantic Forest biome (3 Mha), followed by Cerrado (approximately 2 Mha) and Pampa (755,000 ha). Amazon, Caatinga and Pantanal will have an additional 630,000, 469,000 and 9,000 ha of planted forest, respectively.

TABLE 20: PROJECTION OF ADDITIONAL LAND FOR PLANTED FOREST IN EACH BIOME THROUGH 2030 (HA)

	2000	2014	Share 2000	Share 2014	Estimated share 2030	Total projected 2030	Additional land needed
Amazon	251.36	414.68	4.75%	5.87%	7.39%	1,043,824.21	629,140
Cerrado	1,736.16	2,267.79	32.83%	32.11%	30.95%	4,371,361.21	2,103,566
Caatinga	111.38	221.52	2.11%	3.14%	4.89%	690,428.35	468,906
Atlantic Forest	2,747.80	3,513.48	51.96%	49.75%	46.80%	6,609,429.23	3,095,950
Pantanal	4.08	6.41	0.08%	0.09%	0.11%	15,284.80	8,870
Pampa	437.66	637.75	8.28%	9.03%	9.86%	1,392,954.02	755,208
Total	**5,288.44**	**7,061.64**				**14,123,281.82**	**7,061,641**

Note: Figures may not sum due to rounding.

All the scenarios and calculated land allocations are presented in Tables 21–27. The "Total" value in the tables represents the area needed to accommodate the expansion of crops, biofuel and reforestation. This study assumes that this area will be released by extensive pastures, as reported in the studies cited in this report (e.g. Soares-Filho et al. 2014 and REDD-PAC 2015). The "zero" scenario assumes no deforestation (absolute deforestation = 0); in the "net zero" scenario deforestation is completely compensated by restoration (deforestation = restoration); while in the "80% reduction" scenario deforestation will occur but at rates equal to 20% of deforestation recorded in 2005 (deforestation 2030 = 0.2 deforestation in 2005).

TABLE 21: SCENARIOS AND THE ALLOCATION FOR BRAZIL (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recovered	Total
Zero	-	14,422,030	6,560,583	7,061,641	12,000,000	**40,044,254**
Net zero	12,000,000	14,422,030	6,560,583	7,061,641	12,000,000	**28,044,254**
80% reduction	10,454,914	14,422,030	6,560,583	7,061,641	12,000,000	**29,589,340**
Zero	-	14,422,030	6,560,583	7,061,641	20,000,000	**48,044,254**
Net zero	20,000,000	14,422,030	6,560,583	7,061,641	20,000,000	**28,044,254**
80% reduction	10,454,914	14,422,030	6,560,583	7,061,641	20,000,000	**37,589,340**

If Brazil is to achieve the absolute zero deforestation scenario and 12 Mha recuperated as indicated in the INDC with a concurrent increase of soybean, sugarcane and planted forest, then 40 Mha would need to be released from pastureland through 2030. If the higher reforestation goal of 20 Mha of PLANAVEG is considered, 48 Mha will be required to satisfy the demands of soybean and sugarcane. If the net zero scenario is considered, the additional area required to meet all these demands will equal 28 Mha for both INDC and PLANAVEG scenarios. If deforestation is reduced by 80%, an additional 29 Mha of pasture will be needed to accommodate all demands given INDC reforestation targets, and 37 Mha given PLANAVEG. It is important to note that Brazilian law protects only the area of RL and APP on the property; any forest beyond that legally required can still be deforested when authorized by the environmental agencies. In fact, the total forest on private land that could be deforested by an authorization is unknown without the total registries in the CAR.

In the case of the Amazon, if INDC reforestation targets are considered (4 Mha in the Amazon), the area of pastureland needed to accommodate additional land demands will equal 7.6 Mha for the absolute zero scenario; 3.3. Mha for the net zero scenario; and approximately 1.9 Mha given the 80% deforestation reduction scenario (Table 22). With PLANAVEG targets, these values will equal 10.5, 3.3, and 4.8 Mha for the absolute zero, net zero, and 80% reduction scenarios, respectively.

TABLE 22: SCENARIOS AND THE ALLOCATION FOR THE AMAZON (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recuperated	Total
Zero		2,630,116	36,680	629,140	4,315,440	**7,611,376**
Net zero	4,315,440	2,630,116	36,680	629,140	4,315,440	**3,295,936**
80% reduction	5,704,200	2,630,116	36,680	629,140	4,315,440	**1,907,176**
Zero		2,630,116	36,680	629,140	7,222,519	**10,518,455**
Net zero	7,222,519	2,630,116	36,680	629,140	7,222,519	**3,295,936**
80% reduction	5,704,200	2,630,116	36,680	629,140	7,222,519	**4,814,255**

The Cerrado is projected to require the highest release of pastureland given the absolute zero scenario (Table 23). In the case of the INDC this will equal 15.6 Mha, while an even higher increase in area is predicted when PLANAVEG targets are considered. In this case, an additional 17.6 Mha will be needed. For both net zero and 80% reduction scenarios, approximately 12.5 Mha will be needed for each scenario given INDC targets, while about 14.0 Mha for PLANAVEG targets.

TABLE 23: SCENARIOS AND THE ALLOCATION FOR THE CERRADO (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recuperated	Total
Zero	-	6,395,715	4,007,551	2,103,566	3,067,326	**15,574,158**
Net zero	3,067,326	6,395,715	4,007,551	2,103,566	3,067,326	**12,506,833**
80% reduction	3,646,029	6,395,715	4,007,551	2,103,566	3,067,326	**11,928,130**
Zero	-	6,395,715	4,007,551	2,103,566	5,133,618	**17,640,451**
Net zero	5,133,618	6,395,715	4,007,551	2,103,566	5,133,618	**12,506,833**
80% reduction	3,646,029	6,395,715	4,007,551	2,103,566	5,133,618	**13,994,422**

The Atlantic Forest biome is predicted to have the second highest area (after the Amazon) to be recuperated according to the INDC (3.5 Mha) and PLANAVEG (5.8 Mha) (Table 24). This increase, together with the area needed for allocation of soybean and sugarcane will total 12.5 Mha of additional pastureland to be released in the biome given INDC targets and under the absolute zero scenario (Table 24). A very similar area will be required under the 80% reduction scenario (12 Mha), while the net zero reforestation scenario results in an additional 9 Mha needed. With PLANAVEG targets, there will be approximately 15 Mha release of pastureland needed to accommodate all demands considered in this study under the absolute zero and 80% reduction scenarios, while 9 Mha will be needed if net zero reduction is considered.

TABLE 24: SCENARIOS AND THE ALLOCATION FOR THE ATLANTIC FOREST (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recuperated	Total
Zero	-	3,411,928	2,545.542	3,095,950	3,489,683	**12,543,104**
Net zero	3,489,683	3,411,928	2,545,542	3,095,950	3,489,683	**9,053,421**
80% reduction	117,514	3,411,928	2,545,542	3,095,950	3,489,683	**12,425,590**
Zero	-	3,411,928	2,545,542	3,095,950	5,840,495	**14,893,916**
Net zero	5,840,495	3,411,928	2,545,542	3,095,950	5,840,495	**9,053,421**
80% reduction	117,514	3,411,928	2,545,542	3,095,950	5,840,495	**14,776402**

In the Caatinga biome, the largest amount of additional area of pastureland needed to accommodate reforestation, soybean expansion and sugarcane given the INDC targets required under the absolute zero scenario (approximately 1.1 Mha) (Table 25), while the net zero and 80% reduction scenarios will require 0.45 Mha and 0.43 Mha, respectively. Given PLANAVEG targets, the additional area of pasture needed to accommodate the agricultural expansion and reforestation equals 1.6 Mha, 0.45 Mha, and 0.90 Mha under the zero deforestation, net zero deforestation, and 80% reduction scenarios, respectively (Table 25).

TABLE 25: SCENARIOS AND THE ALLOCATION FOR THE CAATINGA (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recuperated	Total
Zero	-	6,280	25,495	468,906	694,978	**1,144,668**
Net zero	694,978	6,280	25,495	468,906	694,978	**449,691**
80% reduction	710,400	6,280	25,495	468,906	694,978	**434,268**
Zero	-	6,280	25,495	468,906	1,163,147	**1,612,838**
Net zero	1,163,147	6,280	25,495	468,906	1,163,147	**449,691**
80% reduction	710,400	6,280	25,495	468,906	1,163,147	**902,438**

The Pantanal biome has the smallest area to be restored given INDC and PLANAVEG targets (76,000 ha and 128,000 ha, respectively). Under the absolute zero deforestation scenario and INDC targets, the additional area of pastureland in the biome needed to accommodate the expansion of soybean, sugarcane and reforestation is approximately 108.5 Mha (Table 26). Under the net zero and 80% reduction scenarios, the additional area equals 32,000 and 75,000 ha, respectively. Given the PLANAVEG reforestation targets, the required expansion into pastureland in Pantanal will be approximately 160,000 ha under the absolute zero deforestation scenario, and 32,000 and 23,000 ha under the net zero and 80% reduction scenarios, respectively.

TABLE 26: SCENARIOS AND THE ALLOCATION FOR THE PANTANAL (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recuperated	Total
Zero	-	26,117	-2,792	8,870	76,353	**108,549**
Net zero	76,353	26,117	-2,792	8,870	76,353	**32,196**
80% reduction	183,386	26,117	-2,792	8,870	76,353	**-74,837**
Zero	-	26,117	-2,792	8,870	127,788	**159,984**
Net zero	127,788	26,117	-2,792	8,870	127,788	**32,326**
80% reduction	183,386	26,117	-2,792	8,870	127,788	**-23,402**

In the Pampa biome, the area of pastureland needed to accommodate the expansion of soybean, sugarcane and reforestation equals 3.0 Mha, 2.7 Mha, and approximately 3.0 Mha for the absolute zero, net zero, and 80% reduction scenarios, respectively under INDC reforestation targets (Table 27). With PLANAVEG targets, the expansion will be 3.3 Mha, 2.7 Mha, and 3.2 Mha for the absolute zero scenarios, net zero, and 80% reduction, respectively.

TABLE 27: SCENARIOS AND THE ALLOCATION FOR THE PAMPA (HA)

Deforestation scenario	Deforestation	Soybean expansion	Sugarcane expansion	Planted forest expansion	Area to be recuperated	Total
Zero	-	1,951,873	-903	755,208	356,220	**3,062,398**
Net zero	356,220	1,951,873	-903	755,208	356,220	**2,706,178**
80% reduction	93,386	1,951,873	-903	755,208	356,220	**2,969,013**
Zero	-	1,951,873	-903	755,208	596,187	**3,302,365**
Net zero	596,187	1,951,873	-903	755,208	596,187	**2,706,178**
80% reduction	93,386	1,951,873	-903	755,208	596,187	**3,208,979**

Pasturelands are expected to accommodate crop and biofuel expansion, and to meet reforestation targets. However, in order to achieve such large-scale land allocation for restoration, a proportion of the pasture area will require intensification of cattle-ranching.

In the Amazon, in order to achieve INDC and PLANAVEG reforestation targets under the zero net deforestation scenario, pasture productivity will need to be at 70% and 75% of potential maximum sustainable productivity (as per Strassburg et al. 2014). Productivity will need to nearly double by 2030, as the current level is 46% of the potential (Table 28; Figures 10 and 11). If deforestation is reduced by 80%, pasture productivity will need to reach 65% of the potential productivity if the INDC restoration target, and it will need to reach 69% in order to meet the PLANAVEG target.

