Commodities demand growth and its impacts on deforestation and CO_2 emissions in the Brazilian Amazon region[1]

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Abstract: Brazil is one of a small group of countries which accounts for most of the global exports in agricultural commodities. Food and Agriculture Organization of the United Nations estimated that Brazilian soybean exports would increase by 18%, beef exports would grow by 49% and biodiesel would increase by 37% from 2018 to 2027. Historically, those activities are considered important drivers of deforestation in the Brazilian Amazon. Considering the increasing in recent deforestation rates, it is important to study the consequences of these scenario over land use change and CO_2 emissions. To achieve this goal, we use an interregional dynamic computable general equilibrium model (CGE) for 30 regions in the Amazon and the rest of Brazil with a land use module. The results suggest that between 2018 and 2030 total deforestation could increase by 136,403 km^2 in the baseline scenario and more 10,887 km^2 because of the growing commodities. However, in a scenario with Soy Moratorium deforestation would be smaller, around 10,340 km^2 relative to the baseline. That means a reduction of 29 $MtCO_2$, with marginal economic impacts. In a scenario of zero deforestation, regional economic impacts would be greater. However, there would be a reduction of almost 7,000 $MtCO_2$.

Key words: general equilibrium model, Amazon, exports, deforestation, CO_2 emissions

JEL Classification: C68, Q15, R14

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1. Introduction

The positive trade balance of the Americas is expected to expand further over 2018 to 2027 (FAO, 2018). Brazil has a central role since it is one of the most important countries in agricultural production and one of the five main exporters of sugar, soybean and beef. It was estimated, for example, that Brazilian soybean exports would increase by 18%, beef exports would grow by 49% and biodiesel would increase by 37% from 2018 to 2027 (FAO, 2018). One of the effects of growing commodity production to meet this increased demand may be to expand the Brazilian agricultural frontier, mainly in Brazilian Legal Amazon region. As it has been recognized that tropical forests are important to global climate regulation, it is relevant to study the impact of this scenario on deforestation, CO_2 emissions and economic variables of the region.

Historically, a huge part of deforestation has occurred to increase the Brazilian agriculture frontier, mainly due to the large-scale agriculture and the slash and burn agriculture. The extensive livestock with low productivity has been pointed out by the literature as one of the main drivers of deforestation in Amazon region (MARGULIS, 2003; MERTENS et al., 2002). The increase in deforestation for the establishment of low productivity pastures is also motivated by land tenure and speculation. According to the Brazilian Institute of Geography and Statistics (IBGE), from 1990 to 2006 the herd of the region increased from 21.1 million head (18% of the national total) to 73.9 million (43% of the national total) (IBGE, 2006). About 75% of the new cattle added to the national herd comes from the Amazon. However, this expansion presents very low productivity, less than one head per hectare (MMA, 2012; ALENCAR et al., 2004), which suggests its use also for speculative purposes.

The soybean growth has been also considered an important driver. According to Brandão et al. (2006), the agriculture growth in the 2000 decade was characterized by a strong expansion of the total planted area. In the soybean case, the influence on deforestation in Amazon is mainly indirect. The crop expansion has occurred basically in pastures already formed, where the cost of implantation of the activity is smaller. However, the soybean, by occupying these existing pastures, ends up pushing the expansion of livestock to other areas of forests (ALENCAR et al., 2004). According to Domingues and Bermann (2012), the soybean expansion is causing deforestation through the dynamics of forest clearing, the implantation of livestock and the later transformation of the area into mechanized agriculture. At the same time, this process would lead to the expansion of the agriculture frontier, meeting the increasing consumption.

Encompassing one of the world's largest tropical rainforests, the Amazon region has already lost about 15% of its total forest area. According to INPE (2013), there was a decline in deforestation rates from 2004 to 2012. This decline is related to economic factors, such as the reduction in international soybean and beef prices and the appreciation of the Brazilian currency, which discouraged exports. Another crucial factor was the increased surveillance of the Amazon, which has been made possible by the implementation of government programs, such as the Action Plan for the Prevention and Control of Deforestation in the Amazon (Soares-Filho et al., 2009; Assunção et al., 2012).

However, in recent years deforestation has increased. Between 2014 and 2015, the relative variation in deforestation was 24%, 27% between 2015 and 2016, -11% between 2016 and 2017 and 8% between 2018 and 2019, reaching 7,536 km^2 of deforested land in 2018 (PRODES, 2019). This increase may be related to the economic recession from 2014 to 2016, which imposed fewer resources to control the deforestation in Amazon region. In addition, the recent intensification of deforestation strengthens with the federal government, taking office in 2019, with a discourse against the preservation policy and questioning the deforestation data presented by the official organ INPE (2019). This scenario facilitates the activity of loggers in Amazon, in addition to generating greater pressure on natural resources, with the objective of increasing commodities exports and higher income earning (Pereira et al., 2019).

Another region that has showed to be an important agricultural frontier in Brazil is Matopiba[2], which is at the forefront of Cerrado agricultural expansion, with the soybean area increasing by 253% between 2000 and 2014 and approximately 30% of this expansion occurred at the expense of native vegetation (Carneiro Filho and Costa, 2016). According to Carneiro Filho and Costa (2016), in the last 10 years, the dynamic of agricultural expansion in the Cerrado biome was essentially due transformation occurred by human action. At least 33.4 million hectares of anthropized areas in Cerrado would be suitable for direct conversion into grain production. Brazil and the United States are expected to have similar levels of soybean production throughout the next decade, with production reaching around 130 Mt in 2027 (FAO, 2018). And this expansion can occur mainly in the Cerrado biome.

