The threat of political bargaining to climate mitigation in Brazil

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In exchange for political support, the Brazilian government is signaling landholders to increase deforestation, putting the country's contribution to the Paris Agreement at risk[1]. The President of Brazil has signed provisionary acts and decrees lowering environmental licensing requirements, suspending the ratification of indigenous lands, reducing the size of protected areas and facilitating land grabbers to obtain the deeds of illegally deforested areas[2]. This could undermine the success of Brazil´s CO_2 emission reductions through control of deforestation in the previous decade. Integrated Assessment Models (IAM) are tools to assess progress in fulfilling global efforts to curb climate change[3,4]. Using IAMs developed for Brazil, we explore 2°C-compliant CO_2 emission scenarios estimating the effort needed in other sectors of the economy to compensate for the weakening of environmental governance, potentially resulting in higher deforestation emissions. We found that the risk of reversals of recent trends in deforestation governance could impose a burden on other sectors that would need to deploy not yet mature technologies to compensate for higher emissions from land-use change. The abandonment of deforestation control policies and the political support for

predatory agricultural practices make it impossible to meet targets consistent with Brazil´s contribution to a 2°C world.

Brazil is the seventh largest greenhouse gas (GHG) emitter. Between 2005 and 2012, the country's GHG emissions were reduced by 54% [5], mostly by cutting deforestation by 78%. However, the country's recent record on land-use policies and practices has not been bright. On one hand, by the end of 2017 some 65% of Brazil's 5.4 million rural properties have joined the rural environmental registry, a system to monitor compliance with environmental laws, and the country committed to reduce its annual emissions to 1.3 Gt CO_{2e} in 2025, and an indicative of 1.2 Gt CO_{2e} by 2030, in its Nationally Determined Contribution (NDC) as part of the Paris Agreement. On the other hand, since 2012, following the relaxation of the Forest Code[6], there has been a reversal in the declining deforestation trend in the Brazilian Amazon, while deforestation has levelled out at high rates in the Cerrado biome, which has already lost more than half of its original vegetation[6]. Since May 2016, Brazil's presidency has deepened this negative reversal by attempting to deconstruct several successful environmental policies[7].

At the core of the current government´s coalition is the powerful rural/mining caucus, which holds some 40% of the seats in Congress[8]. In order to avoid responding for corruption accusations, the President has proposed legislative projects and signed provisionary acts and decrees that lowered environmental licensing requirements[9], suspended the ratification of indigenous lands[10], reduced the size of protected areas in the Amazon[11], and facilitated land grabbers to obtain the deeds of illegally deforested areas as large as 2,500 ha per farm in the Amazon rainforest[12].

Analysis of the environmental governance in Brazil helps to explain how the political crisis can be a major driver for increasing deforestation and carbon emissions in the country. Deforestation control is the resultant of forces arising from institutional arrangement, such as enforcing the rule of law and sending signals that may, directly or indirectly, incentivize

economic agents to decide whether or not to illegally deforest. The institutional arrangement can also be affected by the degree of cooperation with the international regime on climate change. By analyzing these forces over the last two decades, environmental governance in Brazil can be divided into three major periods (see Supplementary Material): pre-2005, a period with very poor governance and high rates of deforestation; 2005-2011, a period with improvements in environmental governance and effective results in reducing deforestation[13]; and 2012-2017, when governance suffered a gradual erosion with the large amnesty granted to past illegal deforesters in the revision of the Forest Code[6], which led to a reversal of the deforestation reduction trend in the Amazon after 2012 and, later, to an increase in deforestation during 2015-17.

Based on these past records, we devise three environmental governance scenarios (Figure 1):

- **Weak environmental governance (WEG)**: this scenario assumes the abandonment of current deforestation control policies, as well as a strong political support for predatory agricultural practices. In practice, by 2025 this scenario represents the annulling of the governance gains obtained since 2005. This represents the worst-case scenario and should be understood as a complete deconstruction of environmental governance in Brazil, with severe impacts on deforestation rates, which could potentially return to pre-2005 levels. Such return of deforestation rates to peak levels of the last decade would lead to annual losses of more than 27 thousand and 18 thousand km^2 of the Amazon and Cerrado biomes already by 2025, respectively. Hence, cumulative CO_2 emissions from deforestation could escalate to 23.1 Gt CO_2 from 2010 to 2030.
- **Intermediate environmental governance (IEG)**: this scenario assumes the maintenance of current deforestation control policies, while, contradictorily, considering a growing political support for predatory agricultural practices. This includes the legal support to land-grabbing practices, the creation of fewer protected areas and the downgrading, downsizing and degazettement of key protected areas together with lax enforcement

of the Forest Code. At the end, IEG represents the current business-as-usual scenario in Brazil, according to which the increasing deforestation trend observed in the Amazon since 2013 is extended until 2030. As a result, annual deforestation would reach some 17 thousand and 15 thousand km^2 in the Amazon and Cerrado biomes by 2030, respectively. This implies in cumulative emissions from deforestation of 16.3 Gt CO_2 for the same 2010-2030 period.

