World Economics Association
Conferences, 2014
Is a more inclusive and sustainable development possible in Brazil?
2014, n. 1: 5th May – 20th July

Title of Paper: Economic analysis of limitation of deforestation in Brazil

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Abstract:

With the advent of the phenomenon of global warming, the greenhouse effect, countries that emit more greenhouse gases (GHGs) have suffered strong international pressure to reduce such emissions. In Brazil, much attention is focused on deforestation, one of the largest emitters of carbon dioxide. Therefore, Brazil has committed to reducing its emissions by 36.1% and 38.9% compared to projected emissions for 2020. In order to accomplish this, the deforestation in the Amazon be reduced by 80% and in the Cerrado (savannah) by 40% by the year 2020. Simultaneously, food production is one of the biggest challenges of the modern world, and second the OECD and FAO, Brazil is the country with the greatest potential to increase agricultural production. Moreover, data show that agribusiness is a key sector of the Brazilian economy in terms of income generation and promotion of foreign exchange. But to reduce deforestation, agriculture and livestock can be quite reached, since its expansion nowadays is happening on Cerrado and Amazon areas. One hypothesis is that halting deforestation would imply lower production of these sectors and food, and lower income in the long run. This article discusses the economic impacts of a restrictive policy of deforestation on the agricultural and livestock sector and the national economy using a computable general equilibrium model. The results point to little losses in GDP from the limiting deforestation scenario compared to the baseline, but greater impacts in the agricultural, livestock and food sector.

Keywords: Deforestation. Land use changes. Agriculture and livestock. General equilibrium.

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Introduction

The global warming phenomenon known as the “Greenhouse Effect” is one of the most alarming phenomena of environmental degradation. Increasing the amount of greenhouse gases (GHGs) modifies the atmospheric and oceanic temperature, circulation of wind and weather types. Estimates of the Intergovernmental Panel on Climate Change (IPCC) point to an increase in average atmospheric temperature between 1.1 ° C and 6.4 ° C between 1990 and 2100, but the maximum level reached in the last million years is 1ºC (IPCC 2007a; 2007b, 2007c). The activities that amplify the concentration of these gases in the atmosphere is the burning of fossil fuels, deforestation, use of fertilizers with high nitrogen concentration in agriculture, use of refrigerant gases and the large amounts of methane produced by cows.

Because of the current scenario, countries that have been larger emitters of greenhouse gases (GHGs) have therefore received strong international pressure to reduce such emissions. In Brazil, much of the attention is focused on the issue of deforestation, a leading cause of carbon dioxide (CO^2). According to the latest Brazilian Emissions Inventory, 77 % of CO^2 in 2005 were caused by land use change, which grew 64 % compared to 1990 (BRASIL, 2010b). This was due to the high rate of deforestation in Amazonian and Cerrado (savannah) in the past decade. Estimates of the National Institute for Space Research (INPE – acronym in Portuguese) of the Program to Calculate Deforestation in the Amazon (Prodes – acronym in Portuguese) indicate that more than 700,000 km^2 have been cleared in the Amazon, which corresponds to 17% of the original forest. Of this total, 183,500 km^2 (about 26 %) were deforested in the last decade. In the Cerrado, data from the program Monitoring of the Cerrado biome of the Ministry of the Environment show that the annual deforestation rate was 14.18 million km^2 between 2002 and 2008 and 7.63 million km^2 in 2009. Remaining natural areas have decreased from 55.73 % of biome in 2002 to 51.54 % in 2008.

Considering the need to adopt effective measures to mitigate emissions of greenhouse gases and deforestation reduction, the Brazilian government presented to Congress two projects Law that instituted a policy and a national fund on climate change. Approved by Law No. 12,187 of December 2009, the National Policy on Climate Change (PNMC – acronym in Portuguese) guides the development of the National Plan on Climate Change, the state plans and other plans such as the Plan of Action for Prevention and Control of Deforestation in the Legal Amazon (PPCDAm – acronym in Portuguese) and Plan of Action for the Prevention and Control of Deforestation and Burning in the Cerrado (PPCerrado – acronym in Portuguese), programs and projects related to climate change (BRASIL , 2009a). Moreover, the country has committed to reducing its emissions between 36.1% and 38.9% compared to projected emissions by 2020. In order to accomplish this, Law No. 12,187 was enacted, which regulates that deforestation in the Amazon be reduced by 80% and in the Cerrado (savannah) by 40% by the year 2020.

Simultaneously, the production of food is one of the biggest challenges in the world. According to estimates by the Organization for Economic Cooperation and Development (OECD) and the UN Food and Agriculture Organization (FAO), income growth in developing countries and the process of urbanization in countries like China and India, which still hold the majority of its population in rural areas, should increase the demand for food by 70% by 2050 (OECD and FAO, 2011). Moreover, according to these organizations, Brazil is the country with the greatest potential to increase agricultural production, around 40% by 2019.

Furthermore, the importance of food production to Brazil is enhanced by the fact that agribusiness is a key sector of the Brazilian economy in terms of its contribution to both income generation and for promotion of foreign exchange. According to the IBGE, the sector accounted for over 22% of the GDP in 2011, while agriculture accounted for 28.8% of GDP agribusiness, industry and distribution accounted for

59.4%, and inputs for agriculture. Agribusiness exports were 36.9% of total of exports in 2011, generating a balance of US$ 94.6 million for the trade balance.

In case of limiting deforestation in Brazil, probably the most affected sector is the sector which makes use of the deforested area, namely agriculture. According to a survey of the Brazilian Agricultural Research Corporation (Embrapa – acronym in Portuguese) and the INPE, livestock is the most responsible for deforestation in the Amazon, occupying more than 62% of the deforested area (EMBRAPA and INPE, 2011). Cattle raising is the most important land use in all states of the Amazon, which in general has shown growth in all of them, and that makes livestock economic activity with the greatest impact throughout the region (Rivero et al. 2009). In the Cerrado, the expansion of farming presses increasingly the remaining areas of native vegetation. Considered the last agricultural frontier on the planet, the Cerrado occupies 21% of the national territory, and about half of the original two million square kilometers were transformed into planted pastures, annual crops and other uses (KLINK and MACHADO, 2005).

However, analyzing the economic impacts of such measures is also quite relevant to ensure the economic and social development. Since this discussion is recent, Brazilian literature economic is still limited and has focused their attention mainly on regional, municipal or state level. As an example, Costa (2009) evaluated the impacts of policies to contain deforestation in Southeast Pará mesoregion using a model of the input-output matrix. Have Padilla Jr. (2004) survey the major impacts on agricultural activity before the execution of the Legal Reserve in Paraná State.