TABLE 28: NECESSARY INCREASES IN PASTURELAND PRODUCTION CAPACITY RELATIVE TO MAXIMUM SUSTAINABLE POTENTIAL

	Amazon	Cerrado	Caatinga	Atlantic Forest	Pantanal	Pampa
Current	46%	36%	21%	24%	81%	43%
Zero net deforestation	63%	49%	23%	30%	99%	73%
Zero deforestation + 12Mha restoration	70%	52%	24%	32%	100%	81%
Zero deforestation + 20Mha restoration	75%	54%	24%	34%	100%	87%
80% reduction in deforestation + 12Mha restoration	65%	50%	24%	32%	93%	79%
80% reduction in deforestation + 20Mha restoration	69%	52%	24%	33%	96%	84%

FIGURE 10: CATTLE RANCHING PRODUCTIVITY INCREASE NECESSARY TO ACCOMMODATE THE EXPANSION OF SOYBEAN, SUGARCANE AND COMMERCIAL REFORESTATION UNDER DIFFERENT REFORESTATION TARGETS (INDC AND NVPL) AND UNDER DIFFERENT DEFORESTATION SCENARIOS (ZERO NET AND 80% REDUCTION)

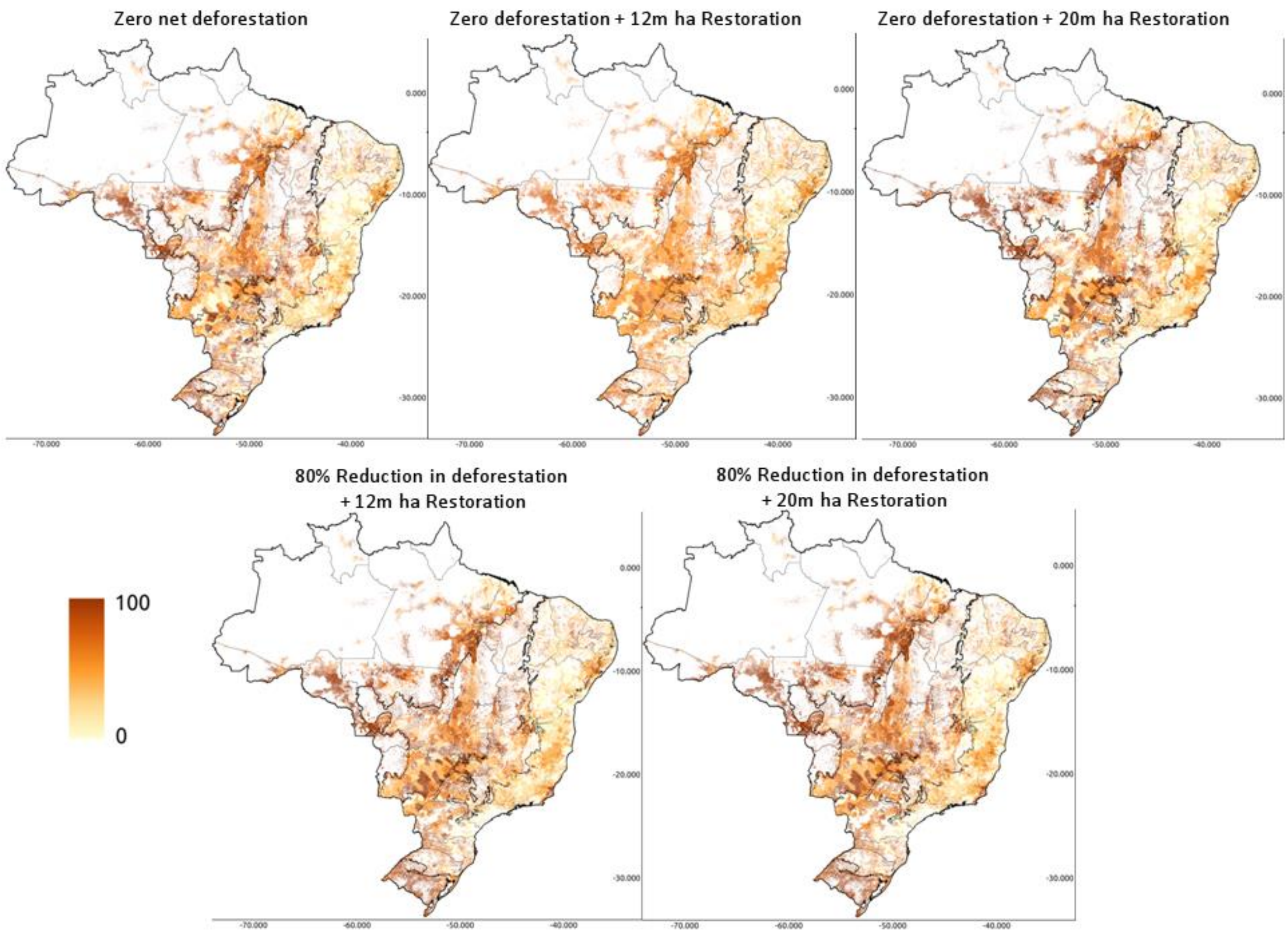
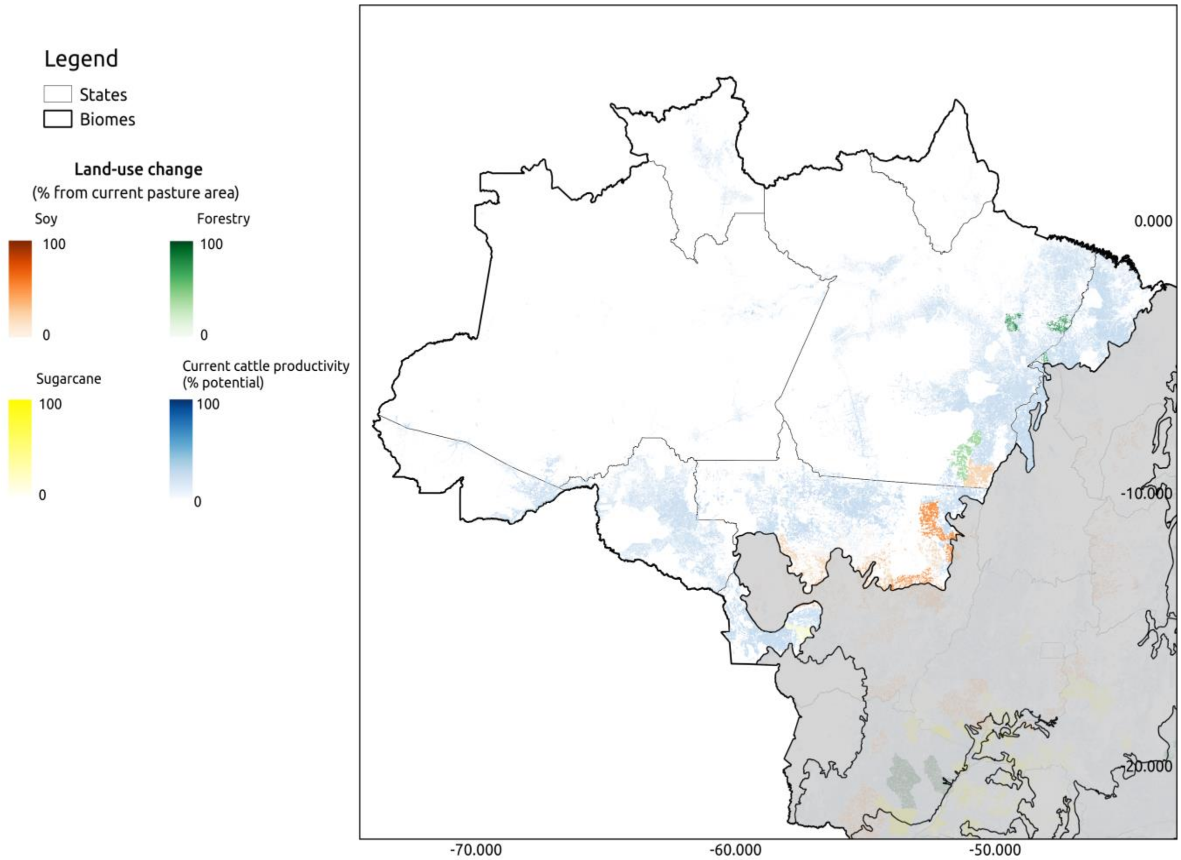
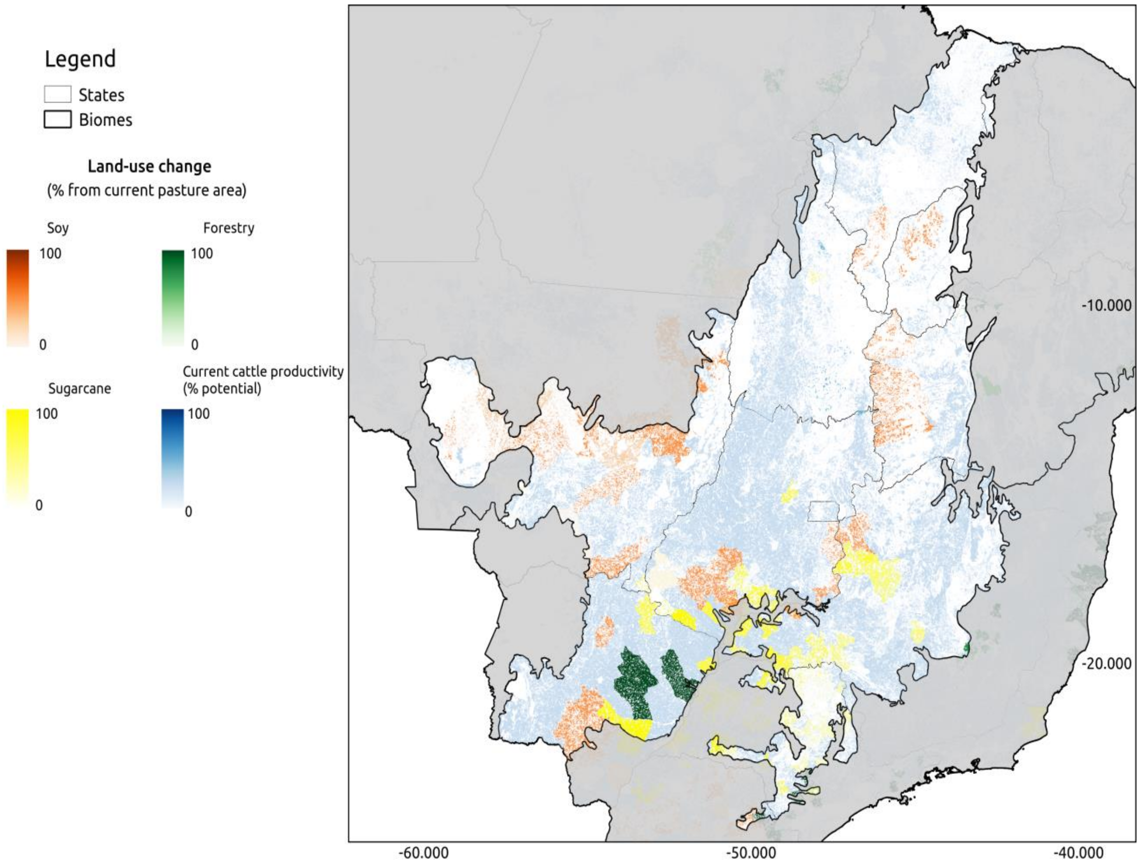


FIGURE 11: PROJECTED ALLOCATION OF AGRICULTURE, BIOFUELS AND FORESTRY IN AMAZON INTO PASTURELAND, AND THE CURRENT PRODUCTIVITY OF PASTURELAND



