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Reducing carbon emissions from avoided deforestation in the Brazilian Amazon: an approach based on the Business-as-Usual (BAU) scenario

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Abstract

Objective: Historically, Brazil's largest source of GHG comes from changes in land use, strongly correlated with deforestation in the Amazon, which can compromise the Reduced Emissions (RE) established in the Intended Nationally Determined Contribution presented in the so-called Agreement from Paris. This study aimed to analyze the Business-as-Usual scenario (BAU scenario), projecting the reduced CO2 emissions from avoided deforestation originating from Land Use Changes in the Brazilian Amazon.
Methodology: Estimates of RE values referring to the historical baseline of deforestation from 2006 to 2020. In addition, the projection of the BAU scenario is based on the linear regression model of RE data from 2021 to 2030.
Relevance: Studies of deforestation scenarios are fundamental. Especially, this one consists of answering how emissions from deforestation would be configured if nothing changed in the future concerning the usual scenario or BAU scenario.
Results: In a pessimistic scenario with high deforestation rates, the BAU Scenario estimates would be: – 121.85 and – 271.31 MtCO2 in 2025 and 2030, respectively. Furthermore, the RE targets for the years: 2020 (154.7 MtCO2), 2025 (719 MtCO2), and 2030 (887 MtCO2) would be overestimated, contradicting the emission mitigation goals.
Conclusion: The main conclusion of the study is that in the context of the return of the high rates of deforestation in the Amazon, Brazil still has a great challenge to reach the desired levels of GHG emissions.

Keywords: Reduced emissions. Avoided deforestation. Business-as-Usual. Land use change.

Redução de emissões de carbono por desmatamento evitado na amazônia brasileira: uma abordagem baseada no cenário Business-as-Usual (BAU)

Resumo

Objetivo: O Brasil, historicamente, tem como principal fonte de emissão de GEE aquelas decorrentes de mudanças no uso da terra (MUT), fortemente correlacionado com o desmatamento na Amazônia, que pode comprometer as Emissões Reduzidas (ER) estabelecidas na Contribuição Nacionalmente Determinada Pretendida apresentada no chamado Acordo de Paris. Este estudo teve por objetivo analisar o cenário Business-as-Usual (cenário BAU) por meio da projeção de emissões de CO2 reduzidas por desmatamento evitado originário de mudanças de uso da terra da Amazônia Brasileira.
Metodologia: São realizadas estimativas de valores de ER referentes à linha de base histórica do desmatamento do período de 2006 a 2020, além da projeção do cenário BAU baseada no modelo de regressão linear dos dados das ER de 2021 a 2030.
Relevância: Estudos de cenários para o desmatamento são fundamentais, e este, em especial, consistiu em responder como se configurariam as emissões por desmatamento se nada se alterasse no futuro em relação ao cenário habitual ou cenário BAU.

Resultados: Em um cenário pessimista com altas taxas de desmatamento, as estimativas do cenário BAU seriam: –121,85 e –271,31 MtCO2em 2025 e 2030, respectivamente. Ademais, as metas de ER para os anos 2020 (154,7 MtCO2), 2025 (719 MtCO2) e 2030 (887 MtCO2) estariam superestimadas, contrariando os objetivos de mitigação de emissões.
Conclusão: A principal conclusão do estudo é que, em um contexto de retorno das altas taxas de desmatamento na Amazônia, o Brasil ainda tem um grande desafio para alcançar os níveis desejados de emissões de GEE.

Palavras-chave: Emissões reduzidas. Desmatamento evitado. Business-as-Usual. Mudança de uso da Terra.