As exception, Ferreira Filho and Horridge (2012) analyze how the Brazilian agricultural frontier limited could affect domestic food prices and exports of agriculture, using the model of computable general equilibrium TERM-BR. The results obtained show that the stoppage of deforestation would increase the price of food in 2% by 2025 relative to the baseline due to a drop in agricultural production and rising prices, but the Brazilian GDP would decrease by only 0.5 % by 2025, and real exports and real wages would fall by 1%.

In summary, there is a discussion in vogue about the deforestation in Brazil and consequent GHG emissions, both from the side of the Forest Code and implementation of programs to reduce deforestation in the Amazon and the Cerrado, as the commitments made at COP15. What are the possible economic impacts of policies to limit deforestation in Brazil, since the land use will be restricted? One hypothesis is that it would imply lower agriculture production, higher prices of agricultural products and food, and lower income.

Thus, the aim of this paper is to estimate the economic impacts of deforestation restrictive policies on the agricultural sector and the national economy. In other words, how these restrictions will affect the aggregate income, the level of activity and trade flows of agricultural and food sectors and changes in land use, more specifically, in relation to the areas of pastures, crops and natural. For this purpose, it is used a general equilibrium model which is able to consider the relationships between the different sectors of the economy and a broad range of policy distortions. Thereby, the study aims to guide the formulation of coordinated environmental and economic policies, as well as check out some consequences of such policies, since it still needs more studies

1. METHODS AND DATA

1.1. Features and data

The analysis method used in this study is the modeling of computable general equilibrium (CGE). This approach takes into account all the interactions between markets and, consequently, all interrelationships between sectors are explicitly considered, and the interdependency among economic agents, different sectors, countries and regions. Unlike partial equilibrium analysis in which all prices of other goods, except the object of study, are fixed, in general equilibrium models prices vary. Moreover, these models allow obtaining the directions and magnitudes of exogenous shocks, in this study, policies to reduce deforestation.

The CGE model used is known as the Emissions Prediction and Policy Analysis (EPPA), developed by the MIT Joint Program on the Science and Policy of Global Change as described in Paltsev et al. (2005). The EPPA consists of a multi-sector, dynamic-recursive, multi-regional model designed to simulate scenarios of anthropogenic emissions of greenhouse gases and to estimate the economic impact of policies to mitigate climate change, as Reilly and Paltsev (2007) Paltsev et al. (2008, 2009, 2012) and Gurgel, Reilly and Paltsev (2007) and Jacoby et al. (2009). The version of the model being utilized is the fifth version of EPPA, calibrated for the base year 2004, being solved endogenously for the year 2005 and thereafter, at intervals of five years, between 2005 and 2100, providing projections for sixteen countries and regions. Countries and regions, as well as the sectors and factors considered in EPPA for this work are presented in Table 1.

Table 1 – Aggregations used by the EPPA model

Regions	**Sectors**	**Factors**
United States (USA)	**Não Energia**	Capital
Canada (CAN)	Agriculture – Crops (CROP)	Labor
Mexico (MEX)	Agriculture – Livestock (LIVE)	Oil from shale
Japan (JPN)	Agriculture – Forestry (FORS)	Coal
European Union (EUR)	Food (FOOD)	Natural gas
Australia & N. Zealand (ANZ)	Services (SERV)	Hydro
Russia (RUS)	Chemical, rubber, plastics, paper (CRP)	Nuclear
Eastern Europe (ROE)	Steel and metallurgy (IRON)	Wind & Solar
China (CHN)	Non-ferrous metals (ALUM)	Land:
India (IND)	Nonmetallic minerals (CIME)	- crops
Brazil (BRA)	Other industry (OTHR)	- livestock
East Asian (ASI)	Transportation (TRAN)	- forestry
Middle East (MES)	Own-supplied transport (FTRAN)	Natural forest
Africa (AFR)	**Energy**	Natural livestock
Latin America (LAM)	Coal (COAL)	
Rest of Asia (REA)	Conventional crude oil (OIL)	
	Refined oil (ROIL)	
	Natural gas (GAS)	
	Electricity (ELEC)	
	Hydro electricity (H-ELE)	
	Nuclear electricity (A-NUC)	
	Wind electricity (W-ELE)	
	Solar electricity (S-ELE)	
	Biomass electricity (biELE)	
	Electricity NGCC[1] (NGCC)	
	Electricity NGCC - CCS[2]	
	Electricity IGCC[3] - CCS	
	Gas from coal (SGAS)	
	Biofuel (1° generation)	
	Biofuel (2° generation) (BOIL)	
	Oil from shale (SOIL)	

Source: Paltsev *et al*. (2005) and EBC (2012).
[1] NGCC: converting natural gas into electricity using combined cycle generation
[2] CCS: carbon capture and sequestration
[3] IGCC: generation technology of natural gas from coal

The EPPA model is solved numerically using the General Algebraic Modeling System (GAMS) (BROOKE et al., 1998), which is a modeling system for mathematical programming and optimization software, developed for modeling large-scale and it allows building models easily adaptable to new situations or proposals. The syntax of the algorithm used is a Modeling System Programing program for General Equilibrium (MPSGE), which was developed by Rutherford (1999). The MPSGE builds algebraic equations that characterize the conditions for zero economic profit for production, balance between income and consumer spending and balance between supply and demand in goods and factor markets.

The fact that the EPPA model is recursive-dynamic means that economic optimization decisions are made at each period, considering only current prices and quantities in the same period ("myopic" expectations). For the following period, the reference values for the optimization process are the results obtained in the previous period. This means that in each period the model has a static solution process, in that the agents do not care about future expected values for the other variables.

In each period, production functions for each sector of the economy describe the combinations of capital, labor, land, energy and intermediate inputs to produce goods and services. The choices among different inputs reflect the technology used, in other words, the possibility of replacing various production factors and intermediate inputs in the production process. While consumption is modeled by the presence of a representative consumer who seeks the maximization of utility by the consumption of goods and services, and substitution between goods and services illustrates their preferences. The representation of the ability of consumers and firms to make choices between different inputs and goods is essential in the EPPA model. These choices are determined by the parameters of elasticities of substitution in production functions and utility consumers.

The optimization problems are addressed in the model as a mixed complementarity problems due to the large amount of economic agents and distortions. This approach requires zero economic profit, market equilibrium and balance of income. For these conditions to be satisfied, prices, quantities and income cannot be negative.

The condition of zero economic profit means that any industry that produces a positive amount of product must have income equal to zero. In other words, the value of inputs of any activity must be equal to or greater than the value of production. The condition of market equilibrium requires that there is a positive price for any good whose supply equals demand and that, along with any excess supply must have a zero price. The equilibrium condition requires that income for each agent, including government entities, the amount of income must be equal to the value of factor endowments and tax revenues.

