# COSTS OF REDUCING DEFORESTATION IN BRAZIL: A GENERAL EQUILIBRIUM APPROACH

Adriana Xavier Francisco [a]

Angelo Costa Gurgel[a,b]

***Abstract***

*Climate change is the major environmental concern of global scale nowadays, and is caused by excessive greenhouse gas (GHG)emissions. Brazil is the seventh larger GHG polluter and land use changes have been the major source of such emissions historically. We investigate the potential economic impacts of stopping illegal deforestation in Brazil by 2030. We employ a dynamic and global computable general equilibrium model, able to represent the competition for alternative land uses. The results indicate that land use constraining policies cause agriculture intensification and increase yields. The livestock production is slightly negatively affected by 2.3% to 3.6% in comparison with a baseline scenario in 2030 and 2050, respectively. The Brazilian GDP suffers less than 0.1% decrease. There are negligible changes in deforestation on the rest of the world. Equivalent payments for environmental services of US$1.3 billion in 2030 and US$3.9 billion in 2050 would be required to incentive farmers to avoid deforestation in those areas allowed by the current land use law (New Forest Code).*

***Key words**: land use changes; deforestation; agriculture; economic impacts; computable general equilibrium model*

[a] Sao Paulo School of Economics, Fundação Getulio Vargas – FGV/EESP.

[b] CNPq Research Fellow, Brazil.

## 1. Introduction

Concerns about climate change and environmental protection have grown exponentially over the last few years. Within this context, Brazil holds some of the richest biomes on the planet, is a world power in agribusiness and has committed to collaborate on international agreements to control and mitigate environmental issues. Brazil is the nation with the largest deforested area in the 1990s and 2000s (FAO, 2010). The average area deforested per year in the Amazon during these decades was 18.6 thousand $km^2$ and 19.1 thousand $km^2$, respectively. As a result of the measures taken against deforestation, this average decreased to 6 thousand $km^2$ per year between 2012 and 2017. Nevertheless, since 2013 the deforestation rate is returned to an upward trend.

In September 2016, Brazil extended its commitment to COP-15 by ratifying the Paris Agreement, approved at COP-21. In this agreement, Brazil committed to reducing greenhouse gas emissions by 2025 to a level 37% lower than in 2005 and indicated the reduction to a level 43% lower by 2030. To this end, the country has committed to end illegal deforestation and restore and reforest 12 million hectares (Mha) of forests.

Deforestation in Brazil has several drivers, including illegal logging and land grabbing, but most of the cleared area is used later for the practice of agriculture and livestock (Imaflora, 2014), which are sectors that play a fundamental role in the Brazilian economy. Brazil currently has the largest commercial cattle herd in the world and is among the world's largest producers of soybeans, sugarcane, coffee, tropical fruits, frozen orange juice, cotton, cocoa and tobacco (Arias, Vieira, Contini, Farinelli, & Morris, 2017). Agricultural exports accounted for 37.4% of total Brazilian exports in 2017 and agribusiness accounted for 7 of the top 10 products exported by the country that year (MDIC, 2018).

A study from the *Instituto Escolhas* (2017) assesses that the land use legislation ("Forest Code") currently in force allows the legal deforestation of an area of 11.7 Mha in the Amazon, 8.35 Mha in the Atlantic Forest, and 43.63 Mha in the Cerrado (Brazilian savannas). From these totals, the areas suitable to agricultural use would be only 3.12 Mha in the Amazon, 5.89 Mha in the Cerrado, and 2.51 Mha in the Atlantic Forest. The study also indicates that the activity practiced in lands with lower aptitude is initially limited to wood exploitation, followed by practice of extensive livestock with low productivity. In the absence of incentives for land restoration, the improper use of this resource is perpetuated, preventing production gains and compliance with the environmental law.

Given the potential benefits and costs of controlling deforestation, this study investigates the possible impact that different scenarios of decrease in deforestation in Brazil would have on the Brazilian and global economies.

**2. Literature Review**

Several studies seek to evaluate the socioeconomic impacts resulting from measures related to changes in land use in Brazil. Ferreira Filho and Horridge (2012) analyze the effect of the reduction in deforestation on food supply and on the Brazilian economy, using the general computable equilibrium model (EGC) TERM-BR. They conclude that the end of deforestation generates an increase in food prices of 2% and a 0.5% drop in Brazilian GDP. In the agricultural frontier regions there would be a 6% drop in GDP.

Diniz (2012) compared the impacts of the land use legislation (Forest Code) in place at the time of the research and the proposal of the New Forest Code (NCF) on the Brazilian economy. Using the Term-BR EGC model, he concludes that compliance with the previous version of the Forest Code would lead to a drop in GDP of 0.37%, but with the NCF the drop becomes 0.19%.

Cabral (2013) applied the MIT-EPPA model, a global dynamic economic model, to evaluate the impacts of a restrictive deforestation policy in the Brazilian Cerrado and Amazon, in agreement with the Brazilian Climate Change Plan. The results suggest that restrictions on deforestation generate a 0.15% drop in national GDP, a small negative impact in production in agricultural and livestock sectors but allow preserving about 68 million hectares of forest by 2050 (Cabral, 2013).

Carvalho and Domingues (2014) investigate the relationship between the reduction of deforestation in the Legal Amazon and the economic growth of the region by 2030. To this end, they developed a dynamic economic model that considers indirect land use changes in 30 mesoregions of the Legal Amazon. The regions with the highest GDP projected in the base scenario, located in the agricultural frontier region and/or in soybean and cattle producing areas, are the most affected, as well as the regions in which family farming predominates. An annual productivity gain of 1.4% would be enough to attenuate the economic impact of deforestation control, combined with surveillance and economic incentives for conservation.