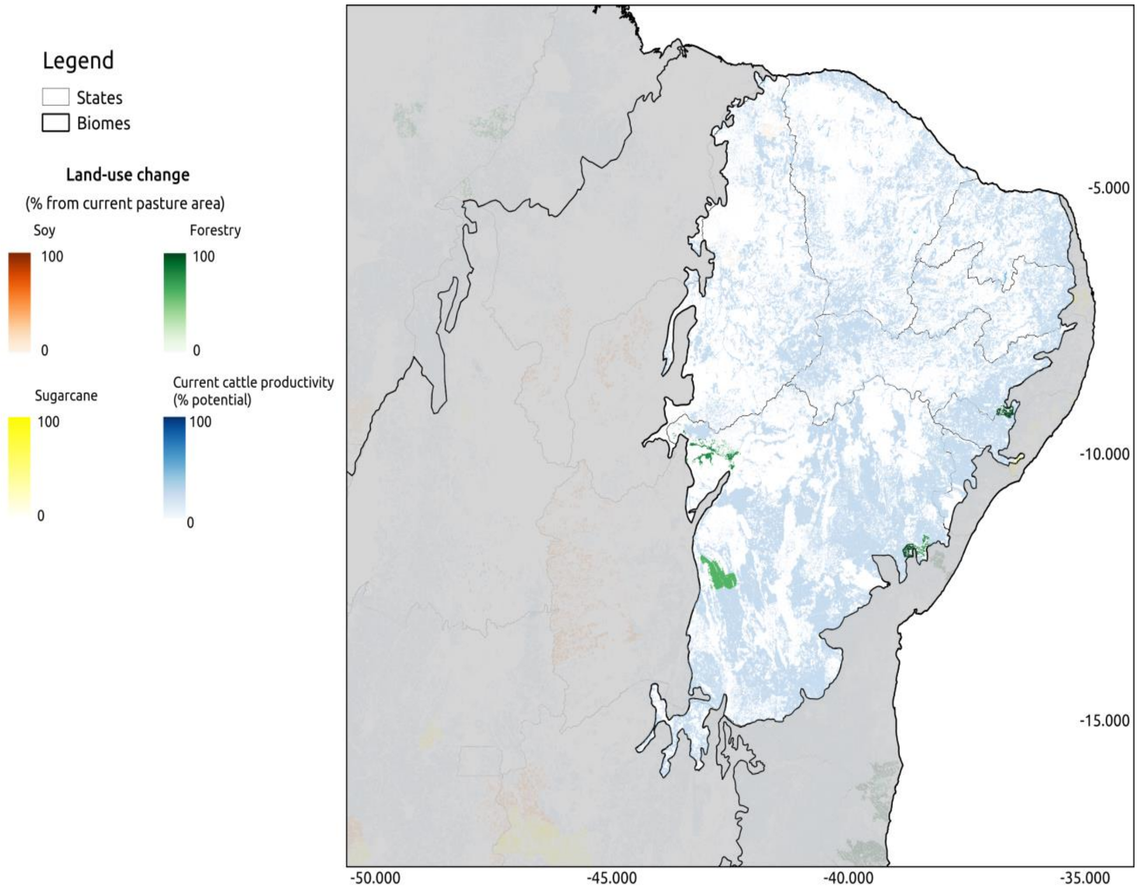
As with the Amazon, an increase in cattle ranching productivity will also need to occur in all other biomes (Table 28). In the Cerrado biome, with a current productivity of 36% relative to maximum potential sustainable productivity, cattle ranching productivity will need to increase to 52% and 54% in order to accommodate the INDC and PLANAVEG targets, respectively, and to permit the projected cropland expansion (Figures 10 and 12). Considering the scenario of 80% reduction in deforestation, the potential productivity will need to increase to 50% and 52% for the INDC and PLANAVEG targets, respectively.

FIGURE 12: PROJECTED ALLOCATION OF AGRICULTURE, BIOFUELS AND FORESTRY IN CERRADO INTO PASTURELAND, AND THE CURRENT PRODUCTIVITY OF PASTURELAND



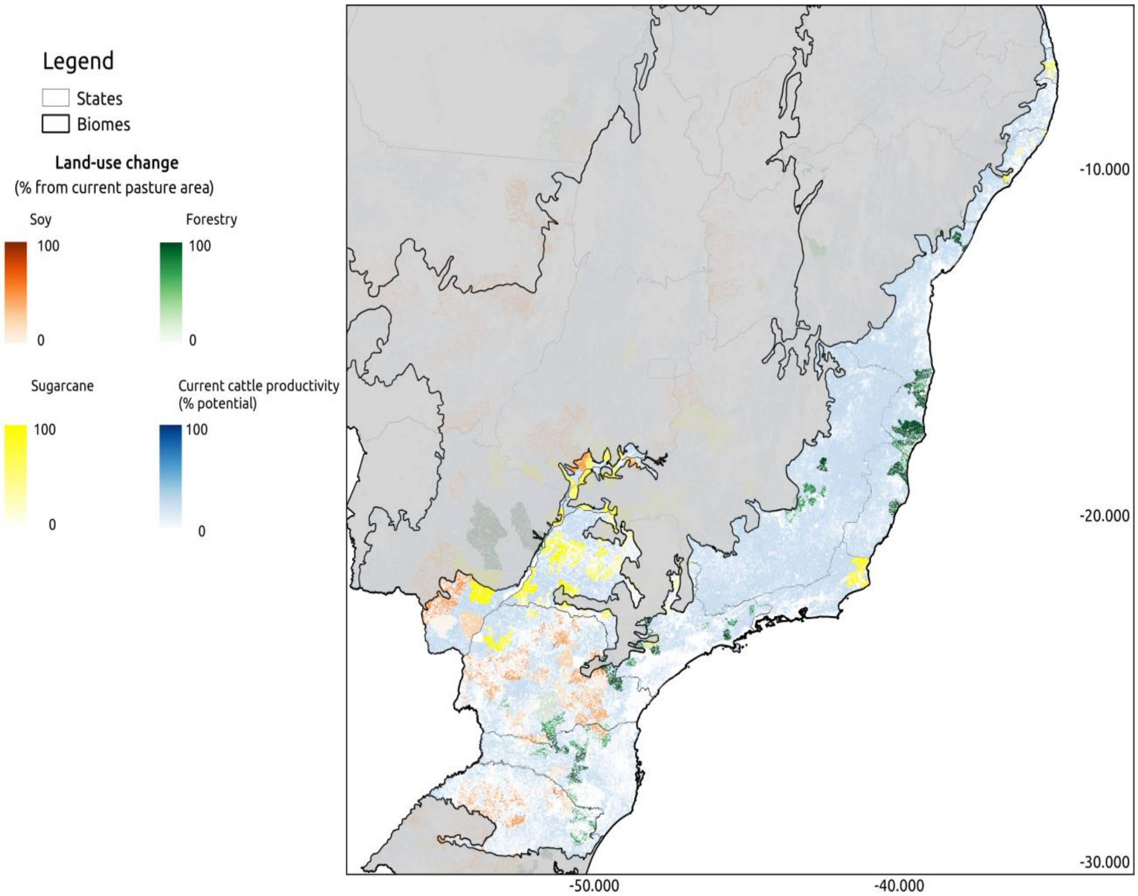
Caatinga has the lowest productivity in the country (21%), and stocking rates will need to increase modestly over the next decades. Under both scenarios of reforestation, zero net and 80% reduction, the increase will need to reach 24% of the potential maximum sustainable productivity in order to accommodate all demands considered in this study and the reforestation targets of INDC and PLANAVEG (Figures 10 and 13).

FIGURE 13: PROJECTED ALLOCATION OF AGRICULTURE, BIOFUELS AND FORESTRY IN CAATINGA INTO PASTURELAND, AND THE CURRENT PRODUCTIVITY OF PASTURELAND



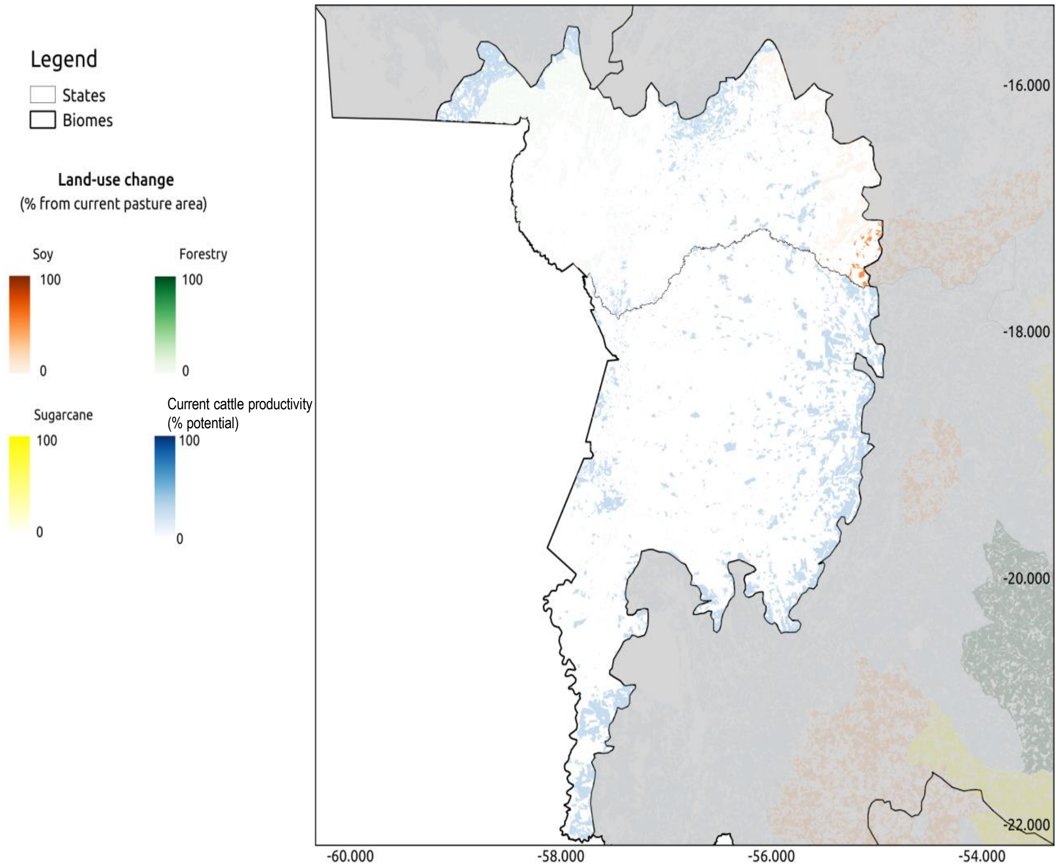
In the Atlantic Forest biome, where the current productivity is less than one-quarter of the potential (24%), an increase to 32% would be needed to achieve the restoration targets of the INDC given both the zero net deforestation scenario and the scenario where deforestation falls by 80%. In terms of PLANAVEG, the productivity would need to increase to 34% and 33%, given the zero net deforestation scenario and 80% reduction in deforestation, respectively (Figures 10 and 14).