That happens because despite of a similar proportion of soy expansion occurred through deforestation between 2004 and 2005 in the Amazon, it was implemented the Soy Moratorium in the region in 2006 (Nepstad et al., 2014). The Amazon Soy Moratorium is a zero-deforestation agreement between civil society, industry, and government that prohibits the buying of soybean grown on recently deforested land in the Brazilian Amazon. According to Soterroni et al. (2019), recently, more than 70 companies and social and environmental organizations signed a manifesto calling for a halt to native vegetation conversion in the Cerrado. However, there is no Soy Moratorium in the Cerrado yet.

Land use change and deforestation currently contribute to over 40% of Brazil's greenhouse gas emissions (SEEG, 2019). According to emissions calculation methodology of INPE-EM (2019), in 2018 the 7,535 km^2 deforestation of the Amazon generated a total gross emission of 409 $MtCO_2$, while the deforestation of 6,657 km^2 in the Cerrado would have accounted for 129 $MtCO_2$. Could uncertainties about future policies aimed at combating deforestation in the Amazon increase the deforestation rates of the region, and consequently GHG emissions? Still, could the potential trade barriers that would arise from further deforestation strengthen agreements such as the Soy Moratorium? And would that be enough to stem deforestation in the region? Moreover, the increase of the agricultural frontier, notably to increase soybean production, could move to the Cerrado biome? And the rapid expansion of cropland in the Cerrado has the potential to undermine climate mitigation efforts if emissions from dry forest and woodland conversion nullify some of the benefits of avoided Amazon deforestation (Noojipady et al. 2017).

In this context, this article seeks to evaluate the economic, land use and CO_2 emissions impacts of FAO (2018) projections in the Brazilian Amazon, also considering two states of the MATOPIBA region (Maranhão and Tocantins). Specifically, the main goal is to forecast three different scenarios: i) commodities demand growth project by FAO (2018); ii) commodities demand growth plus the soy moratorium in the Amazon biome and Cerrado; iii) commodities demand growth in a scenario of zero deforestation. For this, we used the dynamic interregional computable general equilibrium model, REGIA+, calibrated to 30 mesoregions of the Brazilian Amazon (including all the mesoregions of Tocantins and Maranhão) and the rest of Brazil.

[2] MATOPIBA is a region that includes parts of Maranhão, Tocantins, Piauí, and Bahia states.

2. Methodology

2.1. REGIA+ model

REGIA+ is an extension of REGIA which is a Regional Computable General Equilibrium model (CGE) with a recursive dynamic and land-use module for 30 regions of the Brazilian Legal Amazon and the rest of Brazil. It is a bottom-up model, that is, a multiregional model where the national results are aggregations of the regional results. Moreover, it is the first CGE model built for the Amazon economy with this very detailed regional disaggregation. REGIA+ was calibrated for 2010 and it consists of 75 sectors in each one of the 30 regions, including 14 agricultural commodities[3]. Besides, we added a CO_2 emissions module by land use change and deforestation and a dynamic labor market.

REGIA+ has at least three advantages: i) the first one is the treatment of land use in a recursive dynamic model, so it is possible to analyze the impacts of different scenarios over time as well as the endogenous adjustment of land supply; ii) The second is the largest regional disaggregation - 30 regions of the Amazon and the rest of Brazil. Therefore, it is possible to analyze the impacts in a regional level; and iii) the third is to account the CO_2 emissions from land use change and deforestation.

REGIA+ follows the theoretical structure of Australian TERM model (Horridge et al., 2005) and its complete description can be seen in Carvalho (2014) and Carvalho et al., (2017). It is a standard CGE model composed of blocks of equations determining relationships between supply and demand, according to optimization assumptions and market-clearing conditions. Also, several national aggregates are defined in these blocks as the aggregate employment, GDP, household consumption, balance of trade and price indexes. The productive sectors minimize production costs subject to a technology of constant returns to scale in which the combinations of intermediate inputs and primary factors (aggregated) are determined by fixed coefficients (Leontief). There is substitution via the prices of domestic and imported goods in the composition of inputs according to a constant elasticity of substitution (CES) function. A CES specification also controls the allocation of a domestic compound among the various regions. In REGIA+, substitution also takes place between capital, labor and land in the composition of the primary factors through CES functions.

In the model, there is a representative household for each region consuming domestic and imported goods. The choice between domestic and imported goods (from other countries) is held by a CES (Armington assumption[4]) specification. The treatment of household demand is based on a combined system of preferences, CES/Klein-Rubin. The specification gives the linear expenditure system (LES)[5], in which the share of expenditure above the subsistence level for each good represents a constant proportion of the total subsistence expenditure of each family. The REGIA+ model also has a recursive dynamic specification. Investment and capital stock follow mechanisms of accumulation and intersectoral shift from pre-established rules related to the depreciation and rates of return. Thus, one of dynamic characteristics of REGIA+ is the connection between annual investment flows and capital stocks.

Government consumption is exogenous. The model operates with market equilibrium for all goods, both domestic and imported, as well as the market factors (capital, land and labor) in each region. The purchase prices for each user in each region (producers, investors,

[3] REGIA was calibrated for 2005 with 27 sectors and 30 regions and the rest of Brazil (Carvalho et al., 2017).
[4] Armington hypothesis - goods of different origins are treated as imperfect substitutes.
[5] The LES function is suitable for broad aggregates of goods where specific substitutions are not considered. That is, cross-price elasticities are equal to the income effect given in the Slutsky equation without any contribution from the cross-price effects. This implies that all goods have a weak complementarity. The linear expenditure system does not allow the inclusion of inferior goods (that is, negative income elasticities).

households, exporters, and government) are the sum of the basic values, sales taxes (direct and indirect) and margins (trade and transport). Sales taxes are treated as *ad valorem* taxes on basic flows. Demands for margins (trade and transport) are proportional to the flow of goods to which the margins are connected.