Carvalho, Magalhães and Domingues (2016) evaluate the contribution of deforestation on the economic growth of the Amazon between 2006 and 2011. They identify that deforestation generates little growth in the region. By designing a policy to control deforestation in the period 2012-2020, they conclude that there is a marginal loss of growth due to the deforestation control (Carvalho, Magalhães, & Domingues, 2016).

Ferreira Fillho, Ribera and Horridge (2016) use the TERM-BR model to estimate the economic impacts of the end of Brazilian deforestation. They simulate the policy to reduce deforestation in the Amazon (PPCDAM), which targets 80% reduction in the annual deforestation rate compared to the annual average observed between 1996 and 2005, as well as the end of deforestation by 2015. The results indicate a small decrease in GDP, which can be offset by increased agricultural efficiency.

Santos et al. (2017) used the physical-economic model of partial equilibrium Globiom-Brazil in conjunction with the TERM-BR Model to compare the economic impacts of the NCF. The study considers the full implementation of NCF as a basic scenario and compares it with two scenarios: one in which market mechanism allowing farmers to negotiate their surplus and deficits of preserved areas is not adopted and the other in which small properties are not exempted to obey the law. The results show a decrease in investments of 0.83% in the first scenario and 3.08% in the second scenario, soybean cultivation and livestock products lose area throughout the territory and the states of the Midwest suffer the greatest impacts in falling GDP, employment and real wages (Santos et al., 2017).

Instituto Escolhas (2017) investigates the economic effect of three different scenarios projected for the period between 2016 and 2030: 1) zero deforestation, 2) zero deforestation on public lands and in the Atlantic Forest by 2030 and deforestation allowed on private areas of high agricultural aptitude and 3) zero deforestation on public areas and the Atlantic Forest by 2030 and deforestation allowed in private areas. The reduction or end of deforestation has a low economic impact at national level, however, agricultural frontier areas suffer greater negative impact and lower income populations are more negatively affected.

Ferreira Filho and Horridge (2017) assess Brazil's ability to meet the targets set at COP-21, to reduce GHG emissions by 37% by 2025 and by 43% by 2030 when compared to the 2005 level. They focus on deforestation and land use in the Amazon and Cerrado regions. The study projects three scenarios: the first considers the end of illegal deforestation by 2030, the second includes the first scenario plus the reforestation of 12.3 million hectares (Mha) of reforestation and the third maintains the total deforested in the second scenario, but transfers the total deforestation that occurred in the Amazon to the Cerrado region. The results indicate that the target set by 2025 would be met only in the recovery scenario of the 12 Mha of secondary vegetation - while the commitment made for 2030 is not met in any of the projected scenarios. The authors also note that the compensation for the end of deforestation in the Amazon through deforestation in the Cerrado has a significant impact on the capacity to comply with the obligations assumed and that emissions as a whole are increasing in the Brazilian economy, requiring greater effort to meet the commitments of the COP21.

Among the reviewed studies, only Cabral's (2013) uses a global economic model, in which world markets are all connected and endogenous to the model. However, she evaluates the policy of deforestation control at the time, which contemplated its reduction by 80%. Thus, the present work contributes to the literature by investigating the economic impacts of the end of deforestation, considering the systemic effects on world markets and potential changes in land use in Brazil and the rest of the world.

## 3. Methodology

We employ the 6th version of the Economic Projection and Policy Analisys (EPPA) model developed by the MIT Joint Program on the Science and Policy of Global Change (Paltsev et al., 2005; Chen et al., 2017). It is a dynamic-recursive, multi-regional and multi-sectoral computable general equilibrium model of the global economy. The EPPA has a structure based on the theory of general equilibrium and information on natural resources and the environmental consequences of the use of these resources. The model is used to analyze the links of the economy with the terrestrial system, the impacts of changes in this system for global and regional economic growth and the implications of economic policies aimed at stabilizing the relationship of economic agents with the planet. Some recent applications of the model include Gurgel et al. (2019, 2016) and Lucena et al., (2016).

The model is calibrated for the historical period from 2007 to 2015 and is solved at intervals of five years from 2020 until 2050, for 18 regions and 14 sectors (Table 1). The model also considers alternative technologies (backstop), that is, sectors that offer energy technologies used on a small scale and evaluated as potentially relevant in the future (Table 2). The EPPA also considers the breakdown of household consumption in purchases of transportation services, use of own transportation (private cars) and consumption of other goods and services.

The EPPA model database consists mainly of input matrices that represent the structures of the regional economies, from the Global Trade Analysis Project – GTAP. They cover regional consumption, sectoral production, bilateral trade flows, macroeconomic indicators, and representation of energy markets in monetary and physical units (Hertel, 1997; Narayanam et al., 2012). The economic growth of the base year through 2015 is calibrated with real GDP data. IMF projections are used to guide future trajectories of the economy, and for more distant periods in time is used the projection of Patselv et al. (2005) adjusted to reflect projections from United Nations (2013), Gordon (2012) and Brazil (2007).