In each region and sector, a representative firm chooses a level of output, from the combination of quantities of primary factors and the amount of intermediate inputs coming from other sectors in order to maximize their profit. The optimizing behavior of the firm implies the equilibrium condition that price equals marginal cost. A representative agent for each region presents initial allocations of supply of factors of production that will be sold or rented to firms, choosing the level of consumption and saving in each period to maximize their utility function subject to the budget constraint, given their level of income. Finally, the system of equations is closed, and the equilibrium prices in different markets for goods and factors of production determined by expressions of market equilibrium.

In the EPPA model assumes that production functions and utility functions are represented by constant elasticity of substitution (CES) nested. This provides flexibility in the determination of substitution between different groups of inputs and factors, and the elasticities of substitution, particularly with regard to fuel and electricity and other sensitive issue and its costs of mitigation processes. However, these structures in the EPPA model are very complex, since they have various levels of branching.

The temporal evolution of the model is based on scenarios of economic growth resulting from the behavior of consumption, saving, investment and capital accumulation, as well as exogenous assumptions about the increase in labor productivity, energy and land. Structural changes in the demand for goods and services produced by each sector, including food and fuel, occur as the product and income increase. Stocks of limited resources such as fossil fuels, decrease as they are used, causing an increase in the cost of extraction and processing. Sectors that use renewable resources such as land compete for the availability of the flow of services provided by them. The development or decline of a particular technology is endogenously determined according to the relative competitiveness thereof. All these phenomena, coupled with simulated policies such as taxes and subsidies to energy use, control pollutant emissions and impose mandates minimum percentages of gasoline blends, determine the evolution of economies and alter the competitiveness and participation of different technologies over time and among alternative scenarios.

As savings and investment are based on variables of the current period, the savings in each period is equal to investment which equals to depreciation and contributes to the formation of capital for the next period. Thus, the investment sector will be represented by a specific production sector, equaling the level of savings determined by the utility function of the representative agent. The marginal propensity to save is kept constant over time, thus avoiding shocks related to economic cycles.

To represent the stiffness of the capital stock, it is divided into two components, a malleable and non-malleable one. It is assumed that the soft portion of the capital stock in each sector is described by CES functions. This means that capital can replace and be replaced by other inputs in the production function. The share of non-malleable capital is treated through a Leontief function, which does not allow substitution among inputs. The share of non-malleable capital and other inputs in the production function are defined at the time that such capital is formed, reflecting the technology being used at the time of employment of that capital. This formulation allows the model to display answers short and long term from changes in relative prices. Over time, the non-malleable capital generated in a given period will depreciate and be replaced by new installments of non-malleable capital, reflecting the technologies in use in recent times, arising from changes in relative prices.

The growth of the workforce is set exogenously, being composed of the separate effects of population growth and labor productivity. Population growth is based on the long-term trend data of the United Nations (UN, 2000 and 2001). The labor productivity is specified to allow playback levels of gross domestic product in the regions of the model as provided by the International Monetary Fund (IMF, 2000).

Regarding the macroeconomic closure of the model, each period is considered that the total supply of each factor of production is constant (except for the different categories of land use, which are convertible into other). Factors are mobile across sectors within a same region, with the exception of non-malleable portion of the capital, and there is no movement of factors from one region to another. The land factor is specific to the agricultural sectors while natural resources are specific to sectors that draw them to produce energy.

There is no unemployment in the model, so factor prices are flexible. On the demand side, the marginal propensity to save is constant and specific to each region according to its share in total consumption and aggregate savings in the initial data base. International capital flows that compensate for disequilibrium in trade in goods and services in the base year of the model are assumed exogenous and declining over time, reducing the deficits or surpluses in current account. Thus, changes in the real exchange rate should occur every period to accommodate changes in the flows of exports and imports. Government consumption can change with variations in commodity prices, as well as revenue from taxes is subject to alterations in activity levels and consumption.

Economic data from the EPPA model are built from the Global Trade Analysis Project - GTAP (Hertel 1997; DIMARANAN; MCDOUGALL, 2002; Narayanan; WALMSLEY, 2008), a consistent database on regional macroeconomic consumption, production and trade flows bilateral, in its seventh version. The database GTAP7 presents input- product matrix to 113 countries and regions and 57 sectors of their economies, and includes a detailed representation of energy markets in physical units. The GTAP was built in programming language known as GEMPACK (HARRISON; PEARSON, 1996), but the EPPA uses the platform GAMS (BROOKE et al, 1998). To resolve this incompatibility, the GTAP data are translated and rearranged from GTAPinGAMS program (RUTHERFORD; PALTSEV, 2000). The data of land use are part of the GTAP database and from the work by Hurtt et al. (2006).

Statistics on greenhouse gases are obtained from inventories maintained by the Environmental Protection Agency of USA. And data from other urban pollutants are from the global database EDGAR (OLIVIER and BERDOWSKI, 2001).

1.2. Land use change

The land use in the EPPA model is divided into five categories: pasture, crops, forestry and secondary forests (areas of forestry, plant extraction and planted forests), natural forests and rangelands. The areas used for crops, pasture and forestry, as well as natural forests and pasture are determined by the terrestrial model called Terrestrial Ecosystem Model (TEM) (MELILLO et al, 2009) based on the work of Hurtt et al. (2006). The TEM model classifies, maps and categorizes the different types of vegetation and land use at the level of 0.5 ° by 0.5 ° latitude and longitude. The model classified the areas of natural forest vegetation typical of the work of Hurtt et al. (2006) in the category of Natural Forests (NFORS), while areas with characteristics of savannah and fields were classified in the category of Natural Fields (NGRASS) of the EPPA model. Areas of secondary forest vegetation recovery (not yet at vegetative stages of equilibrium) and planted forests were classified in the category of Planted Forests and Secondary (FORS). Table 2 shows the distribution of different types of land use in the EPPA model calibrated to the year 2010 in regions of the model.

Table 2 – Area by category in each category of the EPPA model calibrated for the year 2010 - in thousand hectares (ha)

Region	CROP	LIVE	FORS	NGRASS	NFORS	OTHER
United States	189162	110558	181805	95177	240753	112908
Canada	51649	22407	64263	-	345084	456539
Mexico	25659	65704	35700	9035	65910	1513
Japan	5245	680	9426	-	26887	206
Australia & N. Zealand	36371	397773	48436	65548	299153	25416
European Union	136931	57926	99655	22292	118626	59920
Eastern Europe	182540	183021	95820	10014	102798	33342
Russia	161477	156579	166834	33589	648485	509364
East Asia	96311	14673	10993	-	198408	23018
China	273455	237672	57835	21252	99075	244079
India	208851	24250	14037	-	59348	14924
Brasil	65334	138846	109622	95491	421307	23941
Africa	260171	905260	217987	106318	661482	850130
Middle East	21700	231880	28883	43583	55925	140829
Latin America	127751	296366	103626	41501	327545	151548
Rest of Asia	121409	143814	48990	61961	97738	33175

Source: TEM/EPPA.