Following Carvalho *et al.* (2017), one of the main advantages of REGIA+ is the incorporation of a land-use module. Land is one of the primary factors in the model, in addition to capital and labor, and it is an essential factor in the production of agricultural sectors and mainly for the Brazilian Amazon. Land use is modeled separately for each region, keeping the total area fixed and divided into four types: i) cropland, ii) pasture, iii) planted forest and iv) natural forest and other areas. In the model, the agricultural sectors/goods, as well as land use, are specific to each region, and it is assumed that each agricultural sector is connected to one of these types of land uses. The area of natural forest and other uses is defined as the total area of each region minus the cropland, pasture and planted forest. The land process is guide by two levels of substitution. At the first level, cropland and pasture may be allocated between different agricultural sectors according to the land remuneration differential. At the second level, supply of land will allow the factor to move between different categories of land between year t and year $t + 1$. The conversion process is controlled by a transition matrix representing the conversion possibilities of land between two years.

Two modules were added for REGIA+, the labor market adjustment and emissions from land use and deforestation. The labor market presents an element of intertemporal adjustment of real wages at the regional level, involving two other variables: current employment and trend employment. It is assumed that when the employment level at $t + 1$ exceeds trend growth by $E\%$, real wage increases by $\gamma E\%$. Therefore, since there is a negative relationship between employment and real wages in the labor market, the level of employment in later periods adjusts until it converges with the trend level. By its turn, deforestation related emissions are calculated using forecasted deforestation and a emissions per deforested hectares coefficient.

2.2. The Database

The database for the REGIA+ model was constructed through a process of regionalization of a national CGE model database[6]. The procedure was based on the methodology developed by Horridge (2006). Basically, from the input-output data for 2010 and a large set of regional data[7], we estimated an interregional trade matrix using a distance matrix and a gravitational approach. The main hypothesis of the gravitational approach[8] is that interregional trade is based on the distance between the regions and the interaction derived from the size of its economies.

[6] The main database to build the regional data for REGIA+ was the ORANIGBR model, a national CGE model for Brazil consisting of 124 products and 65 sectors which was built by researchers of NEDUR /UFPR.
[7] The regional data was built using: regional output shares (by sector and by region) – IBGE (Brazilian Institute of Geography and Statistics and RAIS, regional investment shares (by sector and by region) – RAIS (Annual List of Social Information), regional household consumption shares (by goods and by region) – POF (Household Budget Survey) and IBGE, regional exports shares (by goods and by region) – SECEX, regional government expenditure shares (by goods and by region) – IBGE, regional inventories shares (by goods and by region) – RAIS, regional imports shares (by goods and by region) – SECEX, regional population – IBGE.
[8] A widespread theoretical justification for the idea that bilateral trade flows are positively associated with regional incomes and negatively with the distance between them is based on a trade model developed by Krugman (1980). Further details about the method and applications can be found in Miller and Blair (2009).

Details of the procedure for building a database for REGIA are in Carvalho (2014). The result of this procedure is a consistency of the database with the official data of National Accounts, Input-Output Matrix, IBGE (*Brazilian Institute of Geography and Statistics*) information, International Trade (SECEX - *International Trade Secretary*), Industrial Production (IAP) and Employment (RAIS - *Annual List of Social Information*). In addition, we used TerraClass land use data produced by INPE and INPE-EM deforestation emissions data to forecast deforestation related emissions.

2.3. Model Closure

Model closure is the determination of sets of endogenous and exogenous variables in simulations. This closure represents hypotheses about the economy and its adjustments to shocks (policies). REGIA+ is a recursive dynamic model and allows for the accumulation of capital over time as well as adjustments to the land market and labor market. The three closures used for the simulations are: i) historical closure, ii) baseline closure and iii) policy closure.

At first, there is a historical closure, from 2011 to 2017 to update the database using observed macroeconomic variables according to IBGE data. In this case, the main national aggregates are considered exogenous, such as real GDP, investment, household consumption, government expenditure, exports and aggregate employment. Thus, other variables, such as the national shifter of normal gross rate of return, the economy-wide government demand shift, the export quantity shift, national propensity to consume, as well as technological change variable are endogenous. In this case, the model calculates how these variables accommodate the national aggregates. Another assumption is that regional areas for “natural forests and other uses” are exogenous and updated using the deforestation rates from 2011 to 2017 according to INPE data.

At baseline from 2018 to 2030, all macroeconomic variables are endogenous following the growth trajectory of the historical scenario. It is assumed that regional consumption follows the regional income and the government expenditure follows the household income. Labor moves between regions and activities, driven by real wages changes. The model works with relative prices, and the nominal exchange rate was chosen as a numeraire. "Natural forests and other uses” variable is still endogenous representing a scenario of deforestation growth following the historical scenario as well.

In the policy scenario, each macroeconomic variable is endogenous, national consumption follows the GDP with endogenous national propensity to consume. And the national total is distributed between regions in proportion to labor income. The government expenditure follows the income of households regionally and nationally.