- **Strong environmental governance (SEG)**: this scenario assumes the expansion of current deforestation command-and-control policies and the full political support for the environmental agenda in the country, including the full implementation of the Forest Code alongside economic incentives for forest conservation. Annual deforestation in the Amazon and the Cerrado biomes would be reduced from 7,989 and 9,483 km^2 – in 2016 and 2015[13], respectively – to under 4,000 km^2 by 2030. Associated cumulative emissions from deforestation reach 9.6 Gt CO_2 from 2010 to 2030.

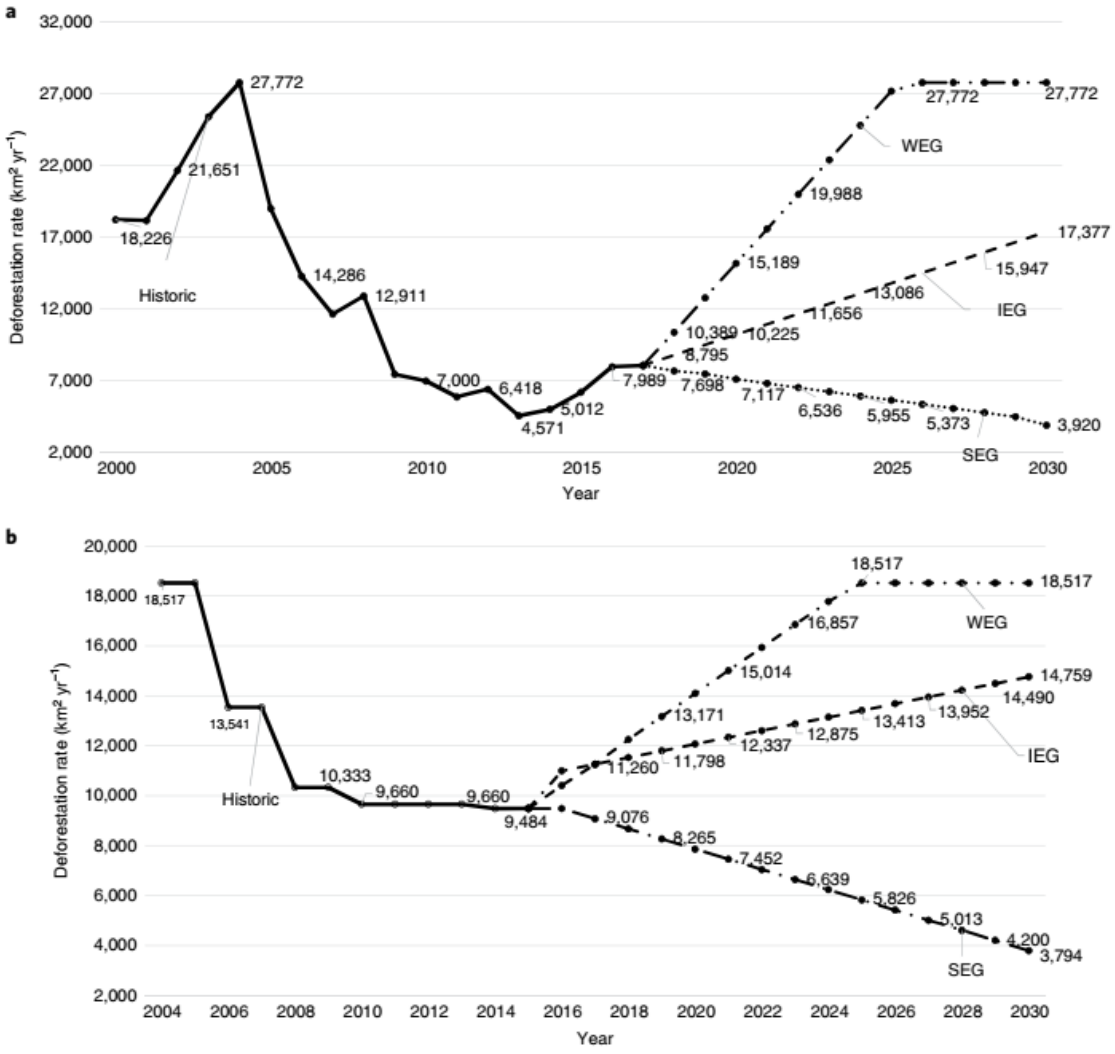

Figure 1 - Deforestation rates for the Amazon (1a) and the Cerrado (1b) biomes

From these environmental governance scenarios, we estimate resulting land-use CO_2 emissions. Then, we evaluate the level of effort and the cost to other sectors of the economy to compensate for higher emissions if Brazil is to meet its commitments under the Paris Agreement and to contribute to a "below 2°C" world.

Recent studies[15-20] indicate a cumulative budget of approximately 24.0 Gt CO_2 for Brazil between 2010 and 2050 in a "below 2°C" world. These studies adopt different allocation criteria (least-cost, population metrics, economic and social development, historic emissions, *per-capita* emissions) in analyses performed using global IAMs. This is the cumulative amount of CO_2 Brazil should emit in a worldwide effort to keep global average temperature increase "below 2°C" by

2100 with a likely chance (66-100% probability). Other GHGs are also considered (see Supplementary Material). In 2010-16, some 4.6 Gt CO_2 were already emitted in Brazil. Hence, there remain 19.4 Gt CO_2 to be emitted from 2017 to 2050.

If Brazil is to contribute with its part in a "below 2°C" world, the remaining emissions budget for other economic sectors (agriculture, livestock, energy production and consumption, waste and industrial process emissions) will depend on the cumulative emissions from deforestation. The higher the emissions from deforestation, the greater will be the effort to reduce emissions elsewhere, and still help the World to reach the "below 2°C" target. Based on the budget that would remain for the other sectors under modeled deforestation scenarios, we simulate cost-optimal mitigation strategies that maintain the overall Brazilian contribution within the 2°C target.