Reducción de las emisiones de carbono derivadas de la deforestación evitada en la Amazonía brasileña: un enfoque basado en el escenario Business-as-Usual (BAU)

Resumen
Objetivo: Históricamente, la mayor fuente de GEI de Brasil proviene de cambios en el uso de la tierra, fuertemente correlacionados con la deforestación en la Amazonía, que puede comprometer las Emisiones Reducidas (ER) establecidas en la Contribución Prevista Determinada Nacionalmente presentada en el llamado Acuerdo de París. Este estudio tuvo como objetivo analizar el escenario Business-as-Usual (escenario BAU), proyectando las emisiones reducidas de CO2 de la deforestación evitada originada por los cambios de uso del suelo en la Amazonía brasileña.
Metodología: Estimaciones de los valores de ER referentes a la línea base histórica de deforestación de 2006 a 2020. Además, la proyección del escenario BAU se basa en el modelo de regresión lineal de los datos de ER de 2021 a 2030.
Relevancia: Los estudios de escenarios de deforestación son fundamentales. Especialmente, éste consiste en responder cómo se configurarían las emisiones por deforestación si nada cambiara en el futuro respecto al escenario habitual o escenario BAU.
Resultados: En un escenario pesimista con altas tasas de deforestación, las estimaciones del Escenario BAU serían: –121,85 y –271,31 MtCO2 en 2025 y 2030, respectivamente. Además, los objetivos de ER para los años: 2020 (154,7 MtCO2), 2025 (719 MtCO2) y 2030 (887 MtCO2) se sobrestimarían, contradiciendo los objetivos de mitigación de emisiones.
Conclusión: La principal conclusión del estudio es que en el contexto del retorno de las altas tasas de deforestación en la Amazonía, Brasil aún tiene un gran desafío para alcanzar los niveles deseados de emisiones de GEI.

Palabras clave: Emisiones reducidas. Deforestación evitada. Business-as-Usual. Cambio de uso del suelo.

Introduction

Reducing emissions from deforestation in developing countries was first introduced at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (COP 11), held in Montreal in 2005, with a proposal supported by the governments of Papua New Guinea and Costa Rica, among others, given the findings of the Intergovernmental Panel on Climate Change (IPCC) on the magnitud21we of emissions from deforestation.

Since then, most countries came to understand the importance of mitigating climate change, particularly related to the great potential for reducing global greenhouse gas (GHG) emissions in developing countries (World Bank, 2015).

Subsequently, an agreement was signed at COP 13 to launch a formal work program under the 2007 Bali Action Plan moved to involve policy approaches and positive incentives for “Reducing Emissions from Deforestation and Forest Degradation (REDD+)”. This mechanism includes reducing deforestation and forest degradation; the role of conservation and sustainable forestry management; and the forest carbon stocks growth in developing countries (Pavan & Cenamo, 2012; World Bank, 2015; WWF, 2016).

Moreover, this is grounded on the idea of encouraging policies to reward countries or projects that aim to reduce emissions from deforestation and forest degradation, contributing to increasing forest carbon stocks (Angelsen, 2008; Angelsen et al., 2013; Young, 2016).

In this context, the deforestation of tropical forests, particularly in the Amazon biome, has gained great prominence in international discussions based on scientific evidence on the impact caused on the stability of the planet's climate. This imbalance is largely due to the role played by forest ecosystems in regulating the carbon cycle due to the capacity to retain GHGs in the biomass, on the surface and below the ground.

To adopt actions in favor of low carbon development, the Brazilian government took a historic step with the approval of Federal Law n. 12,187, on December 29, 2009, which established the National Policy on Climate Change (PNMC). This policy aims to generate socioeconomic development compatible with the protection of the climate system, reducing anthropogenic GHG emissions from different sources.

Models that seek to search deforestation vectors have included several variables (Kaimowitz & Angelsen, 1998; Nepstad et al., 2009; Wunder et al., 2008; Dias, Dias & Magnusson, 2015). These are indicators that help in setting baselines or reference levels for mitigating emissions from deforestation.

One of the points raised in the Bali Action Plan is the importance of developing scenario studies for deforestation, with the idea based on the “Business-as-Usual” scenario (BAU scenario). That one consists of answering how emissions would be configured from deforestation if nothing changed in the future concerning the usual scenario. Thus, this approach considers an estimate of emissions based on a hypothetical scenario, considering that rarely exits measures adopted to promote deforestation mitigation.