2.4. Simulations

The baseline shows a growth of the national economy for the period from 2018 to 2030 representing the projection that is compared to the policy scenario. The main goal of the policy scenario is to evaluate the impacts in Amazon region of the world demand growth for agriculture commodities from 2018 to 2030, mainly on deforestation and land use through the projections by FAO (2018)[9]. It has been pointed out that the growth of global demand for commodities, mainly soybean and beef, threatens the forest maintenance. This could cause an

[9] Brazil is modelled as a small open economy and the shock in the simulation was given in the variable “Export quantity shift”.

important environmental impact in Amazon increasing the deforestation rates over the next years through indirect land use change where the mechanized agriculture invades existing pastures and move them to new areas of forest. Table 1 presents the annual FAO projections of exports demand growth of six agricultural commodities considered in this study.

Table 1 – FAO projections on exports growth from 2018 to 2027 (in annual % change)

Goods	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Rice and Wheat	2,98%	1,66%	0,84%	1,73%	2,62%	2,83%	2,42%	1,74%	1,63%	1,75%
Maize	2,58%	0,82%	0,55%	1,48%	2,65%	1,54%	0,52%	1,41%	3,03%	4,17%
Soybean	5,22%	2,24%	1,04%	1,06%	1,11%	1,04%	1,34%	1,43%	1,45%	1,18%
Beef	8,77%	6,07%	4,80%	3,59%	2,74%	2,72%	3,71%	3,04%	3,00%	2,39%
Biodiesel and ethanol	16,02%	3,30%	3,26%	3,72%	5,13%	5,01%	4,39%	-1,93%	-2,30%	-3,59%

Source: Elaborated by the authors based on FAO (2018) projections

FAO (2018) estimates that soybean exports demand will increase by 18% from 2016 to 2025 and the beef exports will grow 40%. We need to highlight this projection as the international market for these products is considered an important determinant of deforestation in the region. In general, if the growth of cattle and soybean production is based on land expansion this will lead to more conversion of natural forest areas into other productive uses, such as cropland and pasture.

In this way, we have simulated the impact of FAO projections on three different scenarios. In scenario I, we have considered the impact of foreign demand growth for commodities without deforestation control. This scenario is justified since in recent years the policies to control deforestation have been losing financial resources and importance in the political agenda. In scenario II, we have considered scenario I plus the continuation of soybean moratorium in the Amazon biome and its implementation in the Cerrado. The reason is that producers, concerned about their insertion in international markets, tend to continue to comply with agreements showing that soybean is not growing on deforested land. Scenario III is the same as scenario I plus zero deforestation. This scenario is just an attempt to illustrate the economic impacts of stopping deforestation in the region and its contribution to decrease CO_2 emissions.

From the REGIA+ model perspective, the first-round impact of the growth of international demand is to benefit the production of the agricultural sectors (Table 1) and other sectors of the economy through input-output relations. To increase their production, sectors will use more primary factors (labor, capital and land). Then employment, investment and land use increase at the same times as their prices in regional supply is held fixed. Additionally, household consumption is positively impacted by the increase in income. Obviously, the economic outcomes of Scenario I are expected to be better than those of Scenarios II and III due to constraints on land use expansion. However, deforestation and consequently CO_2 emissions from deforestation are expected to decrease in scenarios II and III

Another important expected result is on land use change. As land demand increases, the conversion of natural forests into productive uses also goes up and this will be greater in Scenario I. The simulation results can project the increase in deforestation, and therefore we can answer whether this increase in international demand for commodities could disrupt conservation goals in the region. In addition, we can understand the dynamics of this change in land use: will the increase in the agriculture area occur in existing pastures by driving the pasture areas to new areas of forest?

3. Results and discussion

This section will describe the most important regional economic, land use and emissions results. Before discussing these results, it is important to remember that the baseline scenario presents a growth trajectory of the Brazilian economy of about 2.5% per year without any policy to control deforestation in the Amazon.

Due to recent increases in deforestation rates and the weakening of the institutions which are responsible for its control, a scenario with no restriction on deforestation has been chosen for the expansion of the agricultural frontier in the region. Figure 1 shows the total deforestation observed from 2011 to 2017, followed by REGIA+ projections from 2018 to 2030.

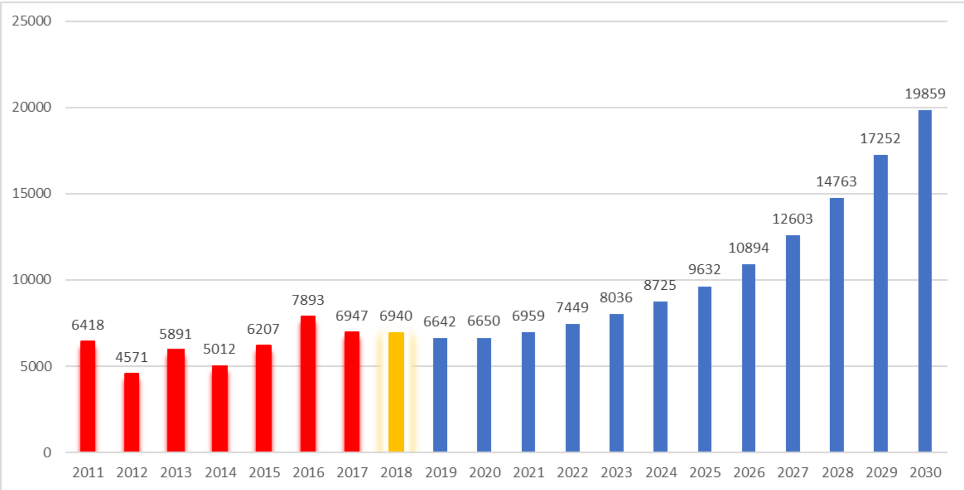

Figure 1 – Total deforestation in Amazon region in km^2
Source: Elaborated by the authors based on INPE (2019) and REGIA results

Although the deforestation in 2018 was projected by the REGIA+, this result can be compared with recent data released by INPE (2019). REGIA projected a deforestation of 6,940 km^2 while INPE have showed that deforestation was 7,535 km^2 (595 km^2 more) in 2018. Note that deforestation in the baseline scenario is gradually increasing and by 2030 reaches 19,859 km^2, which would represent more than 1,000 MtCO^2 emissions only in this year. The total deforested area between 2018 and 2030 would be 136,403 km^2, an area that is almost the size of the state of Ceará, and that would result in a total of approximately 7,500 MtCO_2 emissions.