FIGURE 14: PROJECTED ALLOCATION OF AGRICULTURE, BIOFUELS AND FORESTRY IN ATLANTIC FOREST INTO PASTURELAND, AND THE CURRENT PRODUCTIVITY OF PASTURELAND



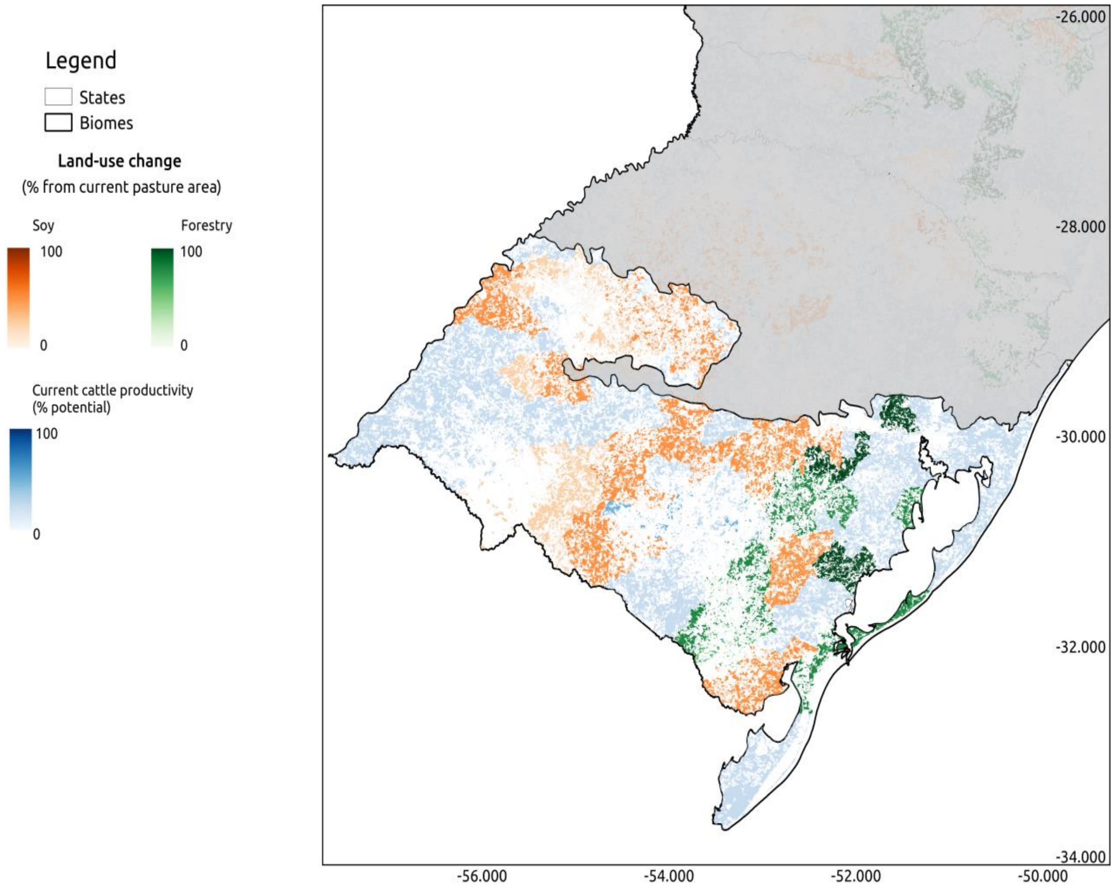
Productivity is currently relatively high In the Pantanal biome, given its sustainable potential (81%). If deforestation were diminished to zero net value, the productivity of the pastureland would need to increase to 100% of the maximum sustainable potential (in order to meet 97% and 99% of the expected increase in beef production and the INDC and PLANAVEG reforestation targets, respectively). This means that a small proportion of cattle ranching would need to be allocated to other biomes (each still has scope to accommodate cattle ranching production, even after meeting all projected demands considered in this study, per region). If the 80% deforestation reduction scenario is considered, the productivity will need to increase to 93% and 96% of potential maximum sustainable productivity (Figures 10 and 15).

FIGURE 15: PROJECTED ALLOCATION OF AGRICULTURE, BIOFUELS AND FORESTRY IN PANTANAL INTO PASTURELAND, AND THE CURRENT PRODUCTIVITY OF PASTURELAND



In the Pampa, where the current cattle ranching productivity is 43% of the potential, an increase to 81% of the potential would be required in order to accommodate areas of expansion of soybean, sugarcane and reforestation targets of the INDC under the zero net deforestation scenario, and 79% under the 80% deforestation reduction scenario (Figures 10 and 16). If the PLANAVEG targets are to be met, the productivity would need to increase by 87% given the zero net deforestation scenario, and by 84% given the 80% reduction in deforestation scenario.

FIGURE 16: PROJECTED ALLOCATION OF AGRICULTURE, BIOFUELS AND FORESTRY IN THE PAMPA INTO PASTURELAND, AND THE CURRENT PRODUCTIVITY OF PASTURELAND



6.1.4 There is enough land already converted to agricultural use

Our results confirm, for all scenarios and for both reforestation targets (INDC and PLANAVEG), that Brazil already has enough land converted to agriculture to meet demands for soybean, sugarcane and plantation forestry until 2030 without the need to convert new land. There are several ways to achieve this goal, and this study considers three scenarios of deforestation. It is of note that the yearly increase of productivity required to meet anticipated demands for meat production while releasing land for soybean, sugarcane and reforestation is smaller than the current productivity levels of other countries (including developing nations (Strassburg et al. 2014). These results confirm the results of other studies (Soares-Filho et al. 2014, REDD-PAC 2015) and expand on the modeling undertaken by Strassburg et al. (2014) using real-world targets for reforestation of INDC and PLANAVEG. In order to achieve such a productivity increase, a significant effort will be required to incentivize this shift, through technical assistance, skilled labor, accessible credit, etc. (Figures 17 and 18).

FIGURE 17: RESTORED AREA IN EXISTING PASTURELAND FOR THE INDC REFORESTATION TARGET

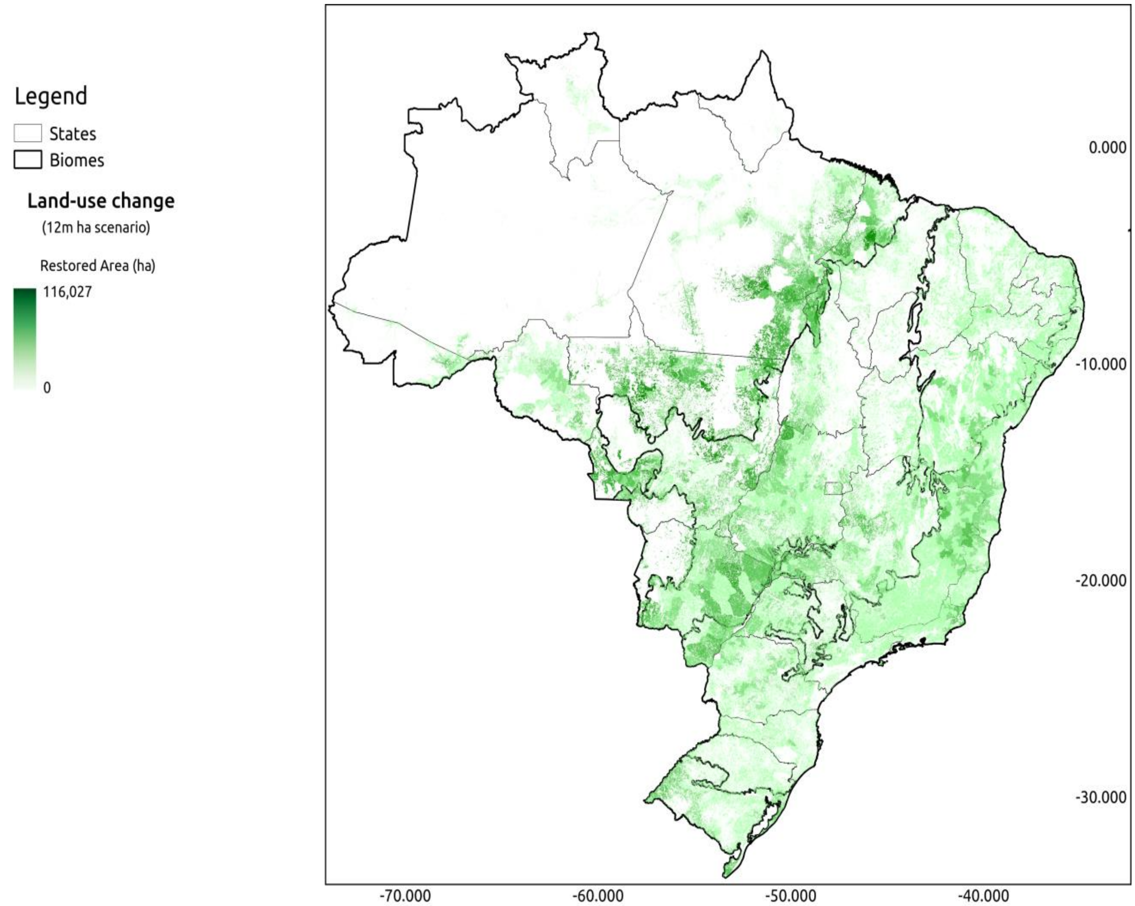
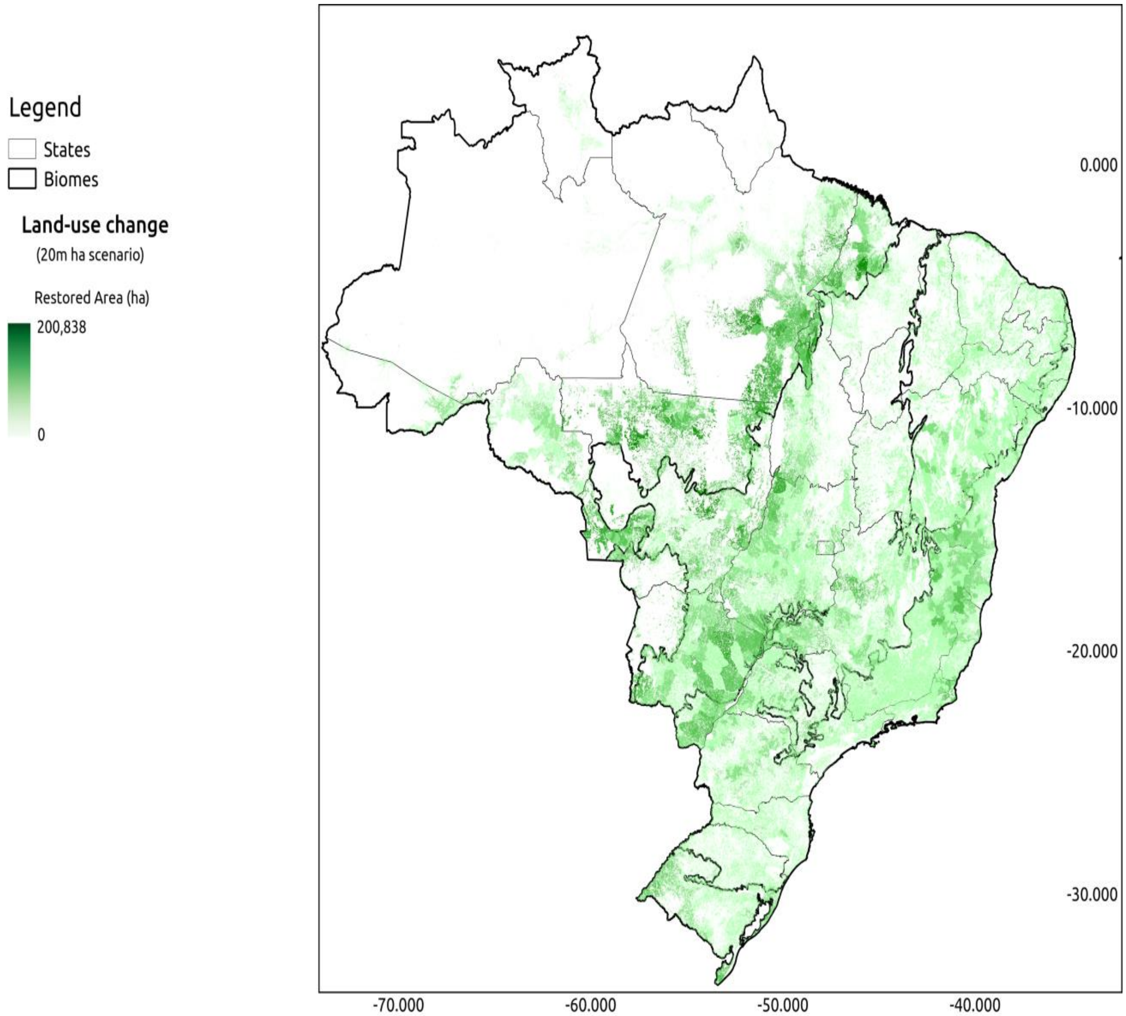


FIGURE 18: RESTORED AREA IN EXISTING PASTURELAND FOR THE PLANAVEG REFORESTATION TARGET



6.2 Financing needs and reduction in carbon emissions

The financing requirements to restore 12 Mha depend on the method used to recover the native vegetation and the biome in which it occurs. For example, costs vary depending on the landscape composition (amount of native vegetation, level of land degradation), history of land use, and potential for technical capacity building (choice of plant species, seedling production, skilled labor, understanding of restoration techniques) (Chazdon 2008, Rodrigues et al. 2009, Brancalion et al. 2012). In the best-case scenarios, restoration cost is limited to isolating the degraded area, thereby permitting the spontaneous regeneration of native vegetation, without further expenditure on planting trees (Holl and Aide 2011). At the other extreme is complete planting, with a very high cost that has been estimated to be anywhere in the range from BRL 10,000 to BRL 25,000 per ha (see below).