It is essential to evaluate the potential for reducing carbon emissions, mainly carbon dioxide (CO_2), taking into consideration the standing Amazon Forest maintenance. In this direction, this article intends to analyze the Business-as-Usual scenario (BAU scenario) through the projection of reduced CO_2 emissions from historical rates of avoided deforestation originating from land-use changes in the Brazilian Amazon.

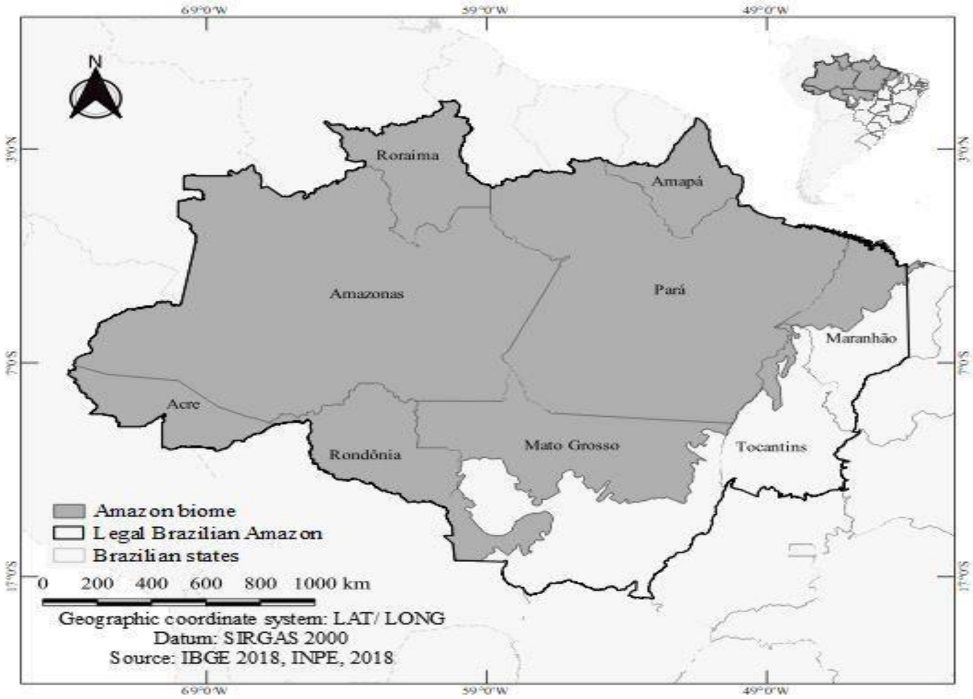
The importance of the Brazilian Amazon

The Brazilian Legal Amazon, covering about 60% of the country (~ 5.0 million km^2), was initially defined in 1953 (Law n. 1,806 of 01.06.1953) as a geopolitical criterion for developing government projects in the region. Therefore, the Legal Amazon included in that

Legal arrangement, the total territory of the states of Acre, Amazonas, Rondônia, and Pará, as well as the Federal Territories of Amapá and Roraima and parts of the States of Maranhão (the west portion of the 44th meridian), Mato Grosso (north of the 16th parallel, south latitude) and west of the state of Goiás at the time (north of the 13th parallel, south latitude), which later became part of the state of Tocantins[1]. The Amazon biome is the region defined essentially by ecological criteria, representing the area occupied by tropical forests (Nogueira et al., 2015). The Figure 1 bellow demonstrates the geographic space that encompasses the Amazon biome, the Legal Amazon, and the Brazilian states.

Figure 1

Amazon Biome, Brazilian Legal Amazon, and the Brazilian States



Source: Own elaboration (2019).

The Amazon biome provides several ecosystem services of crucial importance to humanity. According to the classification of the Millennium Ecosystem Assessment (Scholes & Ash, 2005), the ecosystem services provided by the Amazon rainforest can be classified as follows: i) support for human life: biodiversity, soil, and water; (ii) regulatory services: e.g., climate regulation, hydrological services, nutrient retention, carbon sequestration; (iii) supply services: e.g., timber and non-timber forest products; iv) cultural services: non-use values,

[1] Modifications to this initial configuration occurred with Complementary Law nº 31 of 10. 11. 1977, through which was incorporated the entire state of Mato Grosso into the Legal Amazon, and with the 1988 Constitution itself, which provided for the creation of the state of Tocantins and transformed the Federal Territories of Roraima and Amapá into states.

recreation, and ecotourism. The life support functions of ecosystems are considered "intermediate services", which allow individuals to use the other three categories of services.