3.1. Regional macroeconomic results

The growth of international demand for commodities may positively impact key macroeconomic indicators in the Amazon region. Table 2 presents the results for GDP and Investment for the 30 mesoregions of the Amazon, rest of Brazil and Brazil. Scenarios I and II show only marginally different results, which means that the Soy Moratorium adopted in scenario II does not significantly change the economic gains resulting from higher demand for commodities. The reason is that conversion of natural forest usually happens first to pasture. For this reason, the Soy Moratorium does not significantly change economic results due to the indirect land-to-crop conversion.

Table 2 - Simulated Impacts on GDP and Investment from 2018 to 2030 in Scenarios I, II and III - accumulated deviation relative to Baseline (in % change)

		GDP			Investment		
Regions	**State**	**I**	**II**	**III**	**I**	**II**	**III**
Madeira-Guapore	RO	0,801	0,801	0,332	2,025	2,024	1,479
Leste de Rondonia	RO	0,935	0,934	0,191	2,224	2,222	1,180
Vale do Jurua	AC	1,115	1,116	-0,622	2,493	2,493	0,696
Vale do Acre	AC	0,819	0,819	0,270	2,070	2,070	1,362
Norte	AM	0,779	0,779	0,232	1,639	1,638	0,920
Sudoeste	AM	1,396	1,397	-0,305	2,238	2,238	0,413
Centro	AM	0,369	0,369	0,232	1,319	1,319	1,111
Sul	AM	1,550	1,551	-3,762	2,651	2,652	-3,553
Norte	RR	0,716	0,716	0,266	1,971	1,970	1,201
Sul	RR	1,171	1,171	-1,081	1,803	1,803	0,589
Baixo Amazonas	PA	0,547	0,544	-1,585	0,855	0,854	-1,281
Marajo	PA	1,754	1,767	-0,188	2,805	2,823	0,065
Metropolitana de Belem	PA	0,402	0,402	0,240	1,340	1,338	0,976
Nordeste	PA	1,043	1,042	0,630	1,764	1,763	1,433
Sudoeste	PA	1,403	1,404	-1,549	2,037	2,039	-0,459
Sudeste	PA	-0,977	-0,977	-1,258	-2,226	-2,225	-2,325
Norte	AP	1,428	1,429	-1,188	1,587	1,588	-1,090
Sul	AP	0,630	0,629	0,061	1,702	1,701	0,577
Ocidental	TO	1,080	1,079	0,879	1,905	1,903	1,608
Oriental	TO	1,289	1,280	0,788	2,639	2,628	2,005
Norte	MA	0,495	0,495	0,338	1,465	1,464	1,149
Oeste	MA	0,772	0,772	0,080	1,518	1,517	0,672
Centro	MA	1,419	1,416	-0,179	1,833	1,831	0,122
Leste	MA	1,348	1,322	0,127	2,448	2,417	0,956
Sul	MA	2,000	1,924	0,989	3,305	3,232	2,383
Norte	MT	3,514	3,494	2,037	7,682	7,660	5,822
Nordeste	MT	3,760	3,736	1,017	8,118	8,088	4,689
Sudoeste	MT	1,004	1,002	0,436	2,393	2,389	1,555
Centro-Sul	MT	0,646	0,644	0,327	1,922	1,918	1,399
Sudeste	MT	2,263	2,228	1,674	4,920	4,878	4,328
Rest of Brazil	-	0,336	0,336	0,327	1,131	1,131	1,095
Brazil	-	0,367	0,367	0,316	1,134	1,134	1,057

Source: Elaborated by the authors based on CGE results

Table 2 shows that the regions with the highest GDP gains would be: Sul (MA), Norte (MT), Nordeste (MT), and Sudeste (MT). These regions would increase GDP by 2.00%, 3.51%, 3.76% and 2.26% respectively in Scenarios I and II. These regions benefit mainly from the growth of international demand for soybean, as they are the main producers in the Amazon, accounting for over 80% of all soybean produced in the region, especially the Norte (MT) which alone produces half of the region's soybean. The demand growth for commodities also stimulates investment, notably in the large soybean producing regions. It is worthy to notice that the Sudeste (PA), an important region in livestock production, shows a decline of almost 1% of GDP relative to the baseline. This result is due to the simulated scenario, as the higher demand for commodities causes a rise in domestic prices, discouraging exports in other sectors. And the Sudeste (PA) is responsible for almost 100% of the extractive industry in the region, which is a sector that loses international competitiveness due to increases in domestic prices.

