Biome composition in deforestation deterrence and GHG emissions in Brazil[1]

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1. Introduction and motivation

Brazil has committed to ambitious targets in the United Nations Conference on Climate Change in Paris (COP21). The proposed targets represent emissions of 1.32 GtCO2 in 2025 (target) and 1.2 GtCO2 in 2030 (reference), and fits in the range determined by the Climate Change National Policy of 2010 (PNMC), where the targets for 2020 were set between 1.168 and 1.259 GtCO2 (MCTI, 2014). The targets represent reductions of 37% in total emission in 2025, and 43% in 2030. With this, the per capita emissions in the country shall reduce from 14.4 tCO2 eq in 2004 to 6.2 tCO2 eq in 2025 and 5.4 tCO2 eq in 2030 (MCTI, 2014).

The accomplishment of the Brazilian intended Nationally Determined Contribution – iNDC rely heavily on deforestation reduction. Actually, the country has made enormous progress in curbing deforestation in the tropical Amazon, mostly as result of years of investment in surveillance methods, and command and control policies. Deforestation, however, started to increase again in the last years, as result of poor law enforcement: deforestation in the Amazon biome reached an estimated 0.8 million hectare (Mha) in 2016, after a low of 0.46 Mha in 2014. Although it´s still progress compared to the peak of 2.9 Mha observed in 1995, it raises concerns about the evolution of deforestation.

The figures presented above, however, refer only to deforestation in the Amazon biome. Actually, most of the economic literature on deforestation in Brazil concentrates on this biome, which calls worldwide attention related to tropical deforestation. This attention, however, overshadows deforestation in other very important biomes in Brazil, especially the Cerrado (savannah) biome[4]. The Cerrado biome comprises an area of

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[4] Brazil has six biomes: Amazonia, Cerrados, Caatinga, Mata Atlantica, Pampa and Pantanal. The deforestation frontier is located mostly in the Amazonia and Cerrados and, to a lesser extent, Caatinga biomes.

approximately 203 Mha (IBGE, 2004), located mostly in central Brazil. It´s the second largest biome in South America, and occupies 25% of the national territory, spread over many different states. Most of the grains (soybeans and corn) and cotton production areas in center-west and west regions in Brazil are located in this biome.

The focus of deforestation policies, however, have put much less attention to deforestation in the Cerrado biome compared to the Amazonia. Consequently, the rate of deforestation in this biome increased fast, reaching a peak of 0.75 Mha in 2012, and higher than the annual area deforested in Amazonia biome in some years (Table 1). Although there is less information on deforestation in this biome, it´s well known in Brazil that agriculture is spreading rapidly in Cerrado areas.

Table 1. Annual deforestation in the Amazonia and Cerrado biomes. Brazil. Million Hectare.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Amazonia	2.337	1.383	1.310	1.292	1.113	0.637	0.558	0.435	0.534	0.506	0.604
Cerrado	0.476	0.347	0.437	0.370	0.294	0.364	0.729	0.752	0.418	0.447	0.341

Source: LAPIG (Laboratório de Processamento de Imagens e Geoprocessamento) (2015) SIAD-Cerrado; and PRODES.

This has important environmental consequences, since the rate of GHG emissions is higher in the Amazonia biome than in the Cerrado. Considering, however, that the surveillance and enforcement of deforestation control is much weaker in the Cerrado, it´s possible to observe presently a “spill off” effect of deforestation from the Amazonia biome to the Cerrado biome. Actually, compensation of a halt of deforestation in the Amazonia biome through more deforestation on the Cerrado biome has been advocated as important to keep Brazilian agriculture and rural income growing[5].

Notice that the Brazilian compromise in COP21 refer to the elimination of illegal deforestation, and not of total deforestation. Although it´s not presently possible to know the exact amount of illegal deforestation (since part of it is located on private owned land), it is possible, using satellite imagery techniques, to observe the part located on public and protected land[6] (Table 2).