Table 1 – Aggregation of regions, sectors and factors in the EPPA model

| Região | Setors | | Primary Fators |
|---|---|---|---|
| United States | **Economic Sectors** | | **Non Renewable Natural Capital** |
| Canada | Agriculture- Crops | CROP | Oil |
| Mexico | Livestock | LIVE | Shale oil |
| Japan | Forestry | FORS | Natural Gas |
| Australia/New Zealand | Food | FOOD | Coal |
| European Union[1] | Coal | COAL | **Renewable Natural Capital** |
| Wester Europe | Crude oil | OIL | Solar and wind |
| Russia | Refined oil | ROIL | Hydro |
| Eastern Asia | Natural gas | GAS | Nuclear |
| South Korea | Eletricity | ELEC | Natural forests |
| Indonesia | Energy intensive | EINT | Natural grass |
| China | Other industries | OTHR | **“Produced” Capital** |
| India | Services | SERV | Capital |
| Brazil | Transportation | TRAN | Cropland |
| Africa | **Household “Sectors”** | | Pastures |
| Middle East | Own transportation | HHTRAN | Managed and harvested forests |
| Latin America | Dwellings | DWE | **Trabalho** |
| Rest of Asia | Other services | HHOTHR | |

Source: Gurgel et al., (2016)
[1] EU, Croatia, Norway, Switzerland, Iceland and Liechtenstein;

The EPPA model also incorporates data on greenhouse gases (carbon dioxide, CO2; methane, CH4; nitrous oxide, N20; hydrofluorocarbons; HFCs; perfluorocarbons, PFCs; and sulphur hexafluoride; SF6) and information on other urban pollutants (sulfurdioxide - SO2; nitrogen oxides – NOx, black carbon – BC, organic carbon – OC; ammonia – NH3; carbon monoxide – CO, and non-methane volatile organic compounds – VOC), based on the Emissions Database for Global Atmospheric Research (EDGAR).

Cropland and pastureland data come from the GTAP8 land use and land cover database; the other categories are built based in the database of the Terrestrial and Ecossystem Model (TEM), which reflects the data developed by Hurtt et al. (2006).

EPPA is formulated as a series of mixed complementarity (MCP) problems. This type of approach involves three inequalities that must be met: zero economic profit conditions for production, balance between supply and demand in the goods markets, and factors of production and income balancing. These inequalities are associated with three non-negative variables: prices, quantities and income levels.

Table 2 – Alternative technologies available in the EPPA model

| Technology | Symbol |
|---|---|
| Fist generation biofuels | bio-fg |
| Second generation biofuels | bio-oil |
| Shale oil | sinf-oil |
| Synthetic gas from coal | sinf-gas |
| Hydrogen | h2 |
| Advanced nuclear | adv-nucl |
| IGCC w/ CCS | Igcap |
| NGCC | Ngcc |
| NGCC w/ CCs | Ngcap |
| Wind | Wind |
| Bio-electricity | Bioelec |
| Wind power combined with biomass | Windbio |
| Wind power combined with gas | Windgas |
| Solar | Solar |

Source: Chen et al., 2015.

Families are holders of the primary factors (capital, labor and natural resources) that are offered to the productive sectors in exchange for salaries and profits, which in turn are allocated between consumption and savings. The productive sectors transform the primary factors and intermediate inputs into goods and services that are sold to other producers (domestic or foreign), to families or to the government in exchange for payment. Producers seek to maximize their profit. The government has a passive role, charging taxes from households and producers to finance consumption and government transfers.

The EPPA considers both production and consumption functions as constant elasticity of substitution (CES) and with constant scale returns. The substitution elasticities of the sectors can be observed in Table 3.

Table 3 – Elasticities of substitution

| Description | Value | Comments |
|---|---|---|
| Elasticities of substitution in energy bundles | | |
| Energy-Value added | 0,4-0,5 | |
| Eletric-fuels | 0,5 | All sectors |
| Among fuels | 1 | All sectors except ELE |
| Energy/materials/land-value added. | 0,7 | Only CROP/LIVE/FORS |
| Energy/materials-land | 0,6 | Only CROP/LIVE/FORS |
| Energy-materials | 0,3 | Only CROP/LIVE/FORS |
| Coal-crude oil | 0,3 | Only ELE |
| Coal/crude oil-gas | 1 | Only ELE |
| Labor-capital | 1 | All sectors |
| Resources-all other inputs | 0,6 | OIL, COAL and GAS |
| Nuclear resources-value added | 0,04-0,4 | Regional specific |

| | | |
|---|---|---|
| Other elasticities | | |
| Domestic-imported | 2,0-3,0 | Sector specific |
| | 0,3 | ELE |
| Armington trade elasticities | | |
| Among imports from diferente regions | 5 | Non energy |
| | 4 | GAS, COAL |
| | 6 | ROIL |
| | 0,5 | ELE |

Source: (Chen et al., 2017; Paltsev et al., 2005)

The behavior of households is reflected by a regional representative agent which holds production factors that can be sold to firms. In each period, the representative agent chooses the levels of consumption and savings that maximize its utility function subject to budget constraints. Like production, preferences are also represented by CES functions.

Land use in the EPPA model is divided into five categories: pastures, crops, forests, natural forests and natural pastures. Each land category is considered a renewable resource and can be converted from one type of land use to another. This approach assumes that the marginal cost of conversion between one type and another of land use, in balance, equals the difference between the economic value of the two types of land (zero economic profit).

Land income is obtained through the GTAP database. The land use value is represented by the monetary transactions inferred empirically in each region studied; except in the case of natural land categories, where a reserve value (or "non-use") is determined through data from the Global Timber Market and Forestry Data Project of Ohio State University. This database assumes that the marginal cost of access to new forest areas equals the value of the current stock of wood plus the value of future tree cuttings. The net present value of the land and forest is calculated using an optimal wood extraction model for each region of the world and for different types of wood. The definition of the cost of access establishes the equilibrium condition in which the current income stream of unforested areas for timber purposes is zero because the wood available now and in the future in these regions can only be obtained by affording their access costs.