Empirical studies on ecosystem services in the region have placed more emphasis on regulatory services related to the role of standing forests as a carbon sink (Saatchi et al., 2007; Killen & Portela, 2010), although there are targeted studies to other services (Roma et al. 2013; PBMC, 2018; Joly et al. 2019).

The impact on numerous ecosystem services due to environmental degradation caused by the expansion of predatory production accelerated in 2020, marked by the resurgence of deforestation. The advance of the agricultural frontier is the main cause of this process, and the ongoing deregulation of environmental protection exacerbates this process (Freitas, 2020).

However, this area expansion contributes very little to the economy, since the burned area is mainly designed for low quality and productivity pastures (Rajão et al., 2020).

In this context, the argument that it is necessary to open new forest areas to increase agricultural production is not supported. In addition, there is already a great open area that has been misused.

Besides contributing to climate change mitigation, the end of deforestation in the Amazon is essential for increasing agricultural productivity in the future (IPAM, 2017).

From the point of view of a cost-benefit analysis, a low market value paid for the carbon credit would not generate stimulus for emission reductions. The opportunity cost in terms of the annual income that would have to be lost for not economically exploiting the land in exchange for the profitability of agricultural activity at the current time is very high (Alves, 2019).

The loss of natural habitats also has negative impacts on extractive activity, both for timber and non-timber products, including Sustainable Use Conservation Units with potential for commercial timber exploitation or use by traditional populations linked to the exploitation of natural resources for subsistence. (Ferrante & Fearnside, 2019; Young & Spanholi, 2020).

Furthermore, it is critical to note that ecosystem services that provide a range of benefits that spill over the limit of the geographic space of the Amazon region, which is considered a global public good.

For that point, the social benefits generated by maintaining the standing forest would be disposal not only of residents (Diniz, Alves & Diniz, 2018; Diniz & Diniz, 2019).

In terms of losses of ecosystem functions and biodiversity, deforestation or its environmental implications takes on the character of a public bad. From this perspective, it causes a non-differentiated loss of well-being, regardless of the geographic region that encompasses the ecosystem. In this sense, an essential aspect of governance in the Amazon region is evident in the search for sustainable development at the global level (Sachs, 2008; Lago et al., 2012).

GHG emissions in Brazil: trends and main sources

Between the years of 1990 and 2014, Brazilian emissions range from 4% to 5% of global emissions (gross and net emissions), with wide variation, reaching a peak of 8% of global emissions in 2003. Brazilian per capita emissions remained above the global per capita emission throughout the period, except in 2010, when Brazilian emissions were equal to the global level (about 7.5 tCO_2/per capita/year), remaining between 6 and 8 tCO_2/per capita since then (Climate Observatory, 2016).

According to IBGE data (2020), Brazil reached a population of 204.5 million, a GDP of US$ 1.8 trillion, and a GDP per capita of US$ 8.8 thousand in 2015. This year, the country issued approximately 1.9 billion tCO_2, 9.7 tCO2 per capita, and 1.1 tCO_2 for every US$ 1 thousand of GDP (carbon intensity per national GDP).

Gross emissions of CO_2 in Brazil, equivalent to the Global Warming Potential (GWP) increased from 1.65 billion to 2.17 billion tons between the period of 1990 and 2016, an increase of 32%. During that time, Brazil emitted a total of around 60 billion tCO_2. It is attested that the emissions trajectory had different periods of growth and emission reduction, surpassing 2.5 billion tCO2 in 1995 and 3.8 billion in 2004 and falling to less than half of this value (1.8 billion tCO2) in 2012 (Climate Observatory, 2016).