In the Brazilian case, the initial data of land use of the EPPA model were compared and shown to be compatible with the data Portalbio of the Ministry of Environment and Agricultural Census (IBGE, 2006). The NFORS category includes areas of forest of Amazon, Atlantic Forest and Pantanal biomes. The NGRASS category can relate to the areas of native vegetation of the Cerrado, Caatinga and Pampa.

Each category of land is considered a renewable resource, which can be modified by its conversion into another category, or left in unused category (secondary vegetation). In addition, the land is subject to exogenous productivity improvements, set at 1% per year for each category, which reflects the historical trend of progress in agricultural productivity, as well as the historical crop yields, which has shown an increase of 1% to 3% per year, according to Reilly and Fuglie (1998).

Regarding the transformation of land use, the area under a given category can be expanded by converting other land categories. The representation of land use transformation is performed by conversion equations in a category of land use in another and expansion of the agricultural frontier by reducing areas of natural vegetation. For this to be consistent, two conditions must be satisfied: one is to maintain consistency between the physical accounting of the soil and economic accounting in general equilibrium setting, and the other requires the development of data is consistent with empirical observations.

To model the observed response of the supply of land, we use a fixed production factor with an elasticity of substitution between the fixed factor and other inputs parameterized, to represent the observed response of land supply in response to price changes of the same. The model adopts the observed response of the conversion of land in recent years as a representation of the long-term.

In conversion relations of land use, it is considered that an acre of a land category can be converted to a hectare of another category. The average productivity of converted land will depend on the type of land that was converted and on the region. The marginal cost of converting one type into another land in equilibrium must be equal to the difference between the economic value of the two types of land. This procedure allows maintaining the assumption of zero economic profit in general equilibrium models. Moreover, it is required that in the conversion is used actual inputs through a transformation function of land.

The value of land use is represented by real transactions as inferred by the economic statistical agencies in each country, so this value must be compatible with the data on revenues, costs of inputs and returns of other factors. From the GTAP database (HERTEL, 1997; DIMARANAN; MCDOUGALL, 2002; NARAYANAN; WALMSLEY, 2008), it is obtained the rent of land. As the categories natural forests and rangelands are not used for economic production, because they are not in current use, it takes an effort to infer an economic value for these categories, for this it is used the procedures adopted Gurgel; Reilly; Paltsev (2007). Also it is used data from Sohngen and Tennity (2004) on the cost of converting natural vegetation areas, derived from the hypothesis that the cost of access to new areas at the margin and at equilibrium, must be equal to the stock value of vegetable product (wood) existing in that area plus the present value of future stocks after regeneration of vegetation. Those data with the average rates of regeneration of natural vegetation allow to obtain a value of land rent covered by natural vegetation areas as the net present value of future cuts of wood of natural vegetation, which is obtained after discounting the conversion cost (equivalent to the present value on the balance of the virgin forest) the sales value of the existing wood stocks, and considering the time required for future cuts according to the rate of regeneration of the vegetation.

The values of land rents per hectare of regions in the base year of the model can be seen in Cabral (2013). In general, income from crop areas is the highest (except for areas where grazing countries are very limited), then the income from grazing areas. The planted areas and secondary forests are generally smaller than those of other productive uses, since this category adds not only areas of forestry, but also areas of secondary vegetation regeneration. Areas of natural vegetation (forests and fields) are the lower income of the land, since they are not commercially exploited.

The transformation functions of land use are calibrated to represent the observed response of supply of land since 1990 until today, considering the rising costs associated with the use of inputs and factors for conversion, the need to extend the access infrastructure to remote areas of natural vegetation, and formal and informal institutions (laws, standards of conduct, environmental groups and perception of society) that act on the basis of environmental and conservation reasons, hindering such conversions. For this, it is calculated the price elasticity of supply of land for each region, considering the average increase in land prices from 1990 to 2005 and the average annual area of conversion of forest areas in each region. Based on Hyman et al. (2002), the elasticity of supply is converted to elasticity of substitution between the fixed factor and other inputs used in the conversion, given by dividing the elasticity of supply and the share of costs of other inputs in the cost of the conversion function. To calibrate the functions is still necessary estimates of the share of the country's forest production generated from the cutting of natural forests, as well as the relative area of natural forest being cleared in relation to the total area of the category of land use of planted and secondary forest (FORS). This information can be viewed on Cabral (2013).

In regions where there is no net deforestation and or apparent, elasticities are close to zero as well as other parameters. The largest land supply elasticities are obtained for the regions with the highest rates of deforestation, namely Rest of Latin America, Africa and East Asia.

2. Scenarios and results

2.1. Scenarios

In order to substantially reduce the rate of deforestation, which had an upward trend in the past decade, the Brazilian government created in 2004, the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), in which the principal axes of the plan were the land and spatial planning, monitoring and environmental control, and promoting sustainable productive activities. However, despite efforts under this plan, the rate of deforestation in the Amazon increased again in the second semester of 2007 (BRASIL, 2009b).

With this, the government accelerated the signing of Decree No. 6,321, on December 21, 2007, which established a set of measures to control deforestation, such as editing the list of priority municipalities for the actions of environmental and land control, prohibiting issuing new permits deforestation; and the obligation of embargoes from illegally deforested areas (reinforced by Decree No. 6514 which enhanced the Environmental Crimes Act). Moreover, in February 2008, the National Monetary Council has accepted to modify the rules for granting agricultural credit, to require environmental and land tenure for lending to rural properties in the Amazon.

In December 2009 the government approved Law No. 12,187, which established the National Policy on Climate Change (PNMC – acronym in Portuguese). Also officiated the voluntary commitment of Brazil to the UN Framework Convention on Climate Change to reduce greenhouse gas emissions by between 36.1% and 38.9% of projected emissions by 2020. Instruments for implementation of PNMC are the National Plan on Climate Change, the National Fund on Climate Change, Communication of Brazil to the Framework UN Convention on Climate Change, the action plans for the prevention and control of deforestation in the biomes, lines credit and finance, and developing lines of research by funding agencies.

Pursuant to Decree 7.390, of December 9, 2010, which regulates the PNMC, it is considered as action plans for the prevention and control of deforestation Plan of Action for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm – acronym in Portuguese) and Plan of Action for the Prevention and Control of Deforestation in the Cerrado and Burning (PPCerrado – acronym in Portuguese). Meanwhile, to meet the voluntary commitment to reduce national GHG emissions, these plans should consider actions to:

- Reduce by 80% the annual deforestation rates in the Amazon compared to the average between the years 1996-2005, 2020;
- Reduce by 40% the annual rates of deforestation in the Cerrado biome in relation to the average between the years 1999-2008, 2020.