The model allows the value of wood stock in virgin forests and the value of logging to be deducted. The rents obtained from the value of natural vegetation areas is incorporated into the model as part of the initial income of families in each region. The reserve value of natural lands enters the welfare function of the regional representative agent with a substitution elasticity with other consumer goods and services.

The conversion of natural forests into categories of agricultural use produces wood products, which are perfect substitutes to the forest harvest in managed forest land. A fixed factor is included in the function converting natural areas, with limited replacement possibilities, allowing it to represent a land supply response based on recent conversion rates. This captures factors that influence land conversion, such as institutional constraints, the need to expand access infrastructure to remote natural vegetation areas, and society's perception of environmental services provided by natural areas.

The closure of the model at each period, by the supply side, considers fixed supply of primary factors (except in the case of land use categories), factor mobility within each region (except for the non-malleable portion of capital) and no movement of factors among regions. On the demand side the marginal propensity to save is region-specific and remains constant. The international flows that have compensatory effect on imbalances in trade in goods and services in the base year of the model are taken as exogenous and decline over time, so that deficits and surpluses in current transactions are minimized over time.

The temporal dynamics of the EPPA model is determined by endogenous and exogenous aspects. Exogenous factors include projections for GDP, labor and productivity growth, as well as increased energy efficiency and natural resource productivity. Endogenous factors include savings and investments and depletion of fossil fuels. Savings and consumption are aggregated in the utility function of households; all savings are turned to investments, meeting the demand for capital goods.

The capital in the EPPA model is divided between malleable and non-malleable. It captures the limited capability to convert capital from an activity to other. This allows representing the long maturation time of investments in some sectors (electric, for example) and the difficulty of converting plants and technologies that are in operation.

Alternative technologies represent energy sectors that are not currently in use or are used on a small scale, but may become available in the near future. The entry period of these technologies depends on their relative costs in relation to conventional energy sources. Each technology also has specific fixed factors defined according to its penetration rates, according to Morris, Reilly, & Chen (2014).

## 4. Scenarios

A reference (or baseline) scenario and three deforestation reduction scenarios were designed. These are:

• Reference Scenario (BAU): reflects the historical trend of deforestation in the last 10 to 15 years, considering the effects of the policies in force in this period, but does not include explicit anti-deforestation policies, such as the PPCDAM and PPCerrado programs;

• Policy Scenarios: an instrument of punishment for deforestation is applied in the model, in the form of a tax or fine, so that some exogenous level of deforestation is defined. The tax is endogenously calculated by the model, while the area to be preserved is set exogenously. Such scenarios are:

- Zero illegal deforestation by 2030 with legal deforestation remaining after 2030 (called *Stop_illegal*): deforestation levels are reduced from 2020 onwards (until 2050) by 49% in forests and 52% in cerrados and natural areas.

- Zero deforestation by 2030 (*Stop_2030*): deforestation levels are reduced from 2020 to 2030 by 49% in forests and 52% in cerrados and natural areas, with zero deforestation after 2030.

- Zero deforestation by 2020 (*Stop_now*): theoretical scenario in which deforestation is completely zeroed by 2020.

Table 4 presents the deforestation allowed in each simulated scenario. As the model is not spatially detailed to distinguish forested areas in the Amazon region from the ones in the Cerrado biome or in the Atlantic Forest, then, as an approximation, it is considered that, of the land use categories present in the model, the NFORS category is a close enough representation of the forest areas of the Amazon and the Atlantic Forest, and the category natural grass (NGRASS) is a good representation of the Cerrado (savanna) and pampa biomes. Also, it is not possible to distinguish the areas of legal deforestation (allowed by the New Forest Code - NCF) from those of illegal deforestation, we assume that illegal deforestation would correspond to all deforestation exceeding the numbers calculated by Sparovek et al. (2018) as allowed under the NCF and suitable to agriculture use (Table 5).

Table 4 – EPPA model projections of deforested areas (Mha) in each scenario

| | Forest (Amazon and Atlantic Forest) | Natural Grass (Cerrado and Pampa) | Total |
|---|---|---|---|
| | 2016-2050 | 2016-2050 | 2016-2050 |
| BAU | 6.87 | 20.34 | 27.21 |
| Stop_Ilegal | 3.53 | 8.16 | 11.69 |
| Stop_2030 | 3.12 | 5.89 | 9.01 |
| Stop Now | 0 | 0 | 0 |

Table 5 – Projection of deforestation allowed by the NCF (Sparovek et al., 2018) in Mha

| | Amazon | Cerrado | Atlantic Forest | Total |
|---|---|---|---|---|
| Area allowed to be deforested in the NCF | 11.70 | 43.63 | 8.35 | 63.68 |
| Area suitable to agriculture and allowed to be deforested in the NCF | 3.12 | 5.89 | 2.51 | 11.52 |

As the Atlantic Forest biome in Brazil has been the most deforested in Brazil, with less than 15% remaining of its original cover, we assume deforestation will not take place in its areas. As so, the *Stop_2030* scenario in Table 4 allows the maximum of 3.12 Mha deforested in natural forest areas by 2030 and the limit of 5.89 Mha in the natural grass areas, as shown in Table 5 as suitable to agriculture and able to be deforested.

## 5. Results

### *5.1. Impacts on Land Use - Brazil*

Figure 1 shows the land use and land cover trajectories for cropland (CROP), pastures (LIVE), managed, planted and secondary forests (FORS), natural forests (NFORS) and cerrado natural grass (NGRASS), which includes the Cerrado (Brazilian savannas).