[5] See, for example, a newspaper article by Jank (O Estado de São Paulo, July 17, 2013).
[6] Protected land refers to land designated by law to national parks and indigenous population.

Table 2. Share of deforestation in public and private lands, by biome, and total deforestation (Mha). Brazil.

	Amazonia			Cerrado			Mata Atlantica			TOTAL
	Public (Share)	Private (Share)	Total (Mha)	Public (Share)	Private (Share)	Total (Mha)	Public (Share)	Private (Share)	Total (Mha)	Mha
2005	0.18	0.82	2.34	0.06	0.94	0.48	0	1	0.033	2.85
2006	0.23	0.77	1.38	0.03	0.97	0.35	0	1	0.035	1.77
2007	0.23	0.77	1.31	0.02	0.98	0.44	0	1	0.035	1.78
2008	0.22	0.78	1.29	0.02	0.98	0.37	0	1	0.035	1.70
2009	0.15	0.85	1.11	0.04	0.96	0.29	0	1	0.015	1.42
2010	0.27	0.73	0.64	0.05	0.95	0.36	0	1	0.015	1.02
2011	0.25	0.75	0.56	0.04	0.96	0.73	0	1	0.014	1.30
2012	0.28	0.72	0.44	0.03	0.97	0.75	0	1	0.023	1.21
2013	0.28	0.72	0.53	0.02	0.98	0.42	0	1	0.025	0.98
2014	0.28	0.72	0.51	0.02	0.98	0.45	0	1	0.018	0.97
2015	0.27	0.73	0.60	0.02	0.97	0.34	0	1	0.019	0.96

Source: original data from PRODES and LAPIG, modified by the authors (Imaflora, 2017).

The amount of illegal deforestation in public land is consistently higher in the Amazonia biome than in the Cerrado. This reflects in part the fact that most of the protected land is Amazonia biome, a consequence of the previously mentioned lack of concern about deforestation in Cerrado. The observed share of total deforestation on public land in the Amazonia biome (which, as pointed above, is a floor for total illegal deforestation) is consistently above 0.25 in the last five years and increased in the recent period, while almost total deforestation in the Cerrado area is on private land.

This means deforestation will not stop completely as result of the Brazilian commitments to COP21, since there is still a significant amount of land available for legal deforestation in Brazil. Imaflora (2017, personal communication) estimates that there are still around 36 Mha of land under natural forests, with high and very high agricultural potential, sitting in private lands which can be legally cleared[7]. This trade-off between deforestation in the Amazonia versus Cerrado biomes must be taken into account to properly assess the COP21 Brazilian commitments.

2. Objective

[7] That amount increases to 64.7 Mha if we include land with average aptitude for agriculture.

In this paper, we evaluate the Brazil´s commitment to COP21, with a particular focus on deforestation and land use targets. The trade-off between deforestation in the Amazonia versus Cerrado biome is central for the discussion.

This paper contributes to the existing literature in bringing new information coming from satellite imagery to the analysis, in order to highlight the role of deforestation in the Cerrado biome in the adjustment. This updates and extends results presented in Ferreira Filho and Horridge (2016), which considered only deforestation in the Legal Amazon in the baseline, by including deforestation in the Cerrado biome both in the baseline and in different deforestation scenarios. We use new satellite imagery data (Imaflora, 2017) on deforestation by biome, as well as on private x public land to perform the analysis.

3. Methodology

We use a multi-period computable general equilibrium model of Brazil, based on previous work by Ferreira Filho and Horridge (2014, 2015, and 2016) to analyze the consequences of different scenarios of deforestation for Brazilian commitments to COP21. The model includes annual recursive dynamics and a detailed bottom-up regional representation of Brazil, with 27 states, 110 products and 110 activities, 10 household types, 10 labor grades.