In parallel, the process of formulating policies to mitigate climate change, also gained force proposed modifications of the Brazilian Forest Code, which was replaced on May 28, 2012, by Law 12.561 and MP 571/12, constituting the new Forest Code.

Based on this information, three scenarios for reduced deforestation were simulated in addition to a baseline scenario. However, before describing them is important to clarify that the specifications of the new Forest Code were not simulated in the model due to the complexity in survey and describe the situation of rural property, which is beyond the scope of this work. Moreover, the focus of this work is to limit the withdrawal of natural vegetation cover and not the recovery of deforested areas, which even after recovered, would not be counted as forest or natural vegetation.

1. Baseline scenario - REF: Economic indicators are evaluated as if the government had not implanted policies to reduce deforestation. In other words, REF represents the trajectory of the economy projected by the EPPA model, if it kept under the same dynamic that determines it today, excluding policies to combat deforestation.

2. Scenario of reduction of deforestation considering the current goals - called "C_Goal" scenario: Considers the reduction target of 80% of deforestation in the Amazon and 40% reduction in deforestation in the Cerrado by 2020. However, these goals are kept until 2050, because it is believed that society (mainly from NGOs) will press the government to maintain achievements acquired by 2020 after it.

3. Scenario of zero deforestation for the Amazon by 2050 - AM_Zero: simulates a hypothetical situation that deforestation in the Amazon is completely eliminated by 2050 at cumulative exponential rates every five years, and the current goal of reducing deforestation in the Cerrado is maintained by 2050.

4. Scenario of zero deforestation for the Amazon and Cerrado by 2050, both at exponential rates - AM_CE_Exp: it is assumed that, after completion of the 2020 targets for the Cerrado and Amazon, it is assumed targets for elimination of deforestation by 2050, at cumulative exponential rates every five years.

Below the Table 3 shows the amount of areas that were allowed to deforest model per year per biome.

Table 3 - Deforestation in areas permitted by model - in thousand ha

Deforestation rate	Amazon						
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Current goal	382.92	382.92	382.92	382.92	382.92	382.92	382.92
Zero deforestation by 2050 - exp.	382.92	65.94	11.35	1.96	0.34	0.06	0.01
Deforestation rate	**Cerrado**						
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Current goal	942	942	942	942	942	942	942
Zero deforestation by 2050 - exp.	942	141.30	21.20	3.18	0.48	0.07	0.01

Deforestation allowed in 2020 is based on the reduction target of 80% of annual deforestation rates in the Amazon, from the average of 19,625 km² (1,962,500 acres) recorded between the years 1996-2005, as described in the “Plano Plurianual 2012-2015” (BRASIL, 2011), resulting in 382.9 ha per year of deforestation in 2020. In the Cerrado, it is estimated a reduction of 40% of annual rates compared to the average of 15.7 km² (1,570 acres) occurred between 1999 and 2008 (BRASIL, 2011), resulting in 942,000 hectares deforested in 2020.

2.2. Results

2.2.1. Agricultural, livestock and food production

The results show that the introduction of policies to reduce deforestation has negative effects on the value of agricultural, livestock and food production. Such effects are directly related to the difficulty of the agricultural and livestock sectors to replace the key input to their production, land. However, the impacts are not significant, as shown in the Figure 1. Percentage changes are calculated relative to production observed in the baseline scenario (REF).

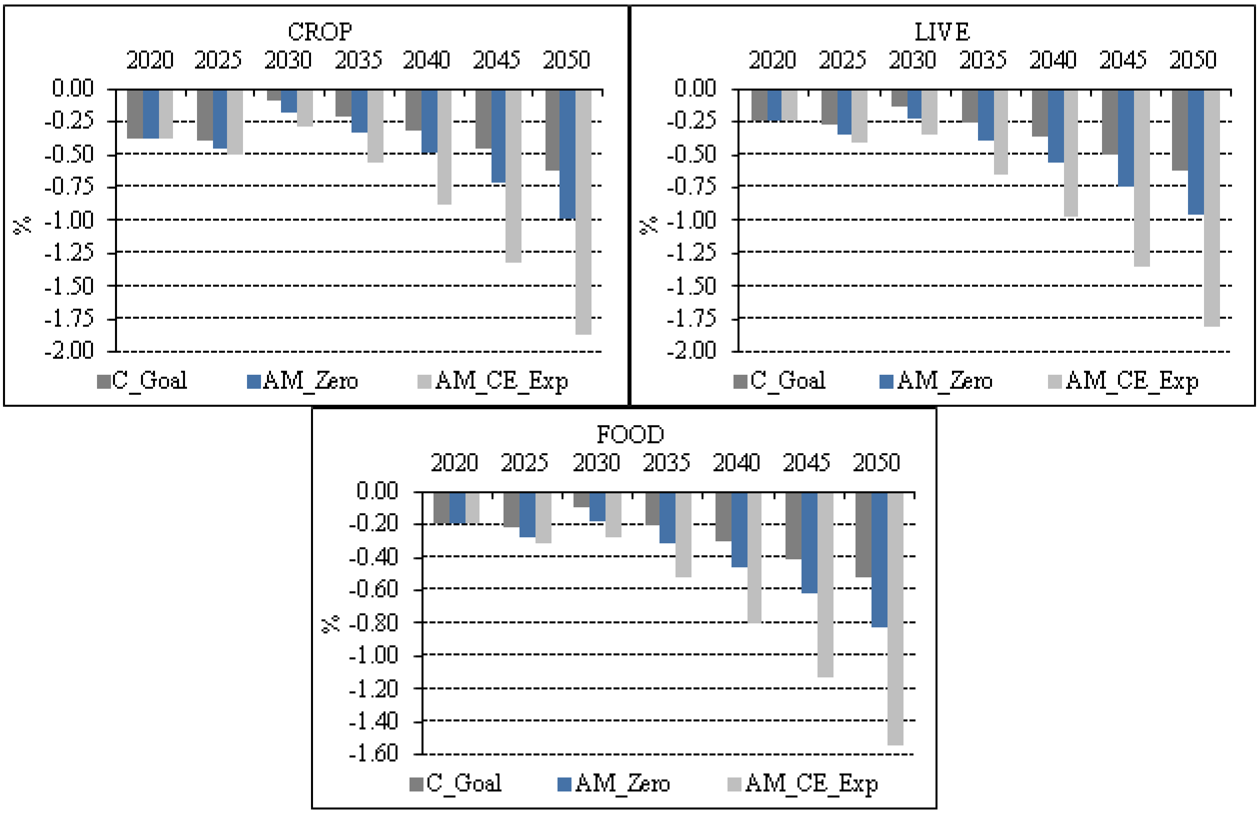

Figure 1 – Changes (%) in agricultural, livestock and food production

As can be seen, the rates of changes in agricultural product (CROP), livestock (LIVE) and food industry (FOOD) among the baseline and the scenarios of reducing deforestation are the same for the year 2020, its every sector - a feature which will be repeated in all other reported results. This is because the rate of reduction of deforestation is the same in all scenarios that year and the expectations of agents are myopic (not consider future indicators for decision making in the present).