6.2.1 Cost of restoration

This section presents our estimates for the spending required to achieve the restoration targets of 12 and 20 Mha. These estimates are based on unitary costs for each restoration method from two external sources (MMA 2013, PLANAVEG, and Instituto Escolhas 2015), and on our scenarios for the allocation of these restoration methods for each biome.

Estimates of the Instituto Escolhas (2015) show that the cost of restoration of 12 Mha ranges from US$ 8.8 billion to US$14.8 billion, generating 200,000 jobs (Table 29). The Instituto Escolhas simulated three scenarios, using five economic models for restoration/reforestation and based on PLANAVEG scenarios, to estimate the cost of recovery of 12 Mha of forests in the Amazon and Atlantic Forest. Originally, they proposed eight models, but these were grouped into five to be consistent with the proposed restoration/reforestation methods in PLANAVEG (see section 3.4) (Table 30). The five final models ranged from low cost (natural regeneration) to high cost (complete planting) (Table 30). The scenarios range from 10% to 30% of complete planting and from 40% to 60% of natural regeneration (Table 31). For each scenario, there is a unit cost per ha for the Amazon and Atlantic Forest biomes (Table 32).

TABLE 29: TOTAL COST FOR EACH RESTORATION SCENARIO WITH AREA PLANTED AND NUMBER OF JOBS CREATED RESULTING FROM 12MHA RESTORATION PROCESS

Scenarios	Total cost (present value in US$ 1,000)	Jobs created
1) 30% complete planting	14.9	215,000
2) 20% complete planting	12	176,000
3) 10% complete planting	8.9	138,000

Source: Instituto Escolhas (2015)

Note: A complete description of scenarios is presented in Table 31.

TABLE 30: ECONOMIC MODELS FOR RESTORATION CONSIDERED BY INSTITUTO ESCOLHAS (2015) AND THEIR CORRESPONDING METHOD FOR RESTORATION IN PLANAVEG

<table>
<tr><th>Description of the economic models</th><th>PLANAVEG method for restoration</th></tr>
<tr><td rowspan="2">1) Natural regeneration</td><td>Natural regeneration (abandoned area)</td></tr>
<tr><td>Natural regeneration (with fencing)</td></tr>
<tr><td>2) Natural regeneration conduct + enrichment</td><td>Low enrichment and low density</td></tr>
<tr><td>3) Densification + enrichment</td><td>High enrichment and high density</td></tr>
<tr><td>4) Total area - seeds planting</td><td rowspan="5">Total planting</td></tr>
<tr><td>5) Total area - seedlings native planting</td></tr>
<tr><td>6) Total area - seedlings planting + 25% eucalyptus</td></tr>
<tr><td>7) Total area - seedlings planting + 50% eucalyptus</td></tr>
<tr><td>8) Total area - agroforestry system</td></tr>
</table>

Source: Instituto Escolhas (2015)

TABLE 31: PERCENTAGE OF EACH METHOD IN EACH SCENARIO (1, 2 AND 3)

Economic models	Scenario 1	Scenario 2	Scenario 3	Number of the economic model for restoration (Table 1)
Total planting	30%	20%	10%	4 to 8
High enrichment	15%	15%	15%	3
Low enrichment	15%	15%	15%	2
Natural regeneration	40%	50%	60%	1

Source: Instituto Escolhas (2015)

TABLE 32: UNITS COSTS OF THE ECONOMIC MODELS FOR THE AMAZON AND ATLANTIC FOREST BIOMES (US$/HA)

Unit cost of economic models	Amazon	Atlantic Forest	Mean[1]
Total planting (agroforestry system)	1,927	1,819	1,873
Total planting (seeds planting)	2,079	1,976	2,028
Total planting (seedlings planting + 50% eucalyptus)	2,358	2,197	2,277
Total planting (seedlings planting + 25% eucalyptus)	2,505	2,325	2,415
Total planting (seedlings native planting)	2,669	2,471	2,570
Average of total planting	2,308	2,158	2,233
High enrichment (densification + enrichment)	1,223	1,158	1,190
Low enrichment (natural regeneration conduct + enrichment)	879	792	835
Average of enrichment	1,051	975	1,013
Natural regeneration	178	173	175

Source: Instituto Escolhas (2015)

Note: [1] Mean = average value for Atlantic Forest and Amazon. The mean value was used as the cost estimate by the economic models for the other biomes (Caatinga, Cerrado, Pampa and Pantanal).

The costs of restoration are still a barrier to environmental compliance. For example, PLANAVEG estimates that the costs range from US$ 400 (natural regeneration) to US$ 2,857 (complete planting) per ha (Table 33). PLANAVEG gives an average cost for Brazil, and assumes that economies of scale and market maturation will drive down costs as restoration efforts are scaled up. Restoration costs per hectare are an important barrier to be overcome, requiring both research and development and robust financing mechanisms. These costs might be a barrier to environmental compliance, especially for small landowners, who need technical assistance and appropriate financing. Further economic incentives might be warranted when significant positive externalities can arise from the choice of restoration method, management regime of the restored area, or its spatial location.

TABLE 33: AVERAGE COSTS OF THE RESTORATION METHODS (PLANAVEG)

Cost of the restoration/reforestation methods	(US$/ha)
Total planting	2,857
High enrichment	1,429
Low enrichment	971
Natural regeneration (with fencing)	686
Natural regeneration (abandoned area)	400

The least expensive method of restoration is natural regeneration, but its applicability ranges from 6.19% (in the Atlantic Forest) to 74.81% (in Amazon) (Table 34). This estimate is based on spatial modeling of the ecological variables that affect restoration (as explained above) and expert knowledge (unpublished data, PLANAVEG). These data are still being refined, but the estimates allow an overview of the potential applicability of each restoration method in the Brazilian biomes.

TABLE 34: PERCENTAGE OF POTENTIAL APPLICABILITY OF EACH RESTORATION METHOD

Method	Biome (%)					
	Amazon	Cerrado	Atlantic Forest	Caatinga	Pantanal	Pampa
Total planting	2.79	22.28	45.99	53.3	19.16	28.33
High enrichment	22.4	46.60	47.82	0	17.97	44.71
Natural regeneration	74.81	31.12	6.19	46.7	62.87	26.96

Source: MMA 2013

Total restoration costs are high in absolute terms, but when diluted over 20 years are a small fraction of the annual public subsidized credit for agriculture. The total capital required for restoring 12 Mha of native vegetation was estimated at US$ 13.7 billion over 15 years, or approximately US$ 900 million per year. This is less than 2% of the annual public agricultural credit. The annual financing requirements for the whole of Brazil for both scenarios are presented in Table 35; the results per biome are presented in Annex B.

Although the estimated restoration expenses represent only a small percentage of total overall agriculture credit, the investments would be likely to have lower financial returns. Despite the positive social and environmental benefits, the revenues would be lower than the costs, and so suggest a negative NPV and IRR. As a result, the immediate economic and fiscal cost would likely be greater than simply expanding agriculture credit for increased agriculture production, for example – with corresponding implications for Brazil's public expenditure and the need to explore additional sources of financing.

TABLE 35: REQUIRED SPENDING FOR THE ANNUAL RESTORATION IN BRAZIL: ESTIMATES FOR TWO SCENARIOS OF TOTAL AREA TO BE RESTORED (12 AND 20 MHA) AND AT TWO RATES OF INCREASE (CONSTANT AND SLOW START)

	20 Mha scenario		12 Mha scenario		20 Mha scenario		12 Mha scenario	
Year	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start 1,000 ha)**	**Spending (US$ 1,000)**
2016	1,338	1,625,010	798	915,876	200	243,752	121	137,382
2017	1,338	1,625,010	798	915,876	402	487,503	240	274,763
2018	1,338	1,625,010	798	915,876	603	731,255	360	412,144
2019	1,338	1,625,010	798	915,876	804	975,006	481	549,526
2020	1,338	1,625,010	798	915,876	1,004	990,556	600	686,908
2021	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2022	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2023	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2024	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2025	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2026	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2027	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2028	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2029	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
2030	1,338	1,625,010	798	915,876	1,707	2,071,888	1,020	1,167,742
Total	**20,064**	**24,375,154**	**11,987**	**13,738,151**	**20,084**	**24,375,154**	**11,999**	**13,738,151**

Financial requirements for restoration will be substantial in absolute terms. Two of the main challenges are: i) to cover the opportunity cost of agricultural activities previously conducted at the site to be restored; and ii) reduce the restoration costs. Despite the potential of restoration becoming a profitable land use, it is still an unattractive activity for landowners, mostly due to the low liquidity of the investments in the early years (Brancalion et al. 2012). A potential way to mitigate these barriers is through economic incentives for restoration/reforestation, providing some compensation and economic stability for landowners. For example, approaches for the PES have been developed in various basins throughout the country, and in the Atlantic Forest, many initiatives have focused on water and carbon through forest restoration (see section 1.1).

The mitigation potential of the restoration targets is substantial, sequestering between 1.4 and 2.3 billion tons of CO_2. Restored areas will not only sequester carbon, but also reduce carbon emissions. In the 12 Mha scenario 1.4 billion tons of CO_2 would be sequestered, while in the 20 Mha scenarios up to 2.3 billion tons of CO_2 would be sequestered. For example, a restored area can sequester from 22.5 tons of carbon/ha (Caatinga) to 97 tons of carbon/ha (Amazon) (Table 36). A proper incorporation of these externalities through, for example, a PES scheme or creating the link to scaled-up REDD+ results-based financed as agreed at COP21 would go a long way in helping to finance restoration efforts. Linking credit subsidies to this mitigation potential and creating tradable climate bonds also have practical potential.

TABLE 36: AVERAGE CARBON (TONS CO_2 HA^{-1}) PER BIOME IN AREAS WITH POTENTIAL TO BE RESTORED

Biome	In natural vegetation (tCO_2 ha^{-1})	In degraded areas (tCO_2 ha^{-1})	Total CO_2 sequestered in 20Mha scenario (Mt CO_2)	Total CO_2 sequestered in 12Mha scenario (Mt CO_2)
Amazon	124,01	97.1	1,923	1,149
Cerrado	45,70	35.8	210	125
Atlantic Forest	121,89	95.0	126	75
Caatinga	28,8	22.5	45	27
Pantanal	31,07	24.3	7	4
Pampa	36,68	28.7	17	10
Brazil			**2,328**	**1,390**

Another key economic mechanism is to pay landowners for the conservation of forests (avoided deforestation) under the UNFCCC's initiative Reducing Emissions from Deforestation and Forest Degradation (REDD and REDD+). Initially, REDD´s focus was on the development of tools and mechanisms to promote reductions of GHG emissions from deforestation and forest degradation to mitigate climate change. More recently, the relevance and need have emerged to incentivize emission reductions from the adoption of forest management and conservation techniques that generate positive externalities for biodiversity protection and poverty reduction. REDD thus evolved to REDD+ (UNFCCC 2010, MMA 2012), which includes forest management and could generate huge economic opportunities.