The area occupied by agricultural activities grows over time in all scenarios, with little difference between them. The major change from the BAU scenario is observed at the scenario Stop_now, which generates 3.22 Mha less cropland in 2030 and 4.71 Mha less in 2050.

In the case of pastures, there is a reduction in the total area allocated to livestock activities even in the BAU scenario, partly reflecting intensification in the sector and control measures implemented over the last 10-15 years. There are large differences between policy scenario areas and the BAU. For 2050, the pasture areas in the scenarios Stop_2030, Stop_ilegal and Stop_now are smaller than in the BAU scenario by 11.2, 8.3 and 15.6 Mha, respectively. These values indicate the intensification of activity and the conversion of pastures to crops on land with higher agricultural suitability.

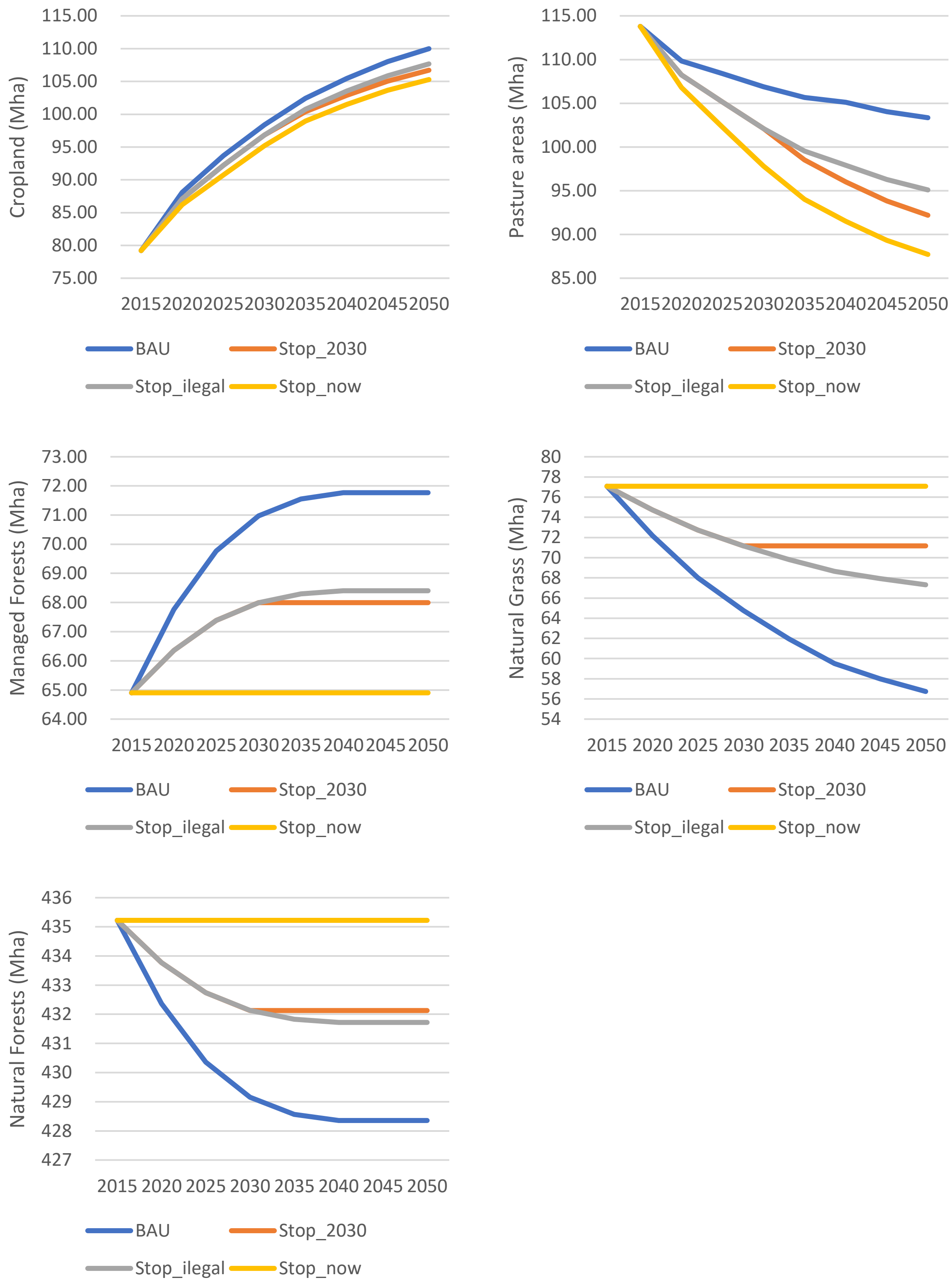


Figure 1. Land use and land cover trajectories to crops (CROP), pastures (LIVE), managed forests (FORS), natural pastures (NGRASS) and natural forests (NFORS).

Managed forests (FORS), which includes forestry plantation as also as secondary vegetation in recovery, increase in all scenarios, except under the Stop_now scenario. This increase is stabilized in 2030 in the Stop_2030 scenario and in 2040 for the BAU and the

Stop_Ilegal scenarios. These results suggest that the conversion of pastures to cropland is a cheaper economic option than the conversion of areas of managed, planted and regenerating forests. In part, this is based on the fact that the areas in regeneration are mostly of low agricultural aptitude and have higher risk or less attractive economic returns if they are converted to crops.