Variations in production in these sectors are quite similar in terms of direction and magnitude. However, policies to reduce deforestation have very significant impacts on the agricultural and food product of -0.38% by 2020 for the agricultural sector, -0.23% for livestock and -0.19% for the food industry, in AM_CE_Exp scenario. The maximum loss reaches 1.87% for agriculture, 1.81% for livestock and 1.54% for the foodservice industry by 2050 in AM_CE_Exp scenario. These reductions do not mean that the product is growing at a negative rate, but that only grow at a slower rate than observed in the absence of reducing deforestation policy.

Also note that the production losses grow in time, which can be connected to the free land for agriculture and the increase in production costs associated with the need for increased efficiency in land use as capital investment, job and other inputs.

Another interesting aspect is that the losses in agriculture are higher than in livestock, even the latter being most responsible for deforestation. This may reflect the large expanse of areas misused or underused pastures in the country, which can be used more efficiently at a relatively lower cost than the intensification of crops. Since agriculture is more intensive in land cost than livestock and has lower ability to substitute land for other inputs. As for the food sector, given the interdependence between it and agriculture, for the use of agricultural products as intermediate inputs, their results can be explained by the unfavorable performance presented by agriculture.

2.2.2. Land use change

Before continuing to analyze some economic indicators, it is important to see how the land use is changed after the shocks of reductions in deforestation, as this may help to clarify the results of economic indicators. Figure 2 shows the trajectory of land use for each end of the four simulated scenarios.

First, observe the trajectory of the natural vegetation areas NFORS and NGRASS in the baseline scenario and the scenarios of reducing of deforestation. The chart "Amazon, Atlantic Forest and Pantanal" in Figure 2, which represents the case of the natural vegetation of the Amazon, Atlantic Forest and Pantanal, shows that deforestation in these areas would be increased in the absence of policies to reduce deforestation, represented by downslope REF. By the last simulated period, the cumulative avoided deforestation is almost 17.2 million hectares (4 % of the total area NFORS in 2010) when comparing to areas of the REF scenario and scenarios AM_Zero and AM_CE_Exp (which have the same deforestation rate for NFORS), and 15 million ha compared to the current goal setting. Given the characteristics of the soil in Pantanal, which are not favorable to the human use, such as agriculture, and the small area of Atlantic Forest, it is concluded that most of the removal of vegetation cover recorded in the REF scenario should occur in fact in areas of the Amazon.

For the category NGRASS consisting of Cerrado, Caatinga and Pampas, the differential deforested areas between the baseline and policy scenarios is greater than in the case of NFORS. Avoided deforestation between REF and C_Goal scenario reaches more than 36 million hectares, and more than 51 million ha (54% of the total NGRASS area in 2010) compared to AM_CE_Exp scenario. This result reflects the high rates of deforestation in the baseline scenario of the EPPA model, which predicts little change in relation to deforestation rates observed since the 1980s in the Cerrado, in the absence of specific policies for that. However, the results suggest that the introduction of policies to limit deforestation is key to preserving the biodiversity of the Cerrado biome.

As for the areas used for crops (CROP), the "Agriculture" graph of Figure 2 shows that the amount of land for agricultural purposes does not suffer significant impacts, and the trajectories of deforestation reduction scenarios just moving the trajectory of the baseline scenario from 2035. The greatest variation occurs between REF and AM_CE_Exp scenarios (as is expected, always), nearly 7 million hectares by 2050.

In the case of livestock, policies to reduce deforestation led to significant changes on the amount of land used for this activity (graph "Livestock" in Figure 2). While the trajectory of the REF scenario is increasing until the end of the period, the trajectories of policy scenarios slightly decrease from 2045. This suggests a significant intensification of the use of pastures, since the reduction in livestock production is not significant, as seen in the previous subsection. The difference between the REF scenario and AM_CE_Exp scenario is nearly 38 million hectares, and approximately 30 million ha compared to the other scenarios, which show similar results.