In addition to the National Climate Change Policy, Brazil has sought to adjust its legal framework to establish and regulate a national REDD+ system and to define forms of controlling and financing environmental services, through the creation of Reduction Units from Deforestation and Forest Degradation (UREDD) and Certified Emissions from Deforestation and Degradation (CREDD). The UREDD would be generated from forest emissions reductions and would be used to obtain non-compensatory resources – that is, for exclusive use in the country (MMA 2012, Santos et al. 2012). CREDDs would be created from UREDDs with compensatory purpose (offsets). This would require regulation of the Brazilian Market for Emission Reductions (Brazilian Law Nº 12,187 of 2009) or international agreements regulating the use of REDD+ as a compensatory instrument of emissions between countries (Santos et al. 2012).

The compensation for REDD+ could be accessed by state and municipal governments. To do this, they would have to establish laws with GHG emission reduction targets, actions and deforestation control projects (Santos et al. 2012). Thereafter, landowners would have access to programs or projects registered in the national REDD+ system at municipal, state or federal level.

The REDD+ initiatives in Brazil need to be coordinated (MMA 2012, Santos et al. 2012). The main difficulties in the implementation of REDD+ are: i) lack of a legal framework; ii) lack of determination of reference emission levels (baseline); and iii) poor governance, among others (May et al. 2011). Thus, it is essential to establish integrated actions and a "nested approach" (Pedroni et al. 2009, May et al. 2011) at national and subnational levels to avoid overestimation of emission reductions by the use of two different baselines. This integrated approach involves complex methods to verify and measure the emission reductions, and to create a national system of records to reduce risks in financial transactions and institutional arrangements for the distribution of resources (Cortez et al. 2010).

REDD+ initiatives in the state of Amazonas pioneered a State Policy on Climate Change, Environmental Conservation and Sustainable Development, which created instruments and recognized projects based on compensation for REDD (Estado do Amazonas 2007, State Law 3,135). Following this, the states of Mato Grosso, Acre and Amazonas set quantitative targets for reducing deforestation and state plans for REDD. In Mato Grosso, for example, a law was approved for the State System of REDD+ (Estado do Mato Grosso 2013, State Law 9,878).

Another innovative example comes from indigenous lands – the Suruí Forest Carbon Project covering 12,408 ha in Rondônia State. To prevent or reduce deforestation, the project seeks to develop financial mechanisms that reconcile economic alternatives, forest conservation and improving the quality of life of the indigenous population (Observatório do REDD 2015). The Juruena Carbon Sink Project in Mato Grosso is designed with small and medium farmers to facilitate carbon sequestration through agroforestry systems, maximizing income generation and carbon sequestration in the municipality of Juruena.

The REDD+ compensation initiatives have different forms of funding (Santos et al. 2012). There are existing funds in Brazil such as the National Climate Change Fund, the Amazon Fund, the National Environmental Fund, and the National Forest Development Fund. Other sources of funding may come from domestic and international bi- or multilateral agreements on mitigation actions and from carbon credit trading schemes, as well as from private investments (Santos et al. 2012).

7. Conclusions

The full implementation of the Brazilian Native Vegetation Protection Law should be the central element in achieving sustainable land-use in Brazil. Key measures are the completion and validation of the CAR, the development of state-level restoration plans, and support for the development and execution of individual property restoration plans.

Brazil already has sufficient converted lands to accommodate the expansion of agriculture, commercial forestry, and livestock, while restoring 20 Mha and reducing or eliminating deforestation. Restoring 15 Mha of currently degraded pastures, as defined by the INDC, is a move in that direction, because current productivity of degraded pastures does not reach even one-third of pastures under intensified management. Productivity gains of restored pastures could release 54% of the additional area required for agriculture in a business-as-usual scenario, or at least 46%, when including the 12 Mha restoration target for native vegetation. Intensified pastures closer to their potential sustainable carrying capacity could at least double the production.

Restoration targets will cost from US$ 13.7 billion (12 Mha) to US$ 24.3 billion (20 Mha) over 15 years. This is equivalent, annually, to only 1.6–2.8% of the public credit for agriculture. However, appropriate financing mechanisms taking account of the different restoration methods and goals are yet to be developed.

Although the estimated restoration expenses represent only a small percentage of total overall agriculture credit, the investments would be likely to have lower financial returns. Despite the positive social and environmental benefits, the revenues would be lower than the costs, and so suggest a negative NPV and IRR. As a result, the immediate economic and fiscal cost would likely be greater than simply expanding agriculture credit for increased agriculture production, for example – with corresponding implications for Brazil's public expenditures and the need to explore additional sources of financing.

Regarding the reduction of deforestation, there is substantial scope for more ambition beyond current legal requirements. Compared with any other land use, leaving forest standing is the still the most effective way of reducing carbon emissions. At present, some 92 Mha of forests could still be legally deforested according to the Forest Code (or 89 Mha when excluding areas in the Atlantic Forest biome, where all remnants are technically protected). These 92 Mha constitute over three times the 28 Mha required for the projected expansion of all croplands, bioenergy crops and forestry. Hence, the INDC target of zero illegal deforestation does not represent an increased effort when compared with the business-as-usual situation, as the areas that may still be legally deforested far exceed those required for agricultural and forestry expansion. The three other stronger deforestation targets discussed are equally feasible, with varying degrees of effort.

Some public policies and multi-stakeholder commitments already offer structural conditions for land-use planning to meet INDC targets. Among developing countries, Brazil is one of the few countries globally with robust legislation restricting the use of natural resources on private lands, especially through the Forest Code. The strengthening of the law through the establishment of the CAR was essential, not only in helping to verify and enforce compliance with the law, but for land-use planning, promotion of intensification opportunities, and to catalyze CRA markets. PLANAVEG aims to scale up the restoration of cleared areas, while the Policy for Planted Forests aims to increase wellbeing and income in rural areas, particularly for small and medium properties.

Multiple policy frameworks exist within Brazil addressing reduction of deforestation, restoration of natural vegetation, tree plantations, carbon emission reductions, carbon storage, and promoting low-carbon agriculture. These frameworks have emerged somewhat independently, at different stages, and from different branches of government, leading to certain incompatibilities due to vested institutional interests as well as different assumptions regarding possible restoration approaches and outcomes.

The NVPL, INDC, and PLANAVEG have converging restoration and reforestation goals, with targets ranging from 12 Mha to 20 Mha. How this restoration will occur is still a matter of debate, and spatial planning to reduce costs and increase the benefits of reforestation is an urgent requirement. Models and simulations have the potential to provide critically important guidance for spatial planning, but these must be sufficiently comprehensive to include the effects of climate change scenarios on natural forests, planted forests and production of different food, fiber, and fuel crops.

The fundamental question of how to define what ultimately constitutes "vegetation restoration" needs to be addressed in forums that involve multiple government sectors and the private sector. This is particularly important for the implementation of forest restoration efforts (e.g. natural regeneration) that do not produce the same outcome as commercial forest plantations. Different approaches to re-establishing tree cover have different social, economic and environmental consequences and tradeoffs. For instance, without clear definitions of forest restoration, the NVPL deficit could be theoretically addressed using monoculture plantations of exotic species, further reducing native forest cover and associated biodiversity loss. Hence, it will be necessary to find common ground and to create synergies among existing frameworks and policies. Using landscape approaches, multiple interests can be served, providing sources of income for landowners without sacrificing environmental protection or ecosystem services.

8. Recommendations

Recommendations to assist the government in accomplishing the INDC targets are set out below. They are mostly aligned with those of the Brazilian Coalition on Climate, Forests and Agriculture, reflecting a broad discussion among government agencies, CSOs, the forestry and agriculture sectors (Waack and Biderman 2016).

1. **Create the proper environment for investment in the native vegetation restoration supply chain.** This includes the regulation of the exploitation of native species, and laws that encourage investment in creating new forest-tree nurseries to supply seedlings and train labor. Moreover, the government should move forward on land tenure regularization and land titling, since investments will not occur without tenure security.
2. **Validate the CAR and monitor compliance with the Forest Code.** Accurate data from the CAR are required to track the extent of RL and APP deficits; to define restoration or compensation demand of rural properties; and to establish the CRA market, which has the potential to reduce the total cost of restoration and could include incentives to conserve and restore native vegetation in priority regions. The CAR allows monitoring compliance with the Forest Code, directing incentives or disincentives to rural properties, and landscape-wide planning forest conservation.
3. **Establish priority areas for restoration.** Government should define priority areas for restoration based on multi-criteria analyses to maximize environmental benefits while minimizing conflict with agriculture. These spatial analyses can also help to achieve scale in restoration projects, which in turn would reduce costs per hectare and increase ecological benefits.
5. **Integrate restoration programs with actions of the agricultural sector to increase productivity.** Environmental agencies can develop actions and coordinated programs with MAPA and state agricultural secretariats and agencies to reduce institutional risk and compensate for the loss of productive area due to restoration.
6. **Expand incentive mechanisms for farmers to implement restoration.** Government may develop incentives for producers who want to invest in restoration programs, linking environmental conservation indicators such as restoration priority areas and landscape connectivity. Incentives could include direct payment for ecosystem services schemes and subsidized credit.
7. **Establish a strategy for forestry credit under the ABC and other financial mechanisms for restoration and integrated CLFS.** Currently there are several lines of funding for restoration, CLFS and restoring regularity under environmental law. However, these resources are not sufficiently accessed. Farmer awareness and training of technicians are part of the actions planned by the ABC, but progress thus far has been limited as regards restoration efforts.
8. **Expand incentive mechanisms for SMEs.** There is at present little information regarding the incentives and enabling environment for SMEs in the forest sector and their role in restoring lands at scale (e.g. in planting, management, etc.), the credit and regulatory constraints, processing of the timber, options for vertical integration (for wood and non-wood), as well as vertical integration of SMEs with larger enterprises.
9. **Develop a mechanism of transparency and establish community-based forest monitoring and restoration programs.** Federal agencies could provide greater transparency about certified forestry products and environmental compliance in the biomes. It would be useful, for instance, if financial agencies could better assess the environmental risk of investments via credit programs. Government

could expand the “Terra Class Project” and similar initiatives to all biomes, producing high-resolution baseline maps of land use and land cover that are updated annually in order to monitor deforestation and different types of reforestation and changes in non-forest ecosystems.

10. **Include ecosystem services considerations within CAR, CRA and PRA.** Biodiversity conservation efficiency indicators (e.g. connectivity in landscape and priority areas) could be used in the valuation of RL forest surplus for compensation in the CRA market.

11. **Increase capacity building for silviculture of native Brazilian tree species and scale up research on these.** Create incentives for investments into the restoration supply chain, especially for tree nurseries for native species, technical assistance, and training. Research initiatives on the genetics of native tree species, improving their silviculture, and to address socioeconomic elements of restoration could help to decrease costs, increase benefits and better engage landowners.

12. **Clearly spell out the roles and accountabilities of different government agencies at the three levels of government (federal, state and municipal).** Current policies and programs such as the National Plan on Climate Change, the ABC, and PLANAVEG are partially overlapping and create ambiguity regarding responsibilities, resource allocation, implementation strategies and monitoring. A comprehensive communications effort by government regarding its overarching INDC implementation strategy – including the expected modes of financing – would be recommended.