The model has also an emissions matrix that tracks emissions in the economy, where emissions are associated to each productive sector and final demand, and can be of two broad types: emissions associated to fuel use and emissions associated to the level of activity of each sector (like fugitive emissions in mining, or CH4 emissions in livestock, for example). All emissions are accounted by the original GHG gases, and transformed to CO2 equivalents using the Global Potential Warming for 100 years (GPW-100) coefficients from the IPCC Second Assessment Report –SAR (IPCC, 1996).

In modeling emissions on LUC, the model has an additional emissions matrix that presents two distinctive aspects for the proposed study:

• A land use change (LUC) module based on a transition matrix approach, which tracks land transitions in use in each state, observed from satellite imagery data of Brazilian land-use changes between 1994 and 2002. We processed this data to distinguish land areas used for three broad types of agriculture, Crop, Pasture, and Plantation Forestry, and one residual type referred as 'Unused', which is mainly natural forest. We distinguished regional land use by state, and, within each state by six soil/vegetation zones (biomes): Amazonia (Amazon forest), Cerrado (Savannahs), Caatinga, Mata Atlantica (Atlantic Forest), Pampa, and Pantanal. The data shows how many hectares of, say, the Cerrado biome in Mato Grosso state, was Unused in 1994, and also how much of that 1994 Unused area was used in 2002 for, say, Crops, or was still Unused. Thus, the data comprises, for each of six biome zones within each state, a full transition matrix between the four broad land uses.

• A GHG emissions matrix associated to the LUC module, which shows observed emissions on transitions, by state and biome. This allows a detailed accounting of emissions on transitions, and the computation of sinks on forest restoration.

4. Scenarios and simulation strategy

We start with a historical simulation to update the database from 2005 (the calibration year) to 2016. In this period, observed macroeconomic data, as well as aggregated data on agriculture and land use are imposed to the model, replicating the observed evolution pattern. After the historical period, we develop a baseline until 2030, using projections of the Brazilian economy from various sources. All the information about land use change, both in the historical and in the forecast period, are by state and biome, capturing regional differences in Brazil (Table 3). We used a GDP growth of 2.5% per year in the projections, as well as population growth rates by state projected by IBGE (2016)[8].

Of particular importance, both in the historical period and in the baseline projections is the evolution of deforestation in different biomes. We´ve obtained data for deforestation in three, out of six biomes of Brazil: Amazonia, Cerrado and Mata Atlantica. Those three biomes (notably the Amazonia and Cerrado) concentrates the bulk of deforestation in Brazil presently. The projected rates of deforestation will follow the observed rates in the last five years for Amazonia and Mata Atlantica, and three years for the Cerrado[9] .

Table 3. Projected deforestation in the simulations, total 2016-2030 (forecast period). Mha.

	1 Amazonia	2 Cerrado	4 MAtlantica	Total

[8] The Brazilian iNDC considers a much higher, GDP growth projection, around 4% per year until 2030. Our estimates of emissions, then, are conservative, although probably more realistic, compared to the original iNDC.

[9] We use the average of the last three years for the Cerrados biome to avoid projecting abnormal high rates of deforestation in the biome for some states.

1 Rondonia	0.87	0	0	0.87
2 Acre	0.42	0	0	0.42
3 Amazonas	0.75	0	0	0.75
4 Roraima	0.19	0	0	0.19
5 Para	3.12	0	0	3.12
6 Amapa	0.02	0	0	0.02
7 Matopiba	0.27	3.95	0.12	4.34
8 PernAlag	0	0	0	0
9 RestNE	0	0	0.01	0.01
10 MinasG	0	0.46	0.12	0.58
11 SaoPaulo	0	0.02	0	0.02
12 RestSE	0	0	0.01	0.01
13 Sul	0	0	0.04	0.04
14 MtGrSul	0	0.21	0.01	0.22
15 MtGrosso	1.64	0.99	0	2.63
16 GoiasDF	0	0.39	0	0.39
Total	7.28	6.02	0.31	13.61

OBS: (1) Maranhão, Tocantins,Piauí and Bahia. (2) Pernambuco and Alagoas; (3) Rest of Northeast states; (4) Rest of Southeast states.