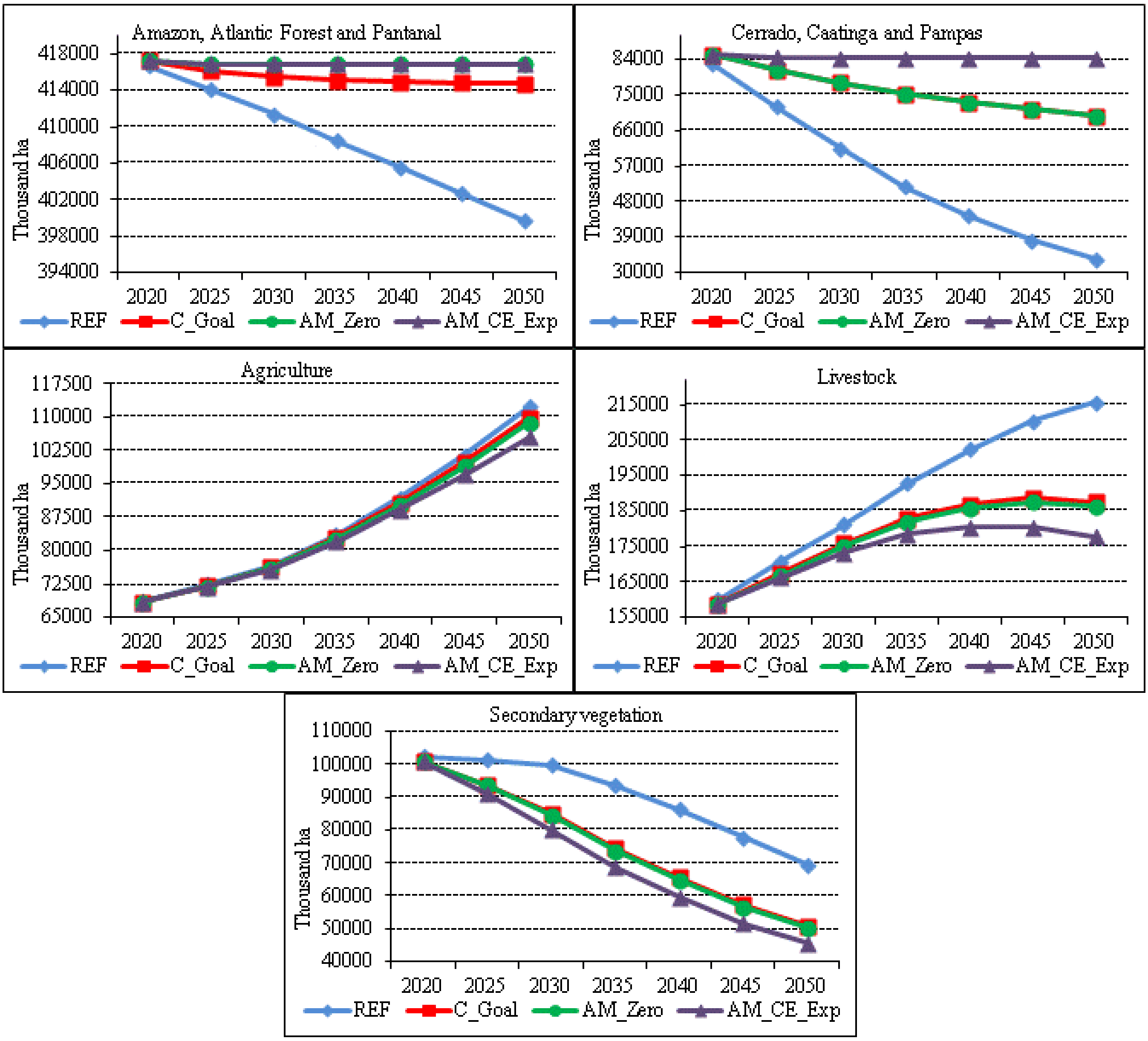

Figure 2 - Trajectory of total areas used by category

One of the most important uses of the land to be analyzed in this context is the FORS category, which includes the areas of secondary vegetation, planted and cultivated areas and abandoned pastures or in the process of degradation that has secondary vegetation recovery as this is where agricultural activities can expand without pressing areas of native vegetation. The graph "secondary vegetation" in the figure above shows that there is a downward trend in FORS areas, even in the absence of policies to control deforestation in the REF scenario. However, under the policy scenarios, the total of these areas gets to have 23.7 million hectares less than in the REF scenario in 2050. This result shows the importance of these areas to ensure the expansion of Brazilian agriculture in the face of restrictions on the incorporation of new agricultural areas, which can be done via technology adoption and best practices in areas already deforested, but currently underutilized.

2.2.3. Sectoral trade balance

The model results also allow us to evaluate the performance of the trade balance of agricultural and food sectors, and any gains or losses in competitiveness of these sectors. Table 4 presents the results of changes in exports and imports of agricultural sectors (CROP) and food (FOOD) in different scenarios for reducing deforestation in relation to the baseline scenario.

In general, changes in exports reflect the directions of changes in production, and how the production of these sectors is lower with the establishment of policy, overseas sales decrease and increase purchases from abroad. However, the introduction of targets for zero deforestation for the Amazon and the Cerrado at exponential rates, requires a reduction of only 3.9% of agricultural exports and an increase of 1.74% of its imports, both by 2050, while for the food sector, this decline in exports is almost 5% and increased of imports of 2.66%. Even though these variations are not very expressive, they show some degree of loss of competitiveness of those sectors.

Table 4 - Changes in exports and imports of food and agriculture in the policy scenarios compared to the baseline scenario – in %

Scenario	2020	2025	2030	2035	2040	2045	2050
				Exports			
				CROP			
C_Goal	-0.93	-0.96	-0.18	-0.41	-0.64	-0.92	-1.28
AM_Zero	-0.93	-1.10	-0.38	-0.70	-1.04	-1.51	-2.03
AM_CE_Exp	-0.93	-1.19	-0.63	-1.22	-1.92	-2.84	-3.90
				FOOD			
C_Goal	-1.03	-1.13	-0.33	-0.67	-0.97	-1.32	-1.66
AM_Zero	-1.03	-1.34	-0.62	-1.08	-1.53	-2.03	-2.62
AM_CE_Exp	-1.03	-1.47	-0.98	-1.81	-2.71	-3.74	-4.95
				Imports			
				CROP			
C_Goal	0.44	0.44	0.06	0.14	0.24	0.37	0.54
AM_Zero	0.44	0.49	0.14	0.26	0.41	0.64	0.88
AM_CE_Exp	0.44	0.53	0.24	0.47	0.78	1.24	1.74
				FOOD			
C_Goal	0.64	0.69	0.16	0.34	0.49	0.68	0.85
AM_Zero	0.64	0.80	0.32	0.56	0.80	1.07	1.38
AM_CE_Exp	0.64	0.88	0.51	0.96	1.44	2.00	2.66

Source: Research results.

2.2.4. GDP and welfare

Table 5 shows the variation in the results expected for GDP scenarios for reducing deforestation in relation to the baseline values. The results show that the policy of limiting deforestation has very insignificant impacts on the Brazilian GDP. Initially, the policy adopted in 2020 reduces it by around 0.03%, and thereafter, the losses increase over time. However, even at maximum 0.15% in the AM_CE_Exp scenario.

This behavior of GDP reflects the performance of the agricultural sectors and food, as well as the prices and the trade balance, which were also not significantly affected, as shown above. Moreover, the magnitudes of the results on GDP also indicate that production costs associated with the increase in the efficiency of land use and implementation of policies on deforestation are not high.

The break in the trend of the variation of losses in 2025 can be attributed to the use of areas of FORS category. In the baseline scenario, the availability of these areas declines more smoothly than in the policy scenarios between 2020 and 2030, as seen in the chart "secondary vegetation" of Figure 2. Thus, increasing expenditure on improvement of these lands are initially required, when introduced deforestation restriction policies, and consequently, greater losses of sectoral output and GDP.

Furthermore, it is important to note that these results do not take into account the associated benefits to controlling deforestation, ie the reduction in the possible damages that would be caused by the loss of biodiversity, emissions of greenhouse gases and its consequent changes in climate, limitation or interruption of the provision of other ecosystem services in the baseline scenario REF, which characterizes a cost-benefit analysis. Given the difficulty that science has to identify and measure in economic terms all these possible losses, such benefits are not considered in monetary values in the EPPA model, limiting the ability to cost-benefit analysis type. With this, the EPPA model only allows cost-effectiveness of policies, in other words, measures only the costs associated with a specific goal of reducing deforestation without receiving the benefits of this goal in terms of losses avoided.

Table 5 - Changes in GDP and welfare between the policy scenario and the REF scenario - in%

Scenario	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
				GDP			
C_Goal	-0.03	-0.05	-0.03	-0.03	-0.04	-0.05	-0.07
AM_Zero	-0.03	-0.05	-0.03	-0.04	-0.05	-0.06	-0.09
AM_CE_Exp	-0.03	-0.05	-0.04	-0.05	-0.07	-0.10	-0.15
				Welfare			
C_Goal	0.05	0.05	-0.01	-0.02	-0.03	-0.03	-0.04
AM_Zero	0.05	0.05	-0.01	-0.02	-0.03	-0.03	-0.04
AM_CE_Exp	0.05	0.05	-0.01	-0.02	-0.04	-0.05	-0.07

Source: Research results.