Table 3 - Simulated Impacts on Employment and Real Wage from 2018 to 2030 in Scenarios I, II and III - accumulated deviation relative to Baseline (in % change)

		Employment			Real Wage		
Regions	**State**	**I**	**II**	**III**	**I**	**II**	**III**
Madeira-Guapore	RO	0,621	0,621	0,219	1,704	1,704	1,281
Leste de Rondonia	RO	0,688	0,687	0,315	1,766	1,765	1,370
Vale do Jurua	AC	0,762	0,763	-0,175	1,835	1,835	0,919
Vale do Acre	AC	0,657	0,657	0,225	1,738	1,738	1,288
Norte	AM	0,473	0,473	0,088	1,571	1,571	1,163
Sudoeste	AM	0,901	0,902	-0,189	1,965	1,966	0,908
Centro	AM	0,164	0,164	0,027	1,282	1,281	1,103
Sul	AM	1,084	1,086	-2,151	2,132	2,133	-0,906
Norte	RR	0,586	0,586	0,206	1,673	1,673	1,270
Sul	RR	0,962	0,963	-0,460	2,019	2,019	0,655
Baixo Amazonas	PA	0,568	0,566	-0,744	1,655	1,653	0,393
Marajo	PA	1,141	1,150	0,025	2,185	2,192	1,103
Metropolitana de Belem	PA	0,247	0,247	0,080	1,360	1,359	1,153
Nordeste	PA	0,721	0,720	0,534	1,797	1,797	1,573
Sudoeste	PA	1,198	1,199	-0,664	2,236	2,237	0,466
Sudeste	PA	0,600	0,600	0,264	1,683	1,683	1,321
Norte	AP	1,096	1,097	-0,274	2,143	2,143	0,828
Sul	AP	0,491	0,491	0,066	1,587	1,586	1,142
Ocidental	TO	0,978	0,977	0,987	2,034	2,033	1,989
Oriental	TO	1,163	1,156	0,783	2,206	2,199	1,803
Norte	MA	0,331	0,330	0,174	1,437	1,436	1,240
Oeste	MA	0,637	0,637	0,273	1,719	1,718	1,331
Centro	MA	1,139	1,137	0,238	2,183	2,181	1,300
Leste	MA	0,959	0,942	0,229	2,017	2,001	1,292
Sul	MA	2,025	1,973	1,411	3,001	2,953	2,383
Norte	MT	2,915	2,906	2,166	3,821	3,812	3,078
Nordeste	MT	3,022	3,011	1,616	3,919	3,909	2,572
Sudoeste	MT	0,767	0,766	0,536	1,839	1,838	1,574
Centro-Sul	MT	0,450	0,448	0,210	1,546	1,544	1,274
Sudeste	MT	1,995	1,974	1,719	2,973	2,953	2,666
Rest of Brazil	-	0,156	0,156	0,171	1,275	1,275	1,237
Brazil	-	0,209	0,209	0,193	1,324	1,323	1,257

Source: Elaborated by the authors based on CGE results

Scenario III results are more heterogeneous. The gains are smaller, and more regions show negative economic results. This is due to the impossibility of increasing agricultural production through deforestation. In this case, regions such as the Sul (AM), Baixo Amazonas (PA) and Sudoeste (PA) stand out with a decrease of 3.76%, 1.56% and 1.55%, respectively. The three regions are not large agricultural producers, however the Sul (AM) and the Sudoeste (PA) have a high share of cattle production in their GDP and livestock is certainly the activity most negatively impacted by a zero deforestation policy. Although many regions of the Amazon have negative results, it should be noted that the fall in GDP and investment in Brazil with this scenario is small, as production is reallocated to other regions.

Table 3 presents indicators for employment and real wages in the three simulated scenarios. Once again, scenarios I and II have very similar results, with a slightly larger reduction in the positive impacts in the Soy Moratorium regions. Employment is stimulated in all regions in scenarios I and II, especially those with the highest GDP growth. But even the Sudoeste (PA) that would reduce GDP in these scenarios showed increased employment stimulated by growth in the agricultural sector. This result shows the importance of the agricultural sector for job creation in the Amazon.

3.2. Sectoral results

In terms of land use changes, the most important results are shaped according to soybean and cattle production, which are both concentrated in specific areas. Figure 2 shows the change in Soybean Production in Scenarios I[10] and III. The changes in soybean production in both scenarios would be more intense in the South of Amazon, especially in Mato Grosso and Tocantins states, where soybean production is already a very import economic activity.

On the other hand, cattle production would be concentrated in the north of Amazon, mostly in the state of Pará. The general impact is smaller compared to soybean, nevertheless it would be an important driver for land use changes discussed in the next section. The region of Marajo stands out with a growth 1.89% above baseline, while for the rest of the state (expect metropolitan region) the growth ranges between 0.79 and 0.69%. But the economic effects on soybean production are smaller in Scenario III. It is noted that some regions of Pará with positive growth in Scenario I, would decrease its production in Scenario III. However, the impact on total soybean production in Brazil in the "zero deforestation scenario" would be 10.35% growth, only 0.8% lower than in Scenario I.