We can see from Table 3 the result of our hypothesis regarding deforestation in the baseline. The Amazonia and Cerrado biome would have most of the land clearing in the period, respectively 7.28 Mha and 6.02 Mha. Deforestation in the Mata Atlantica biome is very low presently, due to depletion of stocks and protection policies. This biome, however, will be important for the discussion about forest recovery, one of the Brazilian targets in the iNDC.

In the baseline projections, we considered that the rate of illegal deforestation in public lands would be the same (average) as in the observed period, once the Brazilian targets for COP21 entail stopping this kind of deforestation in 2030. For private land, however, projections took into account the amount available for legal deforestation (Imaflora, 2017), stopping the process of land clearing in states where and when this stock depleted. This happened in the Amazon biome in the states of Maranhão and Tocantins in 2022, and Rondonia in 2023. In the Cerrado biome the limit was only reached in the state of Parana (in the RestSE region), in year 2021.

Next, we implement policy simulations comprising the land use targets in the Brazilian commitments to COP21, namely:

- Scenario1 (SCEN1): The deterrence of illegal deforestation until 2030. In this scenario 2.25 Mha of forests would be spared from clearing.

- Scenario 2 (SCEN2): Includes Scenario 1 plus the restoration of 12.3 Mha of forests until 2030.
- Scenario 3 (SCEN3): The exchange of deforestation in the Amazonia biome by deforestation in the Cerrado biome. The amount of Amazonia biome cleared in SCEN2 is transferred to Cerrado biome, keeping total deforestation at the same level as in SCEN2. This comprises a transfer of 7.3 Mha of forest clearing from the Amazonia biome to the Cerrado biome.

In what follows, we discuss the criteria used in each scenario. Scenario 1 just considers the elimination of deforestation in public areas, one of the Brazilian iNDC targets. Actually, what we have in this scenario is the elimination of illegal deforestation in public (protected) areas, since it´s not possible presently to calculate how much of illegal deforestation occurs in private areas, as mentioned before. We expect that it will be possible in the near future, with the evolution of the mandatory registration of protected areas in private properties process underway (the Cadastro Ambiental Rural - CAR). Our estimates in this scenario, then, are a lower limit for illegal deforestation, and represents a "least effort" scenario in terms of enforcement.

Scenario 2 represents a more complete execution of the Brazilian commitments to COP21, in terms of land use targets. The restoration target of 12 Mha until 2030 is a general goal in the Brazilian iNDC, but lacks details for implementation, especially in terms of regional details. All the policies, measures and actions to implement the iNDC, however, are under the disciplines of the National Policy on Climate Change, the Native Forests Protection Law (the Brazilian Forest Code) and of the Law of the National System of Conservation Units (Brasil, 2015). We can use the estimates of natural vegetation debts (NVD) by state entailed by the Forest Code to implement the policy simulation of restoration of 12 Mha of vegetation. For that, we use estimates from satellite imagery (Imaflora, 2017) for the different parts of NVD in the Forest Code, namely the Legal Reserves (RL) and Permanent Protected Areas (APP), to locate regionally the required afforestation. The hypothesis used to build this scenario then are:

- Illegal deforestation stops in 2030, starting to decrease linearly from 2020.
- The restoration of NVD will start in 2016, and comprises all of the APP and 50% of the RL deficits. This criterion gives a total of deforestation around 12.3 Mha (Table 4).

- Following Soares-Filho et al (2014), and Ferreira Filho, Horridge and Diniz (2015), we assume that all land restoration would occur over pasture, instead of over crops.

Table 4. Scenario 2. Increase in natural vegetation stocks due to the Forest Code, in relation to the baseline, accumulated in 2030. Mha.