To do this, a comprehensive methodological procedure was established by combining two well proven models developed in, and for, Brazil: the spatially explicit land-use model, OTIMIZAGRO[21,22]; and the optimization model for the national energy and land-use systems, BLUES[23].

Results for the *SEG* scenario place most of the country's effort to reduce CO_2 emissions on avoiding further deforestation and increasing energy efficiency and the use of biofuels. This indicates that Brazil succeeds in upholding the conservation gains obtained between 2005 and 2011, and can meet its NDC targets and go beyond, contributing its share to a "below 2°C" world. In this case, the country's cumulative CO_2 emissions for the 2010-2050 period split between deforestation (9.6 Gt CO_2) and other sources (14.4 Gt CO_2).

In the *IEG* scenario associated with the growing political support for predatory environmental practices, our analyses indicate that Brazil could still meet its share in the world effort to reach the 2°C target. In this case, for the 2010-2050 period cumulative CO_2 emissions from deforestation reach 16.3 Gt CO_2, while cumulative CO_2 emissions from other sources total 7.7 Gt CO_2.

While in the *IEG* scenario Brazil may still cope with its CO_2 budget, emissions under the *WEG* scenario fall close to the cumulative CO_2 budget of 24.0 Gt CO_2. Cumulative emissions from deforestation reach 23.1 $GtCO_2$ and there is no way other sectors can compensate for the emissions associated with the loss in forest coverage (Figure 2). Even using a set of advanced and costly technologies – some of which are not fully commercially deployed yet, such as carbon capture in advanced biomass conversion (BECCS); diesel, bunker and jet fuel from biomass; ethanol powered buses; electric and hydrogen powered buses, trucks and cars; to cite but a few –, the BLUES model was not able to compensate the *WEG* trend in deforestation to keep the country's emissions within its 2°C budget. Actually, an intermediate deforestation rate scenario (IEG) already saturates the climate change options in Brazil.