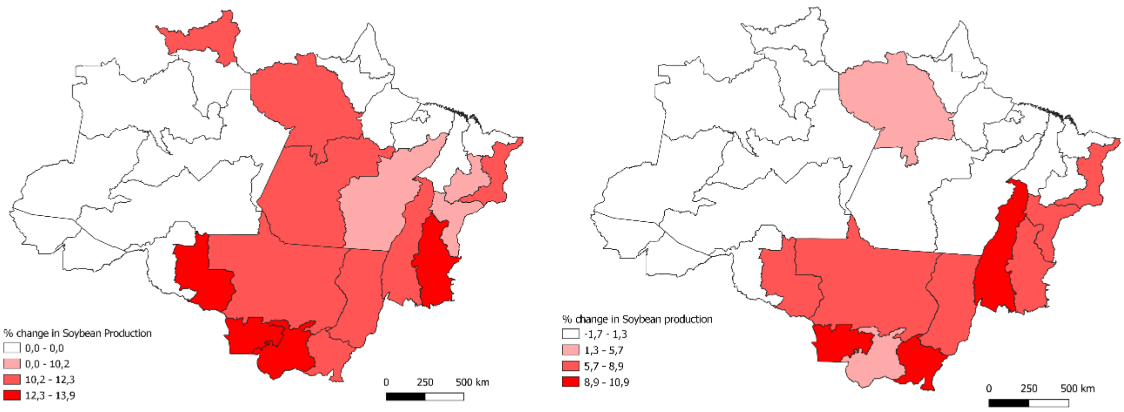

Figure 2 - % Change in Soybean Production in Scenarios I and III (accumulated deviation from 2018 to 2030 relative to baseline)
Source: Elaborated by the authors based on CGE results

On the other hand, cattle production would be concentrated more in the north of Amazon, mostly in the state of Pará. In scenario III, the most negative effects on cattle activity would be concentrated mainly in regions around the arc of deforestation, except for the Sudeste (PA). This result is justified since deforestation usually occurs for conversion of forest to pasture and these regions have higher rates of deforestation. But similarly, at the national level, the cattle sector would grow 2.87% in scenario III, only 0.41% less than in scenario I.

[10] As the economic impacts in Scenarios I and II are almost the same, we are going to show only Scenario I sectoral results.

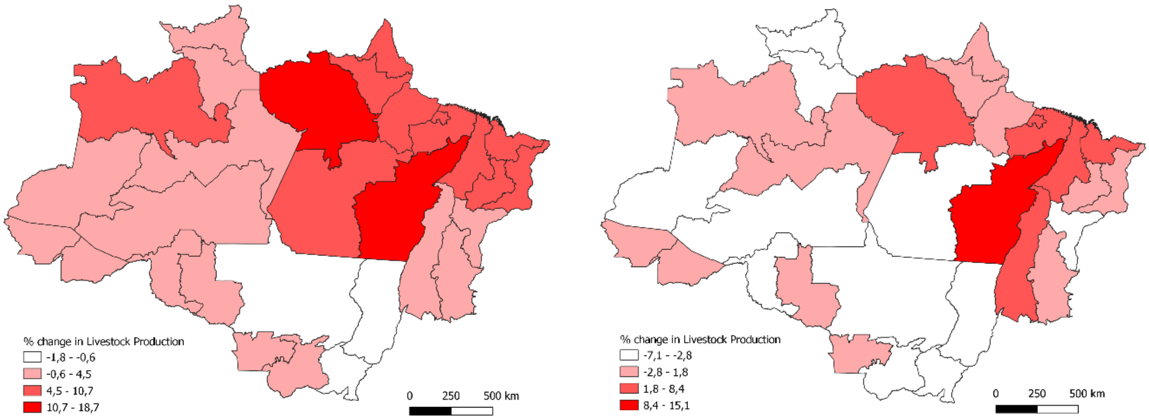

Figure 3 - % Change in Cattle Production in Scenarios I and III (accumulated deviation from 2018 to 2030 relative to baseline)
Source: Elaborated by the authors based on CGE results

3.3. Land Use Results

Given the Scenarios I and II, aggregate deforestation would increase over time which means an additional deforestation relative to baseline scenario. But deforestation is slightly lower in Scenario II, as the Soy Moratorium in the states of Pará, Rondônia, Mato Grosso, Tocantins and Maranhão avoids the conversion of forest areas to soybean activity. Table 4 presents these results and shows that deforestation would be almost 547 km^2 lower in this scenario, implying a reduction of about 29 $MtCo_2$.

Table 4 – Land Use Change in Scenarios I and II in km^2 (accumulated deviation from 2018 to 2030 relative to baseline)

Land use	Scenario I	Scenario II	Variation
Crop	4977,00	4514,40	462,60
Pasture	9060,30	8976,30	84,00
Natural Forest	-10886,70	-10340,40	-546,30

Source: Elaborated by the authors based on CGE results

Regionally, the differences in deforestation rates between scenarios I and II are small. Figure 4 shows deforestation by mesoregion in both scenarios and there is slight change in the pattern, highlighting only the Northern region (MT) that appears in a lower category of total deforestation.

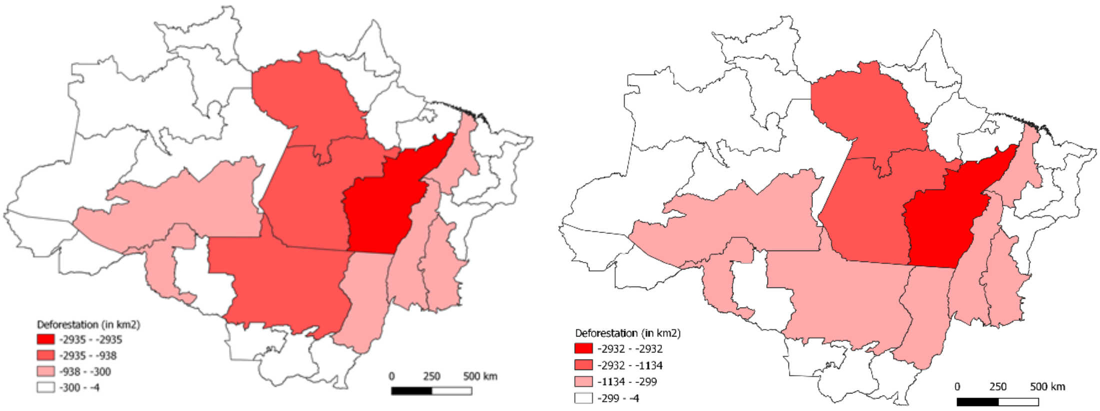

Figure 4 – Deforestation in km² in Scenario I and II (accumulated deviation from 2018 to 2030 relative to baseline)