	Biome			
Region	1 Amazonia	2 Cerrado	4 MAtlantica	Total
1 Rondonia	0.64	0.00	0.00	0.64
2 Acre	0.09	0.00	0.00	0.09
3 Amazonas	0.12	0.00	0.00	0.12
4 Roraima	0.03	0.00	0.00	0.03
5 Para	1.21	0.00	0.00	1.21
6 Amapa	0.01	0.00	0.00	0.01
7 Matopiba	0.41	0.65	0.71	1.77
8 PernAlag	0.00	0.00	0.15	0.15
9 RestNE	0.00	0.00	0.22	0.22
10 MinasG	0.00	0.77	1.02	1.79
11 SaoPaulo	0.00	0.39	0.75	1.14
12 RestSE	0.00	0.00	0.37	0.37
13 Sul	0.00	0.01	1.80	1.81
14 MtGrSul	0.00	0.39	0.12	0.51
15 MtGrosso	1.04	0.64	0.00	1.68
16 GoiasDF	0.00	0.88	0.06	0.94
Total	3.55	3.73	5.20	12.48

Source: Imaflora (2017).

Data in Table 4 shows that in the region called Matopiba (states of Maranhão, Tocantins, Piauí and Bahia), for example, the Forest Code requirements would entail the afforestation of 0.41 Mha in the biome Amazonia, 0.65 Mha in the biome Cerrado, and 0.71 Mha in the biome Mata Atlantica, totaling 1.77 Mha of recovered forests. The Sul (South) region would require 1.81 Mha of afforestation, but in the Mata Atlantica biome mostly. The model accommodates those changes by equivalent falls in the pasture areas in the respective regions.

Finally, in Scenario 3 we examine the consequences of transferring deforestation from the Amazonia biome to Cerrado. We transfer the total area that would be deforested in the Amazonia biome (in the baseline) to the Cerrado biome, distributed regionally in proportion to the deforestation trend in the Cerrado.

5. Emissions in the baseline

As stated above, the Brazilian iNDC takes as reference for emissions the year of 2005. This is a very favorable year for comparison, considering that the iNDC relies heavily on deforestation control: as can be seen in Table 2, deforestation in Brazil considerably reduced after 2005, causing a strong reduction in emissions associated to land use change (LUC, Table 5). Emissions associated to general economic activity increased by 37.1% from 2005 to 2015, while emissions associated to LUC reduced by 83.0% in the same period, causing total emissions in Brazil to fall by 38.2% from 2005 to 2015.

Table 5. Emissions in the baseline, Gt CO2eq. General sources, Land Use Change (LUC) and Per capita. Brazil.

	Activities and final demand	LUC	Total	Per capita (ton CO2)
2005	0.79	1.33	2.12	11.50
2006	0.82	0.73	1.56	11.50
2007	0.87	0.55	1.42	8.20
2008	0.92	0.51	1.42	7.30
2009	0.92	0.40	1.32	7.10
2010	0.99	0.26	1.25	6.40
2011	1.03	0.24	1.27	5.90
2012	1.06	0.27	1.33	5.80
2013	1.09	0.24	1.34	5.90
2014	1.11	0.21	1.32	5.70
2015	1.08	0.18	1.27	5.50
2016	1.11	0.15	1.26	5.10
2017	1.13	0.14	1.27	4.90
2018	1.15	0.13	1.29	4.80
2019	1.19	0.13	1.32	4.70
2020	1.22	0.12	1.35	4.70
2021	1.26	0.12	1.38	4.60
2022	1.30	0.12	1.42	4.50
2023	1.34	0.12	1.45	4.50
2024	1.37	0.12	1.48	4.40
2025	1.40	0.11	1.51	4.30
2026	1.43	0.11	1.54	4.20
2027	1.46	0.11	1.57	4.10
2028	1.50	0.10	1.59	4.00
2029	1.53	0.09	1.62	3.90
2030	1.57	0.09	1.66	3.80
Target for 2025			**1.320**	6.2