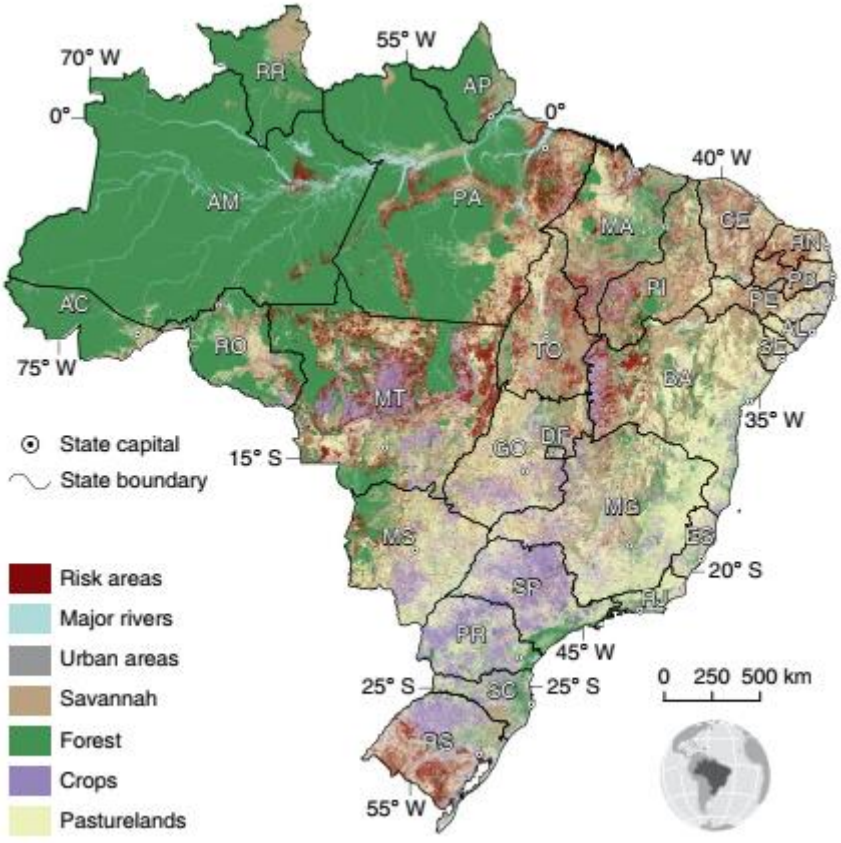

Figure 2 - Land use and deforestation risk areas in the WEG scenario by 2030

The investment costs of the energy system almost double under the *IEG* scenario, when compared to the investment costs of the *SEG* scenario, reaching 2.0 trillion US$$_{2010}$. Additional investments are concentrated in the energy sector, considering both power and fuel production. This means that, to contribute to the world's 2^{o}C path, other sectors of the Brazilian economy would need to pay a high cost for the setbacks in deforestation control policies.

Since Brazil would not be able to stay within its CO_2 budget requirement in the *WEG* scenario, a non-commitment cost for Brazil failing to comply with its CO_2 budget could be considered. One possible narrative is that, under this scenario, the rest of the world would need to reduce its emissions to compensate for Brazil not accomplishing its part. Nevertheless, Brazil could still fulfill its commitment by supporting third parties to reduce emissions in its place, although this would not be a least-cost solution for the world to reach the 2°C target. We estimate this additional cost using an implicit carbon price from trajectories consistent with a "below 2°C" world. Using a mean value of 370 US$/t$CO_2$, and the range of carbon prices available in the literature, as detailed in Figure S1 (162 to 505 US$/t$CO_2$), the total cost in the *WEG* scenario between 2010 and 2050 would be 2.0 to 3.3 times the total cost in the *SEG* scenario, with a mean value of 2.8 times (or 5.2 trillion US$$_{2010}$). Despite having an overall investment cost very similar to that of the IEG scenario, by accounting for the penalty cost in the WEG scenario the total cost highly exceeds those of all other scenarios (Figure 3).