Source: Elaborated by the authors based on CGE results

In scenario III, there is a growth of forest area in relation to the base scenario because of the imposition of zero deforestation rates. Figure 5 shows that 129,435 km² of deforested area would be avoided which would result in avoided emissions of almost 7,000 $MtCO_2$. Thus, it is observed a decrease mainly in the pasture areas.

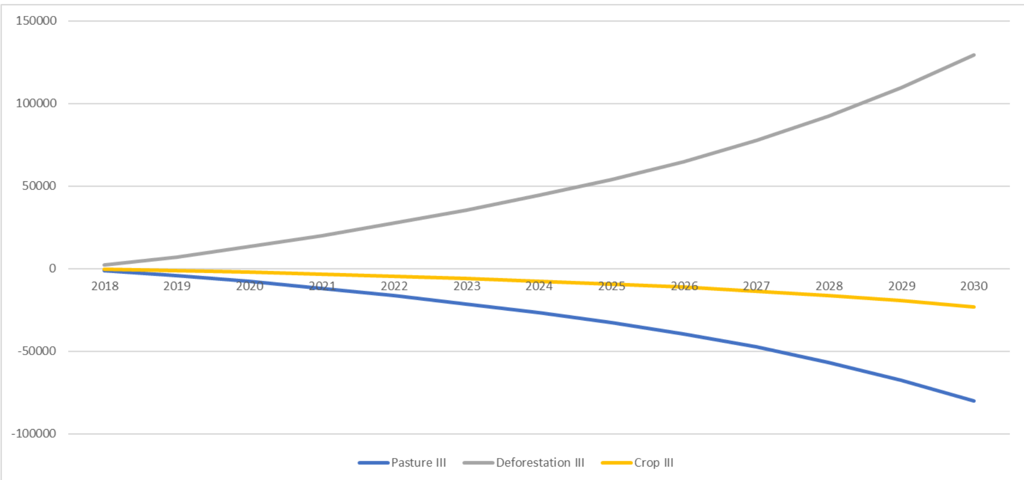

Figure 5 – Total area: Legal Amazon (in Km² - accumulated deviation from 2018 to 2030 relative to baseline)

Source: Elaborated by the authors based on CGE results

Figure 6 shows that in scenario III, the regions around the deforestation arc would have the largest areas of deforestation avoided.

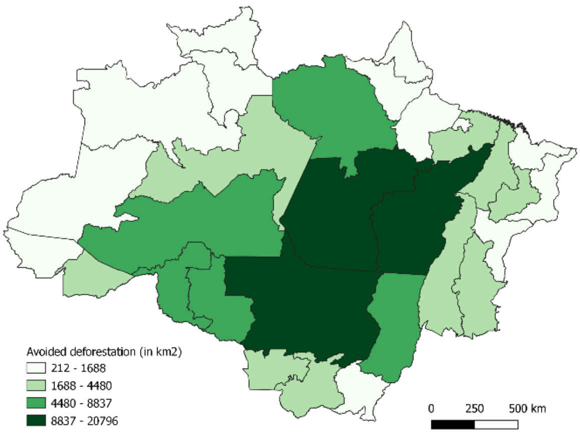

Figure 6 – Avoided Deforestation in km^2 in Scenario III (accumulated deviation from 2018 to 2030 relative to baseline)

Source: Elaborated by the authors based on CGE results

4. Final Considerations

This paper analyzed the economic impacts, land use change and emissions from deforestation considering the growth of external demand for commodities by 2030. FAO (2018) projections for 2018 to 2027 and data of deforestation by Prodes (INPE, 2018) and of emissions by INPE-EM (2019) were used. Three scenarios were built using the interregional dynamic computable general equilibrium model for 30 mesoregions of the Amazon and the rest of Brazil, REGIA. Scenario I considered the increase in international demand without any restriction on deforestation. Scenario II projected the increase in the demand considering the Soy Moratorium in some states. And Scenario III considered the demand growth in a scenario of zero deforestation.

The regional economic gains in Scenarios I and II are very similar. The increase in international demand for commodities drives the GDP, investment and employment growth of most Amazonian mesoregions. The sectoral results show a growth of agricultural activity, mainly soy and cattle. The main difference between the two scenarios is that Scenario II would prevent 547 km^2 deforestation due to the Soy Moratorium in some regions. That would mean around 29 $MtCO_2$ less emissions.

Considering Scenario III, where deforestation does not occur, there is a smaller economic gain in the region, including some regions that show a decrease in some economic indicators such as GDP and employment. However, deforestation of an area of over 130,000 km^2 would be avoided, which would generate about 7,000 $MtCO_2$ less emissions. Although economic results are quite heterogeneous across regions, it is observed that the economic outcome would still be positive for regions that are major producers of commodities considered by FAO (2018) projections.

In general, the results indicate the direction of deforestation expansion, advancing over areas where economic incentives are still low, but may increase as demand for commodities expands. Unless stricter measures to contain deforestation are adopted (as simulated in scenario III), forest areas tend not to be spared and emissions tend to increase.

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