9. Suggestions for a Programmatic Research Approach to Achieve the INDC Forest Restoration Goal, Implementing the Forest Code and PLANAVEG

The following topics would fill important information gaps to better support the forest restoration work that will eventually be conducted under programs that aim to comply with the INDC commitments, the NVPL, and PLANAVEG.

9.1 How to finance restoration

9.1.1 Source of private funds

A study to follow up on this current report regarding the possible origin of funds to finance restoration in Brazil. It should look at funds that are particularly relevant for restoration in Brazil – both international and national/sub-national. The variety of restoration systems and farmers' profiles means that a basket of funding options would likely be appropriate for achieving the overall goal, considering the financial risks, interest rates, and other economic aspects.

9.1.2 Restructuring public credit schemes

A second study could provide guidance on how public credit lines can be restructured in order to achieve the necessary scale, be aligned with producers' needs, and reflect the public impacts (environmental and social) generated by different restoration systems. This would extend to an understanding of the barriers to current forest and rural credit programs that aim at restoration in private properties. For instance, the ABC offers an average of US$ 1.4 billion annually, but less than 5% is taken. This study would be complementary to the previous analysis (source of private funds).

9.2 A deeper understanding of the socioeconomic benefits of restoration

Many studies have highlighted the positive environmental benefits of large-scale restoration, such as climate change mitigation and adaptation, biodiversity conservation, and regulation of water provision. However, there is a lack of information about the potential socioeconomic benefits of restoration, especially in terms of increasing income in poor regions. Large-scale restoration will compete with scarce resources and other forms of more profitable land use. A failure in understanding the socioeconomic benefits of this sector may lead to severe underinvestment.

Restoration is a labor-intensive activity with potentially significant marginal gains to poor rural workers. As such, restoration programs may have positive impacts on poverty and inequality reduction. Preliminary estimates generated for PLANAVEG suggest that hundreds of thousands of new jobs could be created. Other recent reports have confirmed similar figures. However, these preliminary studies have focused solely on direct job creation and have not yet assessed indirect employment and income generation.

9.3 Realizing the potential for natural regeneration

The single largest uncertainty involved in estimating the costs for achieving the restoration targets of the Brazilian INDC and implementing PLANAVEG and the Forest Code is the spatial distribution of the areas with the greatest potential for natural regeneration. Although most studies, and PLANAVEG itself, use the assumption that at least half the target will be achieved through natural generation (which costs a fraction of planting methods), there is little intelligence about where these areas are located. There is also a lack of knowledge about how public policies (from PLANAVEG to Forest Code policies such as the CRA and PRADAs) should be structured to deliver this potential. A deeper analysis and spatial modeling would provide estimates of natural regeneration potential and associated policy recommendations for government at the federal and state level.

9.4 Structuring the restoration supply chain

PLANAVEG identifies the lack of a structured supply chain as a key barrier to achieving the goal of 12.5 Mha of restoration in Brazil. Further work on this would be complementary to the study suggested in section 9.1 above, and would consider devising and implementing policies aimed at fostering the necessary supply chain capacity in each biome in Brazil. This study would aim to support the development and implementation of policies by: i) estimating the supply chain gaps in each biome of Brazil, such as seed demand, regulatory environment, and required technical assistance structures; and ii) providing policy recommendations on how to develop the necessary capacity in each biome. Policies would include financing for restoration businesses (tree nurseries, seeds collectors, and project implementers), technical assistance and regulatory changes. This study would benefit from the results of the study suggested under section 9.3 above, as the identification of how much restoration can be achieved though passive methods has a strong influence on dimensioning regional needs for active restoration supply chains.

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Annex A Methods Relating to Section 6

Agricultural expansion per biome (except biofuels)

MAPA has projected agricultural expansion of sugarcane, soybean and forestry to 2025 using as a baseline areas existing in 2015. We applied the same expansion rate used by MAPA in the period 2015–25 to extrapolate the expected area of these same commodities to 2030.

To allocate the estimated soybean, sugarcane and forestry area in 2030 for each biome, we first calculated the relative share of commodities in each biome using time series from 2000 to 2014 (IBGE), and then applied linear regression to extrapolate the expected shares for 2030. We multiplied the total commodity area in 2030 by the respective biome's shares in 2030. An exception was the soybean in the Amazon since there has been an explosive growth (> 600% in area) in the last decade. Furthermore, the soybean moratorium poses significant barriers to the expansion of this crop in the region. Therefore, we first calculated the share rates in other biomes and applied to the Amazon the positive residual value, since the Cerrado and Atlantic Forest rates have been declining over the last decade.

Biofuel

In Brazil biofuels are produced mainly from soybean (biodiesel) and sugarcane (ethanol). MAPA's projections of expansion of soybean and sugarcane areas considered an increase in biofuel production but not in order to achieve INDC targets. To then calculate the additional demand for land to meet the biofuel targets (18% of energy matrix) we considered an average production of 449 liters of soybean oil/ha, yielding 392 kg of biodiesel/ha, which corresponds to 0.337 tons of oil equivalent (toe)/ha of soybean. These ratios were applied for the year t_0 (2015), while productivity of soybean oil production increases at a rate of 0.41% per year through 2030. In the case of ethanol, we considered average production in t_0 of 7,120 liters of molasses, providing 5,618 kg of ethanol/ha corresponding to 3.63 toe/ha. Productivity in ethanol production increase at the rate of 0.51% per year through 2030. The total area required to supply ethanol and biodiesel in 2030 was calculated considering the ratio between ethanol and biodiesel as per Energy Matrix 2005:

$$Su_{2030} = \frac{TEE_{2030}}{3.63^{1.084797}}$$

where:

Su_{2030} sugarcane area to supply ethanol in Energy Matrix in 2030 (ha)

TEE_{2030} total ethanol energy in Energy Matrix in 2030 (toe)

$3.63^{1.084797}$ estimated energy produced in one ha of sugarcane in 2030 (toe/ha)

and:

$$So_{2030} = \frac{TEB_{2030}}{0.337^{1.067656}}$$

where:

So_{2030} soybean area to supply biodiesel in Energy Matrix in 2030 (ha)

TEB_{2030} total biodiesel energy in Energy Matrix in 2030 (toe)

$0.337^{1.084797}$ estimated energy produced in one ha of soybean in 2030 (toe/ha)

The final additional area to ethanol production was calculated as the sugarcane biofuel area (Su) minus MAPA's projection of sugarcane dedicated to ethanol. Final additional area of soybean was the soybean biofuel area (So) minus MAPA's projection of soybean dedicated to oilseed, assuming that 32.7% of all oilseed produced is used as biodiesel.

Cattle herd and pastureland per biome

In the first step we calculated the relative share of each biome in the total cattle herd in Brazil observed in time series from 2000 to 2014 (IBGE), and then applied double exponential smoothing regression to extrapolate the expected shares for 2030. We then estimated the total cattle herd expected in Brazil in 2030 using time series from 2000 to 2014 (IBGE), applying double exponential smoothing regression and linear regression. The country's final cattle herd in 2030 was assumed as the arithmetic average of both estimates. In the next step, we multiplied the total cattle herd by the respective biome's shares in 2030. We calculated the business-as-usual scenario (with pastureland expansion) in 2030 as:

$$Ap_{2030} = \frac{Am_{2030}}{SR_{2030}}$$

where:

Ap_{2030} additional pastureland in 2030 (baseline 2015) (ha)

Am_{2030} additional meat demand in 2030 (baseline 2015)

SR_{2030} stocking rate projected to 2030 (@/ha). The stocking rate in 2030 was estimated using an increase rate of 1.4% per year with 5.07@/ha as the baseline in 2015.

To allocate the estimated pastureland area in the 2030 business-as-usual scenario for each biome, we calculated the relative share of pastureland in each biome using time series of the Agricultural Census from 1970, 1975, 1980, 1985, 1996 and 2006 (IBGE), and then applied linear regression to extrapolate the expected shares for 2030. We then multiplied the total additional area in 2030 by the respective biome's shares in 2030. For the other scenarios (without expansion of pastureland) we used the baseline as fixed pastureland areas.

Potential forage grass biomass data

We obtained the third estimate for potential forage grass biomass from the GAEZ 5'x5' database (FAO/IIASA 2012), and applied it to all cells classified as pastureland in our base land-use map.

The estimate we obtained consisted of two stages of the GAEZ model, which yield comparable results to the three-stage model described above. Module I of the GAEZ model, "Climate data analysis and compilation of general agro-climatic indicators" gathers geo-referenced climatic indicators and processes spatial grids of historical, base-line and projected future climate. As a consequence, it creates layers of agro-climatic indicators relevant to plant production. First, available monthly climate data were converted to variables required for following calculations. Temporal interpolations were adopted to transform monthly data into daily data to characterize thermal and soil moisture regimes. Thermal and soil moisture regimes include calculation of both potential and actual evapotranspiration based on daily soil water balances. Thermal regime generated in Module I includes: thermal growing periods; accumulated temperature sums (for average daily temperature above 0°C, 5°C and 10°C); depiction of permafrost zones; and quantification of the profiles of annual temperature. Soil water balance was determined by including: evapotranspiration for a reference crop (potential and actual); length of growing period (LGP in days); dormancy periods; cold brakes; start and end dates of one or more LGPs. Based on a subset of the indicators listed above, a classification of multiple-cropping zones was estimated for both rain-fed and irrigated conditions.

Agro-climatic indicators were subsequently used for the evaluation of land suitability and estimation of yields in Module II (biomass and water-limited yield calculation). In Module II ("crop-specific agro-climatic assessment") the land utilization types (LUT) are evaluated for water-limited biomass and yields, for every input level. LUT are agricultural production systems with defined crop-specific environmental requirements and input and management relationships. LUT embraces a variety of sub-types within a plant species – for example, differences in crop cycle length (days from sowing to harvest) or growth and development. LUT sub-types also differ depending on the level of inputs. For example, for high-input level, high-yielding crop varieties, advanced field management and advanced machinery were employed, which provided optimal plant densities and with a high leaf area index.

Module II calculates the maximum attainable biomass and yield as determined by radiation and temperature regimes. Then it calculates respective rain-fed crop water balances and computes optimum crop calendars for these conditions. Crop water balances were used to estimate: crop evapotranspiration; crop water deficit for the whole growth cycle (irrigation requirements for irrigated crops); attainable water-limited biomass; and yields for rain-fed conditions. First, for each grid cell a specific cultivation time is determined depending on LUT (for instance, depending on prevailing LGP). The growth for every LUT was tested for the specific cultivation time with analysis for both irrigated and rain-fed conditions. Then, the optimal crop calendar of every LUT in each grid-cell was defined by the highest (water-limited or irrigated) yield based on the growing dates and cycle length. Module II includes LUT-specific temperature/radiation which defined: maximum attainable yields; factors reducing yields which account for sub-optimal thermal conditions and for soil water deficits; LUT evapotranspiration (potential and actual), accumulated temperature during every LUT crop cycle; and optimal crop calendars.

Finally, we converted the output of GAEZ to sustainable carrying capacity for extensive cattle ranching, which is the maximum number of grazing animals a pasture can sustain without degradation or external feed inputs. The sustainable carrying capacity (scc, in animal units per hectare) is calculated as a function of the biomass yield ("b", kg/ha, from GAEZ), the daily feed intake per animal unit ("I" constant, kg/AU/d), and the grazing efficiency (E, dimensionless), as per the formula:

$$scc = b \cdot \frac{E}{I}$$

We adopted I = 8 kg/AU/d, following the Forage and Grazing Terminology Committee (FGTC, 1992). Grazing efficiency (dimensionless) was set at 0.5 (i.e. 50%), which is considered a realistic value for advanced systems in Brazil (Strassburg et al. 2014).