In 2019, the increase in gross greenhouse gas emissions from Brazil was 9.6%. The country released 2.17 billion tons of CO_2 into the atmosphere, against 1.98 billion in 2018. The national GDP in the same year rose 1.1%, indicating that emissions in Brazil, unlike those of most other large economies, that are detached from a better socio-environmental condition.

Among the largest emitters, Brazil ranks 6th with 3.2% of the total emissions. Excluding the bloc of 28 European Union countries, Brazil became the fifth emitter. In 2019, the average CO_2 emission per Brazilian was 10.4 gross tons, against 7.1 tCO_2/per capita of the world average. Due to deforestation, per capita emissions in Amazonian states such as Mato Grosso, Rondônia and Roraima were three to six times higher than in the US. Regarding the carbon intensity, there is a growth of 3% between 2018 and 2019. This way, the country generates less wealth for each ton of carbon emitted. The increase in the intensity of emissions per unit of GDP is associated with the aggravation of the deforestation process, mainly through illegal activities that generate little wealth.

Deforestation, especially in the Amazon, drove the growth in emissions in 2019. The amount of greenhouse gases released into the atmosphere by the land use change sector increased by 23% this year, reaching 968 million tons of CO_2 against 788 million in 2018. In 2019, land use changes continue to be the main source of gross emissions in Brazil (44% of the total), followed by the agricultural and livestock sectors, with 598.7 million (28% of the total), energy, with 413 .7 million (19%), industrial, with 99 million (5%) and waste, with 96.1 million (4%) (Observatório do Clima, 2020).

In particular, the Land Use Change sector presents large variations in emissions over time due to the dynamics of deforestation, while in other sectors there has been a continuous growth in emissions since the 1990s. Strongly associated with the dynamics of deforestation of the original forest cover in these biomes, mainly due to the impact of agricultural activity on them (Observatório do Clima, 2016). Most gross emissions (93%) are caused by changes in land use, mainly due to deforestation in the Amazon biome, which concentrates 87% (841 $MtCO_2$) of the sector's gross emissions.

According to a study by Azevedo et al. (2020), deforestation in the Amazon can be used as a proxy to understand the behavior of emissions in the land use change sector. In these terms, the authors infer that, considering a more conservative scenario, Brazil will have an estimated increase of 226 $MtCO_2$ in gross emissions for the land use change sector in 2020 compared to 2018, which represents an increase of 29%. If the deforested area follows the same pattern as in 2019, Brazil will have an increase in gross emissions from deforestation estimated by 396 $MtCO_2$, or 51% compared to 2018.

Public policies to reduce deforestation and greenhouse gas emissions

According to Barreto & Araujo (2012), in Brazil, due to greenhouse gas emission growth from deforestation among a series of measures, internal institutional efforts are mobilized with the creation of the Action Plan for Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), gaining greater efficiency and more concrete results for the sustained drop in deforestation.

The first articulated plan to combat deforestation in the Amazon was the PPCDAm, launched in March 2004, which emerged as a response from the federal government due to high deforestation rates in the early 2000s and pressure from civil as well as the international society, for the control of deforestation.

Over two years, the PPCDAm carried out a series of crucial actions, among them (Moutinho et al., 2011): it created Federal Conservation Areas (Protected Areas), including 25 million hectares of areas under pressure due to the expansion of deforestation; denied 60,000 land titles that were not reported to the National Institute for Colonization and Agrarian Reform (INCRA); conducted hundreds of enforcement operations through IBAMA together with the federal police, the army, the National Security Force, among other agencies, using monitoring and intelligence tools and created the Amazon Fund (Federal Decree 6,527 of 2008) intending to raise funds for actions to prevent, monitor and combat deforestation and promote conservation and sustainable use in the Amazon biome (Climate Observatory, 2016).

Although studies indicate other factors that contributed to the reduction to deforestation in the second half of the 2000s, part of the reduction was associated with the PPCDAm and its consequences (Arima et al., 2014; Nepstad et al., 2014; Ferreira & Coelho, 2014; 2015). Between 2004 and 2010, there was a 76% reduction in the deforested area in the Amazon, according to INPE. One of the most remarkable results is the deforestation reduction rate by about 80% in 2015 compared to the beginning of the plan in 2004 (MMA, 2015).