The change in welfare (measured as equivalent variation Hicksiana) is a good indicator of how the expected aggregate impacts affect the level of comfort and satisfaction of families in a country, taking into account all the changes in prices of goods and services and production factors, which ultimately determine household income. Table 5 also shows the results of changes in welfare in the Brazilian economy of deforestation reduction scenarios compared to the baseline scenario REF.

It is observed that the inclusion of targets for reducing deforestation brought small gains of 0.05% in terms of welfare in all policy scenarios for the periods 2020 and 2025. But from 2030 that losses are recorded ranging from -0.01% in all scenarios, and the maximum -0.07% in AM_CE_Exp scenario by 2050. These results represent some modest impacts relevant for a deeper economic analysis. Thus, it is concluded that the adoption of targets for reducing deforestation should not result in major economic and social losses to Brazil on the major areas to be preserved.

CONCLUSION

This study investigated the economic impacts of policies limiting deforestation on agricultural and food sectors, and the national economy. More specifically, it was examined how certain economic variables, such as the activity level of the agricultural sectors, levels of food prices, trade flows and aggregate output respond to some scenarios for reducing deforestation in the Amazon and Cerrado. These scenarios consider the government's targets of 80% reduction in annual deforestation rates in the Amazon by 2020 (compared to the average between 1996 and 2005), and 40% reduction in the annual rate of deforestation in the Cerrado (in relation to the average between 1999 and 2008). From 2020 were considered some possible scenarios for controlling deforestation as: maintaining the rate of deforestation 2020 respective Amazon and Cerrado; decreases at exponential rates of deforestation in the Cerrado and Amazon until reaching zero deforestation by 2050; and maintenance of the rate of deforestation of the Cerrado and 2020, while exponentially reducing deforestation in the Amazon to achieve zero deforestation by 2050.

To perform the simulations, it was used a recursive dynamic computable general equilibrium model, the Emissions Prediction and Policy Analysis (EPPA) developed by MIT. The general equilibrium methodology was chosen because it expected that policies to reduce deforestation are able to generate general equilibrium effects far-reaching in terms of geographic and economic dimensions. In the EPPA model, competition among different land uses is explicit and divided into five categories: pasture, crops, forestry and secondary forests (areas of forestry, plant extraction and planted forests), natural forests and rangelands.

In order to better reflect the statistics produced by national institutions, the initial data of land use of the EPPA model, defined by the model of terrestrial ecosystems, TEM, were compared with data from Portalbio of the Ministry of Environment and the 2006 Agricultural Census, which proved to be compatible. Moreover, it was necessary to make a survey of the main actions and measures to mitigate climate change and reduce deforestation in the Amazon and Cerrado of the Brazilian government, for defining the policy scenarios to be simulated and the model applied.

The results obtained from the simulations provided a direction of the behavior of the economy with the introduction of policies to reduce deforestation in Brazil. Such policies have negative impacts, however, not significant on domestic production of agricultural products and food in relation to production observed in the baseline scenario (REF). All economic variables suffer more impacts on the scenario in which the reduction of deforestation occurs exponentially until it reached zero deforestation by 2050 in the Amazon and the Cerrado, for being the scenario in which the shock given to the model allowed the least amount deforestation in the country. The reduction in sectoral output reaches a maximum 1.87 % in agriculture, 1.81% in livestock and 1.54 % in the food sector by 2050. The fact that losses are higher in agriculture than livestock reflects that the possibility of intensifying of the production is higher in livestock. In the case of the food industry, how agricultural products are used as intermediate inputs, the drop in production is explained by the unfavorable performance of agriculture.

As a consequence of the change in production, agricultural and food industries lose competitiveness in the international market. With the introduction of limiting deforestation policy, overseas sales decrease by up to 3.9% in the agricultural sector and almost 5% in the food sector by 2050, while imports increased 1.74% in agricultural and 2.66% in food sector by 2050.

The evaluation of the results of economic activity suggests that the sacrifice to be held across the country in terms of GDP loss is not significant. The introduction of policies to reduce deforestation somewhat alters the trajectory of economic growth, generating a decrease of at most 0.15% of GDP compared to the trajectory of the baseline scenario by 2050. Nevertheless, it is important to note that due to economic and social discrepancies among the different regions and states of Brazil, the impact on the regional GDP may be different, but this analysis is beyond the scope of the model used.

When analyzed the impacts of the introduction of policies to limit deforestation in terms of welfare, it was observed that the policies led to modest losses to Brazil, down from 0.07% by 2050 compared to the baseline scenario. Therefore, the effort to preserve the natural vegetation in the Amazon and Cerrado is beneficial because the welfare losses will not be significant. Thus, if the country continues to reduce the pace of deforestation, the model results indicate that there will not be huge economic and social losses to Brazil. Moreover, these results do not consider the benefits associated with control of deforestation, such as maintaining biodiversity and reductions in emissions of greenhouse gases, with reduction in damages that can be caused by climate change.

The model predicted the evolution of land use in the country, which contributes to the understanding of the results of economic indicators. The amount of areas used for crops is lower than that observed in the scenario baseline, however, the reduction is no more than seven million hectares by 2050. But on livestock, the introduction of policies to reduce deforestation significantly reduces the amount used in production compared to the REF scenario, approximately 38 million by 2050. This shows that livestock production is intensified when the expansion on areas of natural vegetation is restricted, and in order to free up land for agricultural production in which the possibilities of scaling are smaller. In addition, simulations suggest that the expansion of the agricultural frontier may occur under the vast area of secondary vegetation and abandoned pastures in Brazil, which could be better used via adoption of technology and modern agricultural practices.

As positive effects of policies to reduce deforestation, up to 68 million hectares of forests and savannas are preserved by 2050. Again, these results suggest little significant economic costs on the potential benefits of environmental protection due to the ability to increase productivity of converting Brazilian pastures and fields of underutilized and secondary vegetation in agricultural areas.

As a policy recommendation is suggested that actions which restrict the expansion of the Brazilian agricultural frontier are accompanied by incentives for adoption of more advanced technologies in agriculture that are able to increase crop and livestock productivity, enabling the recovery of degraded areas and pastures, and accelerate the process of technological development in public sector research institutions and the private sector. Thus , it is expected that the increase in demand for agricultural products and food can be accompanied by increased based on the intensification of agricultural production supply, avoiding growth trends in food prices and the loss of competitiveness of Brazilian industry.

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