Source: model results

We see in Table 5 that the projected emissions in the Brazilian economy in the baseline would come close to the targets for 2025 for total emissions, and would meet the targets for “per capita” emissions. This, of course, depends a lot on the projected deforestation trend, as well as on the projected GDP growth rate, since emissions on other sources (economic activities and energy use) would still increase with our projected 2.5% increase in GDP in the baseline[10]. Our estimates show that total emissions in 2025 would be 7.9% above the target in 2025, but below the target in terms of per capita emissions. To reach the total emissions target would require extra efforts in the other sectors of the economy.

In what follows, we analyze how different scenarios will change the baseline results.

6. Results

Our purpose in this paper is to analyze how different scenarios will affect the Brazilian targets, as proposed in the iNDC, focusing in the LUC issues. We notice, in first place, that the macroeconomic effects on the whole economy are small (Table 6).

Table 6. Model results. Selected macroeconomic variables. Percent variation from baseline, accumulated in 2030.

	SCEN1	SCEN2	SCEN3
Real Household consumption	-0.11	-1.10	-0.02
Export Volume (index)	0.32	2.90	0.1
Real GDP	-0.12	-1.10	-0.03
Aggregate employment	0	0	0.01
Real wage	-0.25	-2.50	-0.07

Source: model results.

Agriculture and livestock (primary) production account for 5.3% of Brazilian GDP in 2013 (last year of published Brazilian National Accounts), what makes the policy impacts small in the whole economy. The most severe impacts appear in SCEN2, where the larger amount of forests (12.3 Mha) would have to be restored. GDP loss in this case would be 1.10%, accumulated in 2030, and we refer to this value as the “shadow price” of deforestation, a social (partial)[11] evaluation of deforestation values.

Strong differences, however, appear in the economic losses at regional level (Table 7).

Table 7. Model results. Regional real GDP. Percent variation from baseline, accumulated in 2030.

Region	SCEN1	SCEN2	SCEN3

[10] This value would increase to 14.7% in case of a GDP growth of 4% per year.

[11] It is partial in the sense that the evaluation does not include the environmental services values provided by forests.

1 Rondonia (N)	-1.79	-3.00	-3.11
2 Acre (N)	-1.48	-1.50	-4.89
3 Amazonas (N)	-0.18	-0.30	-0.48
4 Roraima (N)	-0.46	-0.80	-1.37
5 Para (N)	-0.59	-1.20	-2.21
6 Amapa (N)	-0.18	-0.90	-0.15
7 Matopiba (NE)	-0.16	-1.40	0.65
8 PernAlag (NE)	-0.08	-1.00	-0.01
9 RestNE (NE)	-0.11	-1.20	-0.01
10 MinasG (SE)	-0.06	-1.30	0.15
11 SaoPaulo (SE)	-0.06	-0.60	-0.05
12 RestSE (SE)	-0.03	-0.30	-0.02
13 Sul (S)	-0.12	-1.70	-0.07
14 MtGrSul (CW)	-0.14	-1.60	0.15
15 MtGrosso (CW)	-0.41	-3.00	-0.48
16 GoiasDF (CW)	-0.16	-1.90	0.11

N – North region; NE –northeast; SE – Southeast; S – South; CW – Center-west.
Source: model results.

It´s interesting to notice that, even though SCEN1 and SCEN3 caused very little (negative) GDP impacts at national level, their outcomes can be bigger than SCEN2 for some states. SCEN1 is the elimination of illegal deforestation in Brazil that, as explained before, refers to deforestation in publicly protected areas (natural parks and indigenous land). As part of the Brazilian government strategy to protect the Amazon forest, almost all such areas are located in the Amazonia biome (North region of Brazil), and were created as a "security belt" isolating the Amazon region from the advances of the arch of deforestation. Most of this scenario, then, affects states in the North region of Brazil, as is the case of Rondonia and Acre. Even though SCEN1 implies a reduction of only 2.25 Mha of cleared forests compare to the baseline, most of it is concentrated on those states.