In line with these actions, in 2009, the Brazilian government approved the Federal Law 12,187, which established the National Policy on Climate Change (PNMC). This policy aims to turn socioeconomic development compatible with the protection of the climate system, reducing anthropogenic GHG emissions from different sources. Its targets are aligned with the promotion of sustainable development and scientific- technological research, as well as the dissemination of technologies, processes, and practices aimed at mitigating climate change, reducing emissions at their source, and increasing carbon sinks.

According to article 12 of the law that created the PNMC, Brazil started to adopt actions to mitigate emissions, with the intention of reducing between 36.1 and 38.9% of its projected emissions by 2020 (which is equivalent to a reduction of 17% compared to 2005 levels). This objective includes the goal of reducing deforestation by 80% in the Amazon, relative to the average verified between 1996 and 2005, as defined in the National Plan for Climate Change, launched in December 2008 (Moutinho et al., 2011).

One of the objectives proposed by the plan is the sustained deforestation reduction rates in the Amazon, achieving zero illegal deforestation, in addition to eliminating the net loss of vegetation cover (Pavan & Cenamo, 2012; Arima et al., 2014). Over time, the plan was fully incorporated into the National Policy on Climate Change, which allowed Brazil to guarantee its eligibility for the creation of REDD mechanisms (Moutinho et al., 2011). Despite the creation of these environmental measures, in 2020 Brazil had a growing trajectory of GHG emissions, following in the opposite direction of the strong downturn expected for the Brazilian and global economy, going against the goals of the National Policy on Climate Change (Azevedo et. al., 2020).

Subsequently, Brazil submitted its proposed domestic GHG emissions reduction target, the NDC (then called INDC, or Intended Nationally Determined Contribution) presented in the UNFCCC in late 2015. The NDC identifies agreed government actions to reduce emissions previously during the 21st Conference of the Parties (COP 21) of the UNFCCC, held in Paris in December 2015.

As a result of the agreement, Brazil has committed to reduce emissions by 37% by 2025, reaching 43% by 2030, compared to 2005 levels. Furthermore, based on the data presented in the document "Fundamentals for the elaboration of the Intended Nationally Determined Contribution (NDC) of Brazil in the context of the Paris Agreement under the

UNFCCC", of the Ministry of the Environment (MMA, 2016), by 2030 the expectation is to increase emissions by 107% in the Energy sector, 1% in the area of Agriculture, reduce net emissions from the MUT sector by 111% (reduction of 90% of gross emissions), increase by 29% emissions from industrial processes and 17% GHG from waste treatment (always compared to 2005).

Despite the commitments made, the country has not yet presented its plan to implement the first NDC. Besides that, in 2020, Brazil is in an emission trajectory opposite to that recommended in the Paris Agreement (Climate Observatory, 2020). The growth in fires since 2020 will make Brazil one of the few countries in the world to expand GHG emissions even in the context of the Covid-19 pandemic (Azevedo et al., 2020).

Regarding the critical political situation, the Brazilian government started to adopt several measures to weaken the forest protection by environmental governance created in the last decades, including the amnesty of lands deforested in the past, the reduction of protected areas, the weakening of the licensing and the halting of indigenous land demarcations (Carvalho et al., 2019; Ferrante & Fearnside, 2019, Pereira et al. 2019; Reydon, Fernandes & Telles, 2020; Observatório do Clima, 2020).

Regarding this trend, the situation has drastically worsened with the recent administration of the federal government that takes measures that directly affect environmental policies, such as: the extinction of the Secretariat of Climate Change and Forests of the Ministry of the Environment (January 2019); the budget reduction of the Institute for the Environment and Renewable Natural Resources (IBAMA) (April 2019); the change in the composition of the National Environment Council (CONAMA), with the reduction of civil society representation (May 2019); an aggressive discourse in relation to indigenous peoples and their lands, which leads to an increase in illegal activities by land grabbers, small miners and criminally organized loggers; the attempt to change the destination of the Amazon Fund to compensate land expropriation (May 2019) and the consequent suspension of contributions to the fund by donors (Norway and Germany) (August 2019), among other actions (Viola & Gonçalves, 2019; Ferrante & Fearnside, 2019).