In the case of natural pastures (consisting of Cerrado and Pampas), the differences between the BAU scenario and the policy scenarios are noticeable. The policies to reduce deforestation are indispensable for preserving these biomes. Deforestation avoided in the case of the Stop_now scenario is 12.3 Mha in 2030 and 20.3 Mha in 2050. In the case of Stop_2030 and Stop_Ilegal scenarios these values are 6.4 Mha for both in 2030 and 14.4 and 10.6 Mha in 2050. It is also possible to notice a trend of continued deforestation both in the BAU and in the Stop_Ilegal scenarios.

The trajectory of the natural forests areas follows a less accelerated pattern of deforestation than the natural grassland areas. From 2040 onward deforestation is stabilized even in the BAU scenario, which reflects a possible exhaustion of the economic need to open new areas of this category. As expected, the difference between the BAU scenario and the Stop_now scenario is the largest, with the Stop_now scenario avoiding the deforestation of 6 Mha in 2030 and 6.9 Mha in 2050. The difference between the Stop_2030 and Stop_ilegal scenarios and the BAU scenario is 3 Mha in 2030 for both and 3.8 Mha and 3.4 Mha, respectively, in 2050.

*5.2. Impacts on Agricultural and Livestock Production - Brazil*

The adoption of deforestation control policies has a negative impact on the value of agricultural, livestock and food production (CROP, LIVE and FOOD, respectively). However, these impacts are quite small for the agricultural sector (Figure 2). The worse impacts occur in the stop_now scenario, and achieves 0.75% decrease in 2030 and 1.4% in 2050. In the stop_ilegal and stop_2030 the crop sector reduces by 0.38% in 2030 and almost 1% in 2050. The results indicate that the decrease in the agricultural area occupied by crops is associated with increases in productivity and intensification. In the case of livestock the reduction in the product is slightly greater. The production is 2.3% lower in the stop_now scenario compared to BAU and 1.19% lower in the stop_ilegal and stop_2030 scenarios for the year 2030. In 2050 the projections indicate less 3.59, 1.82% and 2.58%, respectively, for each of the mentioned scenarios. The drop in the product indicates that, given the need to reduce the area due to anti-deforestation measures and competition of area with crops and forests, it is necessary to intensify livestock production, which increases the cost of production and reduces supply.

In all cases it is also possible to notice that production increase over time, which is related to the depletion of suitable land to agricultural practices and increase in production costs aimed at improving the efficiency of land use.

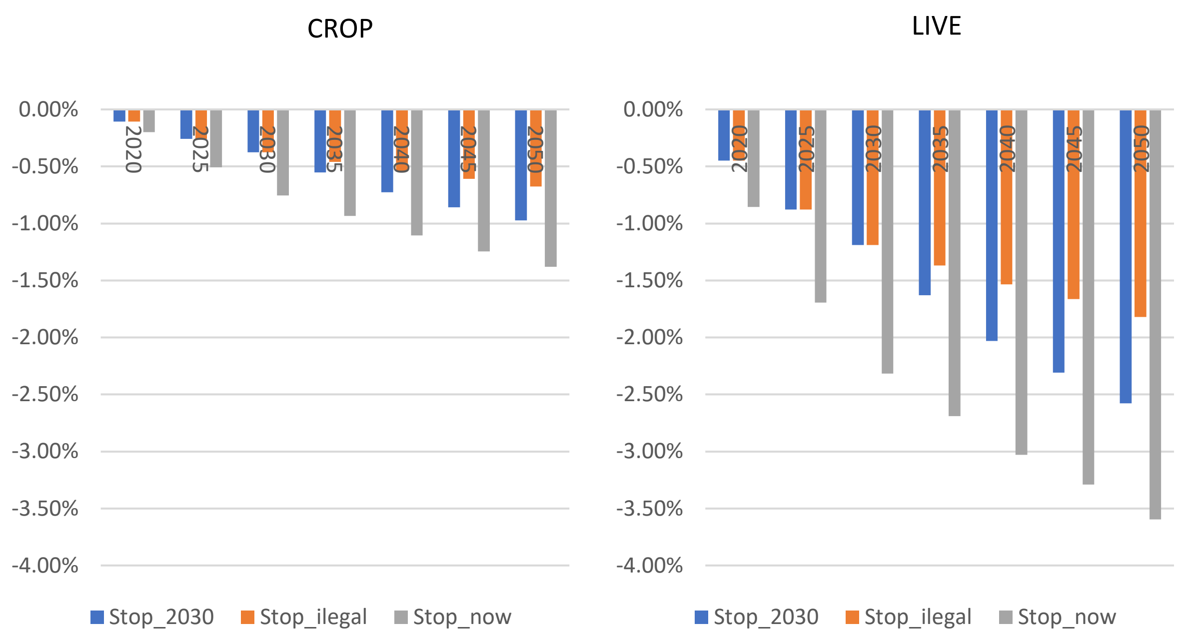


Figure 2 – Change (%) in agricultural (CROP) and livestock (LIVE) output in the policy scenarios relative to the BAU

*5.3. Impacts on Gross Domestic Product - Brazil, and Payments for Environmental Services*

Figure 3 shows the percentage difference the Brazilian Gross Domestic Product (GDP) among the policy scenarios and the BAU scenario. Deforestation restriction policies have a reduced impact on aggregate economic activity. The impacts on GDP are close to zero in all scenarios in 2030 and among -0.07% and -0.02% in 2050. These results indicate that the aggregate economic costs associated with intensification and increased efficiency in crops and livestock, as well as the cost of implementing the policies themselves, are low for the aggregated economic activity in the country.