SCEN3, on the other hand, implies an economic trade-off between states in the north region (Amazon biome) with states in the Center-west region (mostly Cerrado biome), sparing 7.3 Mha of forests in Amazon biome matched by an equivalent amount further cleared in the Cerrado biome. This scenario, then, implies a transfer of the agricultural frontier from the North toward the Center-west, which would gain more in economic terms. The states of Rondonia, Acre, Roraima and Para loose the most in terms of GDP, and more than in SCEN2.

Notice that SCEN2 is the one that causes the larger GDP loss. In this scenario, 12.3 Mha of forests would have to be recovered, the higher value among the three scenarios. This is not, however, the only factor dictating the higher impact. The regional distribution is very important, and can be inferred by the higher losses of states in the Southeast, South and Center-west regions when compared with the other scenarios. Apart from the land distribution in the shocks (Table 4), higher land productivity in those states reinforce the higher economic losses in those regions. As will be seen in what follows, the biome composition in different states have further implications for emissions.

As explained before, Brazil committed to absolute targets for emissions in COP21. As seen previously (Table 5), emissions in the model baseline would be 7.9% above the targets in 2025. Table 8 displays the results for the different scenarios.

Table 8. Emissions in the scenarios (Gt CO2 eq) and variation (percentage) in relation to 2005.

		SCEN1		SCEN2		SCEN3	
	BASE (2005)	2025	2030	2025	2030	2025	2030
General	0.79	1.31	1.39	1.29	1.35	1.31	1.39
LUC	1.33	0.16	0.16	0.02	-0.01	0.18	1.56
Total	2.12	1.47	1.54	1.30	1.33	1.48	2.95
Var (%) rel. 2005 (TOTAL)		-30.8	-27.1	-38.5	-37.1	-30.0	-26.2
iNDC target 2025		-37	-43	-37	-43	-37	-43

Source: model results.

Model results in Table 8 indicate that only SCEN2 meets the target for 2025, and none would meet the target for 2030. These results bring a series of insights related to the evolution of emissions in Brazil.

First, we can see that only curbing illegal deforestation (SCEN1) will not be enough to meet the targets. Additional efforts will be required in order to save extra emissions, either in LUC or in the other actions for the general economy, as is the case of improving the energy emissions profile.

Second, SCEN2 would, by itself, lead to reach the targets in 2025, with no extra effort from the rest of the economy, but not when compared to 2030. Remember that SCEN2 entails the 12.3 Mha afforestation target. It´s an aggressive scenario by any means, especially considering the present situation of the Forest Code discussion, still under debate in the congress. However, as the economy grows in time, the gains from avoiding deforestation reduces in relative terms[12], leading to an increase in overall emissions after 2030, above the targets.

Results in the third scenario (SCEN3) are also very interesting. As explained previously, in this scenario we examine the argument that the avoided deforestation in the Amazonia biome should be compensated by more deforestation in the Cerrado biome. Results show that from a purely economic standpoint this is, indeed, a less costly approach (see Table 6), even though the reasons why preserving the Amazonia biome is preferable preserving the Cerrado is arguable, since this is one the world´s biodiversity hotspot. However, from an emissions standpoint this scenario is even worse than SCEN1, where only illegal deforestation is curbed. To our view, this is one important reason why this argument should not be taken seriously. Even though the average emissions rate in the Amazonia biome are higher than in Cerrado, the emissions arising in Cerrado deforestation are also very important, and will certainly contribute decisively for the total results.

The fall in pastures areas will lead to a rearrangement of crops production, depending on the regional composition of production. At the same time, the fall in primary factor prices (notably labor and capital) lead to an expansion of some crops (Table 9).