Restrictions for each use

In order to restrict land allocation to areas suitable for each use, we applied use-specific constraints to exclude from current pastureland areas considered unsuitable for the respective use.

Soybean was restricted to areas presenting medium or higher suitability (classes 1 to 6) according to GAEZ (GAEZ 2016).

Sugarcane was restricted to areas with high ("App") or medium ("Apr") suitability in the recent sugarcane zoning assessment (Manzatto et al. 2009). Agricultural suitability took into account edaphoclimatic parameters, in addition to slope constraints (areas with declivity above 12%).

Forestry plantation systems were also restricted to areas with declivity below 12%.

Allocation in 2030

In order to explore how plausible the different scenarios are for each biome, we determined whether the pastureland cultivated in 2012 was capable of sustaining the extra animals projected to be necessary to meet demands for meat in 2030 while sparing enough land for all other uses, respecting their constraints. For each scenario, we adopted a simple allocation rule for each land-use considered (crop, biofuel, forestry, and restoration). These rules follow the logic from Strassburg et al. (2014), adapted to include data on Forest Code deficits for the allocation of restoration scenarios.

ALLOCATION PROCESS, IN CONSECUTIVE STEPS, OF CATTLE, SOYBEAN, MAIZE, SUGARCANE, PLANTED FORESTS AND REFORESTATION FOR EACH SCENARIO AND BIOME

	Allocated use	Areas eligible	Allocation order
Step 1	Soybean	Pastureland with medium or higher agronomic suitability for soybean (GAEZ 2016)	Municipalities with highest current production of soybean
Step 2	Sugarcane	Pastureland with agroecological suitability for sugarcane (Manzatto et al. 2009)	Municipalities with highest current production of sugarcane
Step 3	Forestry	Pastureland with terrain conditions compatible with mechanized harvesting (slope <12%)	Municipalities with highest current forestry production
Step 4	Restoration	Pastureland	Allocated proportionally to each municipality's Forest Code deficit (Soares-Filho et al. 2014)
Step 5	Cattle ranching	Pastureland	All remaining land, productivity increased until beef demand is met or sustainable carrying capacity is reached

Restored area and financing needs

We estimated the total capital requirements for restoring 12 Mha of native vegetation. These estimates were based on the projected share of different restoration methods (PLANAVEG) and unit costs from economic models (Instituto Escolhas 2015). We have derived two scenarios for implementation over time.

The constant rate scenario follows the NVPL requirement that, every two years, 10% of the environmental deficit should be restored. The slow start scenario allows for a slower implementation over the first five years, with constant values thereafter. The tables in Annex B show annual values of restored areas and investment needs for each of these scenarios for Brazil and its six biomes.

Carbon sequestration

In addition, we estimated the carbon sequestration associated with the two main restoration scenarios. We used information about the carbon content of mature forests for each biome and also information on the potential carbon sequestration for the restoration of native vegetation for Atlantic Forest (Poorter et al. 2016). Due to the lack of information about carbon sequestration in the restored areas for the other Brazilian biomes, we estimated the ratio between carbon sequestration in the restored Atlantic Forest and its carbon stocks in native vegetation, which was 0.78, and applied the same ratio to the data on carbon stocks for other biomes in order to estimate the amount of carbon to be sequestered in the restored areas of the other biomes.

Annex B Annual Expenditure Required for Restoration of Biomes

Amazon	20 Mha scenario		12 Mha scenario		20 Mha scenario		12 Mha scenario	
Year	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**
2016	481	285,913	287	170,832	72	42,887	43	25,625
2017	481	285,913	287	170,832	144	85,774	86	51,250
2018	481	285,913	287	170,832	217	128,661	129	76,875
2019	481	285,913	287	170,832	289	171,547	173	102,499
2020	481	285,913	287	170,832	361	21,443	216	128,124
2021	481	285,913	287	170,832	614	364,539	367	217,811
2022	481	285,913	287	170,832	614	364,539	367	217,811
2023	481	285,913	287	170,832	614	364,539	367	217,811
2024	481	285,913	287	170,832	614	364,539	367	217,811
2025	481	285,913	287	170,832	614	364,539	367	217,811
2026	481	285,913	287	170,832	614	364,539	367	217,811
2027	481	285,913	287	170,832	614	364,539	367	217,811
2028	481	285,913	287	170,832	614	364,539	367	217,811
2029	481	285,913	287	170,832	614	364,539	367	217,811
2030	481	285,913	287	170,832	614	364,539	367	217,811
Total	**7,215**	**4,288,688**	**4,311**	**2,562,482**	**7,223**	**4,288,688**	**4,315**	**2,562,482**

Cerrado	20 Mha scenario		12 Mha scenario		20 Mha scenario		12 Mha scenario	
Year	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**
2016	342	408,746	204	244,225	51	61,312	31	36,634
2017	342	408,746	204	244,225	103	122,624	61	73,267
2018	342	408,746	204	244,225	154	183,936	92	109,901
2019	342	408,746	204	244,225	205	245,248	123	146,535
2020	342	408,746	204	244,225	257	306,560	153	183,169
2021	342	408,746	204	244,225	436	521,152	261	311,387
2022	342	408,746	204	244,225	436	521,152	261	311,387
2023	342	408,746	204	244,225	436	521,152	261	311,387
2024	342	408,746	204	244,225	436	521,152	261	311,387
2025	342	408,746	204	244,225	436	521,152	261	311,387
2026	342	408,746	204	244,225	436	521,152	261	311,387
2027	342	408,746	204	244,225	436	521,152	261	311,387
2028	342	408,746	204	244,225	436	521,152	261	311,387
2029	342	408,746	204	244,225	436	521,152	261	311,387
2030	342	408,746	204	244,225	436	521,152	261	311,387
Total	**5,128**	**6,131,196**	**3,064**	**3,663,376**	**5,134**	**6,131,196**	**3,067**	**3,663,376**

Atlantic Forest	20 Mha scenario		12 Mha scenario		20 Mha scenario		12 Mha scenario	
Year	Restored area (constant rate, 1,000 ha)	Spending (US$ 1,000)	Restored area (constant rate, 1,000 ha)	Spending (US$ 1,000)	Restored area (slow start, 1,000 ha)	Spending (US$ 1,000)	Restored area (slow start, 1000 ha)	Spending (US$ 1,000)
2016	389	660,073	232	394,392	58	99,011	35	59,159
2017	389	660,073	232	394,392	117	198,022	70	118,318
2018	389	660,073	232	394,392	175	297,033	105	177,477
2019	389	660,073	232	394,392	234	396,044	140	236,635
2020	389	660,073	232	394,392	292	495,055	174	295,794
2021	389	660,073	232	394,392	496	841,593	297	502,850
2022	389	660,073	232	394,392	496	841,593	297	502,850
2023	389	660,073	232	394,392	496	841,593	297	502,850
2024	389	660,073	232	394,392	496	841,593	297	502,850
2025	389	660,073	232	394,392	496	841,593	297	502,850
2026	389	660,073	232	394,392	496	841,593	297	502,850
2027	389	660,073	232	394,392	496	841,593	297	502,850
2028	389	660,073	232	394,392	496	841,593	297	502,850
2029	389	660,073	232	394,392	496	841,593	297	502,850
2030	389	660,073	232	394,392	496	841,593	297	502,850
Total	**5,835**	**9,901,099**	**3,486**	**5,915,885**	**5,840**	**9,901,099**	**3,490**	**5,915,885**

Caatinga	20 Mha scenario		12 Mha scenario		20 Mha scenario		12 Mha scenario	
Year	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**
2016	77	210,343	46	70,616	12	31,551	7	10,592
2017	77	210,343	46	70,616	23	63,103	14	21,185
2018	77	210,343	46	70,616	35	94,654	21	31,777
2019	77	210,343	46	70,616	47	126,206	28	42,370
2020	77	210,343	46	70,616	58	157,757	35	52,962
2021	77	210,343	46	70,616	99	268,187	59	90,035
2022	77	210,343	46	70,616	99	268,187	59	90,035
2023	77	210,343	46	70,616	99	268,187	59	90,035
2024	77	210,343	46	70,616	99	268,187	59	90,035
2025	77	210,343	46	70,616	99	268,187	59	90,035
2026	77	210,343	46	70,616	99	268,187	59	90,035
2027	77	210,343	46	70,616	99	268,187	59	90,035
2028	77	210,343	46	70,616	99	268,187	59	90,035
2029	77	210,343	46	70,616	99	268,187	59	90,035
2030	77	210,343	46	70,616	99	268,187	59	90,035
Total	**1,162**	**3,155,144**	**694**	**1,059,242**	**1,163**	**3,155,144**	**695**	**1,059,242**

Pantanal	**20 Mha scenario**		**12 Mha scenario**		**20 Mha scenario**		**12 Mha scenario**	
Year	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (constant rate, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**	**Restored area (slow start, 1,000 ha)**	**Spending (US$ 1,000)**
2016	9	7,771	5	4,643	1	1,166	1	697
2017	9	7,771	5	4,643	3	2,331	2	1,393
2018	9	7,771	5	4,643	4	3,497	2	2,089
2019	9	7,771	5	4,643	5	4,663	3	2,786
2020	9	7,771	5	4,643	6	5,829	4	3,483
2021	9	7,771	5	4,643	11	9,908	6	5,920
2022	9	7,771	5	4,643	11	9,908	6	5,920
2023	9	7,771	5	4,643	11	9,908	6	5,920
2024	9	7,771	5	4,643	11	9,908	6	5,920
2025	9	7,771	5	4,643	11	9,908	6	5,920
2026	9	7,771	5	4,643	11	9,908	6	5,920
2027	9	7,771	5	4,643	11	9,908	6	5,920
2028	9	7,771	5	4,643	11	9,908	6	5,920
2029	9	7,771	5	4,643	11	9,908	6	5,920
2030	9	7,771	5	4,643	11	9,908	6	5,920
Total	**128**	**116,569**	**76**	**69,649**	**128**	**116,569**	**76**	**69,649**

Pampa	20 Mha scenario		12 Mha scenario		20 Mha scenario		12 Mha scenario	
Year	Restored area (constant rate, 1,000 ha)	Spending (US$ 1,000)	Restored area (constant rate, 1,000 ha)	Spending (US$ 1,000)	Restored area (slow start, 1,000 ha)	Spending (US$ 1,000)	Restored area (slow start, 1,000 ha)	Spending (US$ 1,000)
2016	40	52,164	24	31,168	6	7,825	4	4,675
2017	40	52,164	24	31,168	12	15,649	7	9,350
2018	40	52,164	24	31,168	18	23,474	11	14,025
2019	40	52,164	24	31,168	24	31,298	14	18,701
2020	40	52,164	24	31,168	30	3,912	18	23,376
2021	40	52,164	24	31,168	51	66,509	30	39,739
2022	40	52,164	24	31,168	51	66,509	30	39,739
2023	40	52,164	24	31,168	51	66,509	30	39,739
2024	40	52,164	24	31,168	51	66,509	30	39,739
2025	40	52,164	24	31,168	51	66,509	30	39,739
2026	40	52,164	24	31,168	51	66,509	30	39,739
2027	40	52,164	24	31,168	51	66,509	30	39,739
2028	40	52,164	24	31,168	51	66,509	30	39,739
2029	40	52,164	24	31,168	51	66,509	30	39,739
2030	40	52,164	24	31,168	51	66,509	30	39,739
Total	**596**	**782,458**	**356**	**467,517**	**596**	**782,458**	**356**	**467,517**

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