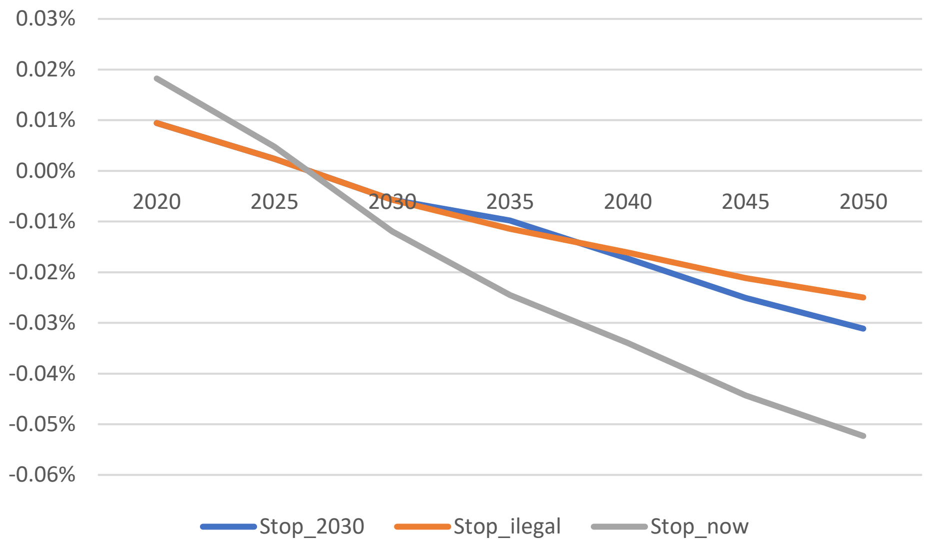


Figure 3 – Change (%) gdp in policy scenarios relative to the baseline scenario

These results are in line with those obtained in the studies by Assunção, Gandour & Rocha (2013), Cabral (2013) and Assunção & Rocha (2014). These authors also concluded that measures to monitor and control deforestation in Brazil had a reduced impact on GDP over time.

The results on GDP and agricultural production allow us to infer how much farmers and society would like to receive as possible payments for environmental services in order to preserve areas that could potentially be deforested by the New Forest Code. For society this value can be thought as the difference between the GDP of the Stop_2030 (or the Stop_ilegal) scenario and the GDP in the Stop_now scenario. For farmers, this value could be inferred as the difference between the value of agricultural production in the Stop_2030 (or the Stop_ilegal) scenario and the value of production in the Stop_now scenario. Such differences can be seen in Figure 4. The payment needed to incentive preservation grows over time. In the case of the society, there would only be a need to introduce such payments from 2030. At this year, the amount to be paid would be around US$ 170 million, which represents about 0.1% of the projected GDP. For the year 2050 these values increase considerably and total US$ 1 billion in the Stop_2030 scenario and US$1.4 billion in the Stop_ilegal scenario. These values represent 0.02% and 0.03% of projected GDP in each of the two scenarios respectively for the year considered.

In the case of farmers, the necessary payment to encourage conservation is considerably higher, which is justified by the nature of the economic activity of these agents, which has the land as the main input. For the year 2030 the projected payment would be US$1.3 billion for both the Stop_2030 and Stop_ilegal scenario, which represents 0.05% of the value of GDP and 0.7% of projected production for that year. For the year 2050 the projected payment amount grows to US$ 2.2 billion for the Stop_2030 scenario and US$ 3.9 billion for the Stop_ilegal scenario, which represents 0.04% of GDP and 0.6% of projected production in the first scenario and 0.08% of GDP and 1.1% of projected production in the second scenario. Interestingly, these values are much lower than the total volumes provisioned by the Brazilian rural credit policy, which reached in recent years values in excess of R$ 150 billion (equivalent to US$ 33 billion at the current nominal exchange rate).

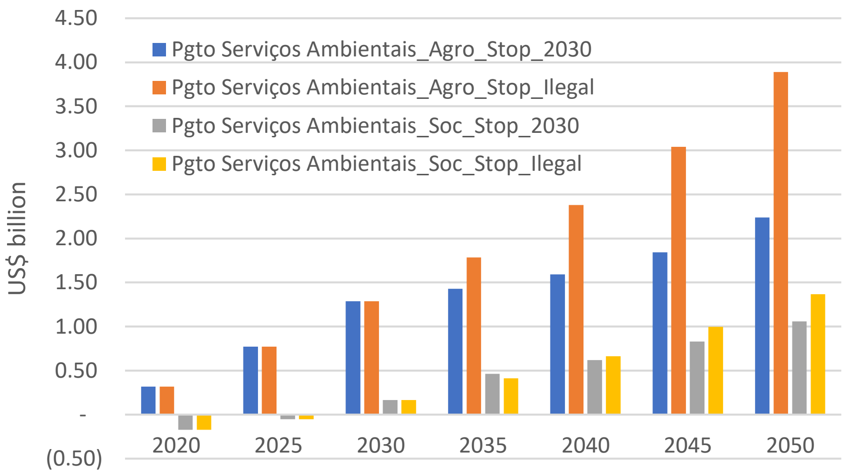


Figure 4 – Projected payment (billion US$) for environmental services

*5.4. Greenhouse gas emissions from land use changes in Brazil*

Figure 5 shows the CO2 emissions from land use changes in each scenario. All scenarios move to zero level of deforestation emissions and, disregarding the hypothetical scenario Stop_now, the other scenarios show that with current environmental policies and/or adoption of complementary policies to combat deforestation, only from 2035 that the level of CO2 emissions would reach zero (2035 in the scenario of stop_2030 and 2045 for the BAU scenario and Stop_ilegal).