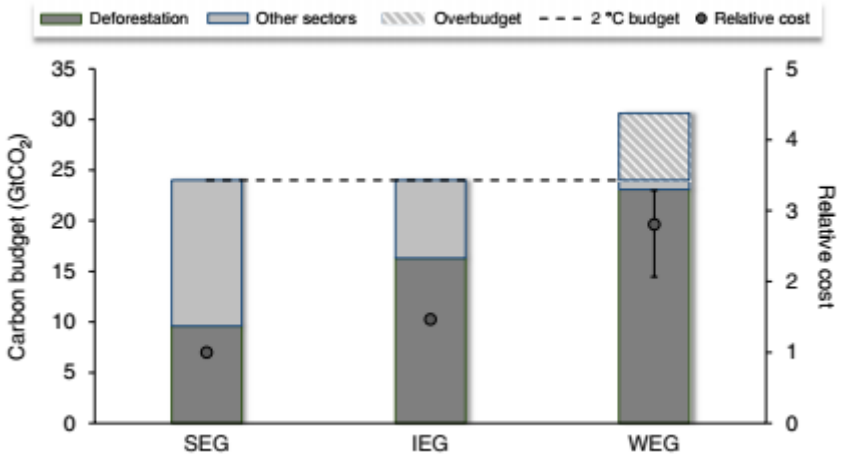

Figure 3 - CO_2 budget and cost analysis

It is worth noting that there are many uncertainties associated with the assumed Brazilian carbon budget for a "below 2°C" world. In the basic runs (*SEG*, *IEG* and *WEG*), an average value of the literature for the Brazilian carbon budget was used. To assess the role of the uncertainty in the budget, two additional cases are proposed: a low budget case, or LB, set according to the 25% percentile (equal to 16.5 $GtCO_2$ up to 2050), and a high budget case, or HB, set according to the 75% percentile (equal to 35.5 $GtCO_2$ up to 2050). While under a HB all three deforestation scenarios are theoretically compatible with a national budget for a "below 2°C" world (*SEG_HB, IEG_HB, WEG_HB*), a LB (*SEG_LB, IEG_LB, WEG_LB*) would be compatible only with the strong environmental governance scenario, *SEG-LB,* but at a much higher cost than the one found for the original SEG scenario (Figure 4).

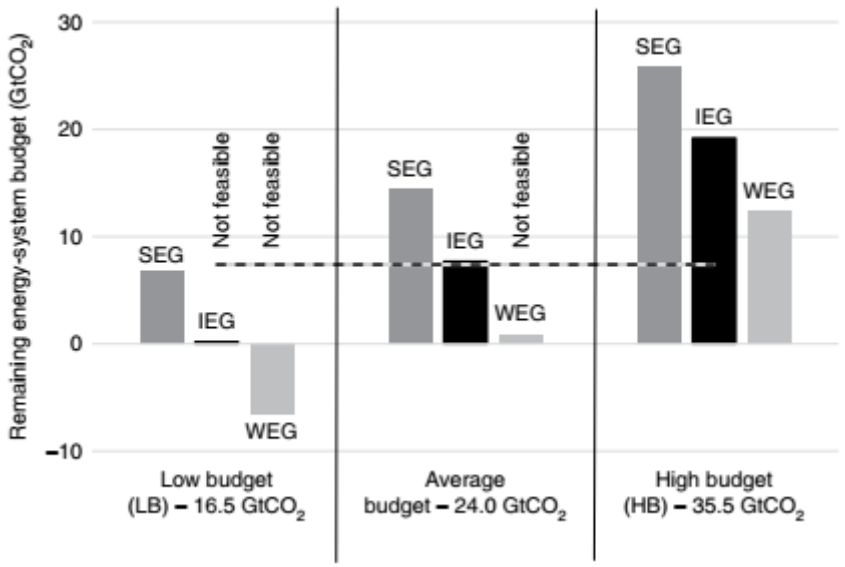

Figure 4 - Sensitivity analysis of different carbon budgets for Brazil

Clearly Brazil's NDC is at a high risk under the current political crisis, in which the government's attempt to dismiss successful environmental policies builds greater deforestation pressure in the Amazon and the Cerrado biomes. Paradoxically, to cope with higher CO_2 emissions ensuing from this "particularistic-short-term predatory" politics, Brazil would have to rely heavily on twenty-first century advanced technologies, many of which are not yet mature nor available, to curb emissions. This would imply in too large a cost for the domestic economy, and hence chances are that the country will not honor its commitments to reduce emissions and help the World fulfill the ambitions of the Paris Agreement. By all means, reducing deforestation is, by far, the lowest-cost option for achieving Brazil's pledges to the Paris Agreement and the ultimate goal of staying below 2°C.

The bottom line is that, either other sectors within the Brazilian economy will have to pay a tremendously high cost to compensate for deforestation, or part of Brazil's emissions reduction bill will fall over other countries' backs. Not to mention that the Amazon and the Cerrado biomes, which provide many important ecosystem services at the national and global scales, are in danger.

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Author contributions: Alexandre Szklo, André F. P. Lucena and Roberto Schaeffer performed the basic integrated modelling and conceived the methodological procedure. Alexandre Koberle and Pedro R. R. Rochedo were responsible for the energy system modelling and the final writing of the Supplementary Material. Britaldo Soares Filho, Juliana Leroy Davis and Raoni Rajão performed the land-use modelling and contributed to writing the manuscript and the Supplementary Materials. Eduardo Viola developed the political analysis and contributed to writing the manuscript and the Supplementary Materials. Regis Rathmann was responsible for the review of the land-use results.

Competing Interests statement

The authors declare no competing interests.

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