Table 9. Model results. Production, percent variation from the baseline. Accumulated in 2030.

	SCEN1	SCEN2	SCEN3
Rice	-0.25	-2.74	-0.05
Corn	-0.26	-2.18	-0.12
Wheat	0.22	2.39	0.11
Sugar Cane	-0.09	-1.04	-0.03
Soybean	0.25	2.21	0.13
Other agric	0.04	0.44	-0.01
Cassava	-0.25	-2.62	-0.01
Tobacco	0.05	0.17	-0.03
Cotton	-0.07	-0.78	-0.02
Citric fruits	-0.17	-1.85	-0.04
Coffee	0.2	1.99	0.00
Forestry	0.17	1.76	0.11
Livestock	-1.38	-11.05	-0.61
Raw Milk	-0.66	-9.91	0.11

Source: model results.

[12] We can also argue that economic growth would put more, instead of less, pressure on deforestation.

Notice that soybean production would increase in all scenarios, and more in SCEN2. This happens because the model generates an exchange rate devaluation, which pushes exports in general. Soybean is an important export product “in natura” in Brazil, as well as an important feedstock for other important exported meat products, like poultry. Combined with the fall in primary factor prices, substitution in production would benefit soybean, generating a further expansion in its area and production.

We see, then, that LUC reduction, as predicted in the Brazilian commitments do COP21, would be enough to meet the targets in 2025. This would require the restoration of 12.3 Mha of forests, an uncertain prospect at this point, to say the least. There is little doubt, then, that the adjustment will require extra effort by the rest of the economy, especially in the field of agriculture and energy, the second and third sources in importance for emissions in Brazil. Those two sources, however, are increasing their emissions, instead of decreasing. Total emissions net of LUC emissions increased by 10.9% in the period 2005-2010. In the same period, agriculture increased emission by 3.7% and energy by 18.65%.

7. Final remarks

Our results show that the accomplishment of the afforestation targets in the Brazilian commitments to COP21 would be enough to reach the emissions targets in 2025, although not in 2030. This, however, depends crucially on the afforestation of 12.3 Mha of land, following the Brazilian Forest Code provisions. To which extent this will be possible, however, remains an open question, given the present uncertainties in the Brazilian economy, as well as uncertainties about the final form of the Forest Code itself. Our simulation shows that this afforestation target would be mandatory for the country to be able to meet its commitments with less effort from the rest of the economy.

Likewise, our simulations show that exchanging deforestation in Amazonia for Cerrado would not be an option in terms of emissions, and would be disastrous in terms of the country´s commitments to COP21.

The prospects for Brazil to meet its commitments in the Climate Convention, then, will very likely depend more on the efforts on the energy emissions than believed at first. In this front, however, the prospects are likely not optimistic. The share of emissions on agriculture and energy in the country increased respectively by 18.6% and 3.7% between 2005 and 2010, and there is not much reason to believe that this trend has changed since then. Agriculture has been the resilient sector in the Brazilian economy since the beginning of the present economic crisis, and is even expanding, contrary to the manufacturing sector. In spite of present efforts to reduce emission in agriculture (eg. the ABC Plan, a low carbon program), agriculture did not change technology significantly so far.

Finally, a note must be added regarding the emissions database. Our model database is from the Second National Communication of Brazil to the United Nations Framework Convention on Climate Change. As noticed by Rittl (2017), the Third Communication, released in 2016 (not in time to allow the update our database) updated the emissions in the base period (2005) from 2.1 MtCo2 eq used as the reference in this paper to 2.73 MtCO2 eq. With this, the iNDC 37% reduction in 2025 would imply an emissions level of 1.7 MtCO2 eq, above the level obtained in the baseline. The Third Communication, then, considerably reduces the severity of the commitments, in absolute terms. Actually, without a revision of the absolute targets, the commitments represent an increase, instead of a decrease, of emissions in Brazil.

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