Brazil's goal in the Paris Agreement seeks a 37% reduction in total emissions in 2025 and 43% in 2030. According to the results from the EPPA model, Brazilian emissions would be reduced from 2.12 GtCO2 eq. in 2005 to 1.3 GtCO2 eq. in 2025 and 1.2 GtCO2 eq. in 2030 (MCTI, 2014). These values would fall in the interval determined by the current climate policy, where the targets for 2020 were set between 1.168 GtCO2 eq. and 1.259 GtCO2 eq. (MCTI, 2014). According to the emissions projected in this study, Brazil would comply with the Paris

Agreement in all policy scenarios, with the emissions in 2025 and 2030 being 44% lower than emissions in 2005 in the scenarios of illegal Stop_2030 and Stop.

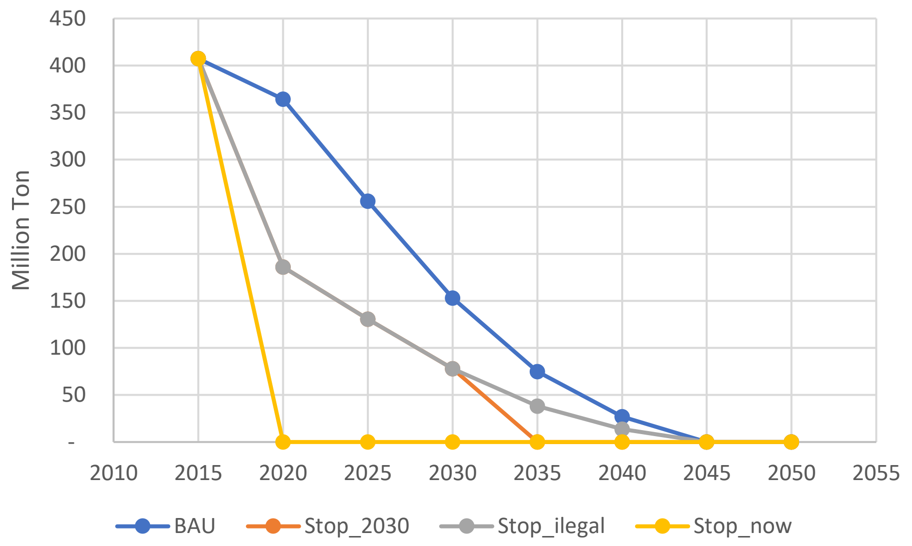


Figure 5 – CO2 emissions (Millions of Tons) from land use changes

*5.5. Land Use Change - World*

The model allows to measure also the deforestation in other world regions. Table 6 shows that the adoption of deforestation control policies in forest and natural grass areas (NFORS and NGRASS) in Brazil has negligible impacts on deforestation in areas of these categories in the rest of the world. It is a consequence of several opportunities to intensify production in Brazil and increase yields in agricultural and livestock sectors.

Table 6 – Preserved area in Brazil and variation of deforestation in the rest of the world (ROW), differences from the policy scenarios to the BAU scenario (Mha)

| 2030 | Natural Grass | | Natural Forest | |
|---|---|---|---|---|
| | Preserved area in Brazil | Deforestation in ROW | Preserved area in Brazil | Deforestation in ROW |
| Stop_2030 | 6.40 | -0.01 | 2.97 | -0.01 |
| Stop_ilegal | 6.40 | -0.01 | 2.97 | -0.01 |
| Stop_now | 12.31 | -0.02 | 6.07 | -0.01 |

| 2050 | Natural Grass | | Natural Forest | |
|---|---|---|---|---|
| | Preserved area in Brazil | Deforestation in ROW | Preserved area in Brazil | Deforestation in ROW |
| Stop_2030 | 14.43 | -0.02 | 3.77 | -0.00 |
| Stop_ilegal | 10.58 | -0.01 | 3.36 | -0.00 |
| Stop_now | 20.34 | -0.03 | 6.87 | -0.01 |

## 6. Conclusion

We simulate the potential impacts of the end of illegal deforestation on the Brazilian economy and world land use changes. A global economic model is used to design different deforestation containment scenarios. The results indicate that more restrictive polices to deforestation cause greater intensification and reduction of the area occupied by livestock and greater preservation of natural vegetation. The economic impacts of these restrictions are modest, even under an aggressive anti-deforestation scenario able to stop deforestation by 2020, since losses in crop production do not exceed 1% in 2030 and 1.5% in 2050. GDP would be 0.06% lower than in a scenario without deforestation control. These results indicate that potential costs associated with intensification and increased efficiency in crops and livestock are quite low. The equivalent amount to be paid to farmers and ranchers for giving up clearing legally permitted areas reaches $1.3 billion in 2030 and $3.9 billion in 2050, and the opportunity cost to society ranges from $0.2 billion in 2030 to $1.4 billion in 2050. Deforestation control policies in Brazil would have negligible impacts on deforestation in the rest of the world, indicating that there are no undesirable "overflows" or "leaks" to other countries.

The study indicates that policies to fight illegal deforestation are desirable, given their benefit of environmental preservation, not translated into monetary values in this research. They can also improve the international image of the Brazilian agriculture and livestock products and farmers. Similarly, policies that encourage increased efficiency and intensification of agricultural practice should be pursued. Future studies should include the monetary valuation of the environmental gains from conservation of natural areas, for a complete assessment of benefits and costs, as well as investigate mechanisms to encourage preservation, such as compensation and payment for environmental services.

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