A study on deforestation from 2019 to 2020 demonstrates that forest loss increased in areas considered less affected by that problem such as protected areas, indigenous lands, conservation units (private areas whose properties are included in the Rural Environmental Registry), and even in permanent preservation areas and legal reserve (Azevedo et al. 2021). It reinforces the thesis that there was a decline in the enforcement power of environmental authorities in the country during this period.

The deforestation growth in the Amazon, according to the INPE DETER System, in the June-August 2019 period compared to 2018 was 90% in June, 278% in July, and 222% in August (Viola & Gonçalves, 2019).

Thus, it is not necessary to say that actions currently proposed by the federal executive may have harmful effects on forests, biodiversity, and traditional peoples, including indigenous peoples, quilombola communities, and the population living alongside rivers. This puts international funding agencies on alert regarding the assessment of the risks of investments in projects that cause deforestation and land conflicts, contributing to global warming and human rights violations. The same concern should influence companies and countries that import soybeans, meat, and ores from Brazil. The responsibilities of the various international actors will be a critical issue as the story unfolds in the Brazilian Amazon in the coming years (Ferrante & Fearnside, 2019).

Methodology

Estimate of carbon emission reduction from avoided deforestation

The historical baseline, considering deforestation rates in the Brazilian Amazon provided by the National Institute for Space Research (INPE, 2020), was used to calculate reduced CO_2 emissions between 2006 and 2020.

According to the methodology proposed in projects to raise funds from the Amazon Fund (SFB, 2013), with the objective of calculating the baseline of avoided deforestation, a parameter was adopted based on the average of deforestation in a period of ten years, the Average Deforestation Rate (ADR), which will be subtracted from the annual Deforestation Rates (DR). These decades are updated every five years; for example, the ADR for the years between 1996 and 2005 will be subtracted from the DR, for each year between 2006 and 2010. In the subsequent period, the ADR between 2001 and 2010 will be subtracted from the DR between 2011 and 2015. Finally, the ADR between 2006 and 2015 will be subtracted from the DR between 2016 and 2020.

With the estimates in hand, the reduced carbon emissions (RE) result from the multiplication of the area of reduced or avoided deforestation (ADR - DR) by the carbon stock in the biomass (tC/ha). The formula of the calculus can be represented as follows:

$$RE = (ADR - DR) * tC/ha \quad (1)$$

Where RE represents reduced carbon emissions from avoided deforestation, ADR is the average deforestation rate, DR is the annual deforestation rate, and tC/ha is tons of carbon per hectare of forest.

Regarding the emissions of most greenhouse gases, these can be measured based on the total molecular mass of the gas, that is, the units of carbon dioxide that can be converted to units of carbon, dividing 44/12, or 3.67 (EIA, 1997). In this sense, for methodological reasons, the Amazon Fund established an equivalent of 100 tC/ha in biomass, which represents 367 tCO_2/ha. It is grounded in the conversion from C to CO_2 (= 3.67) (SFB, 2013).

Method for estimating emission reduction baselines

One of the main elements in determining emission reductions is the establishment of a national baseline. In this regard, there is a debate about the terminology of the term 'baseline' that has at least three different meanings: Historical baseline that represents CO_2 emissions from deforestation and degradation rates (DD) in a given period; Baseline that represents the reference or "Business-as-Usual" scenario (BAU scenario), which projects past trends to simulate how emissions could evolve if nothing changes in the future, that is, without actions to tackle the problem of deforestation, and; Credit baseline (e.g., as an emissions quota) that serves as a benchmark for rewarding a country (or project) if emissions are below the desired level (emission quota) or do not result in a reward if there is a deficit due to high emission levels.

According to Angelsen (2008), in a study for carbon pricing in the credit market for this asset from Reducing Emissions from Deforestation and Forest Degradation (REDD), attest that those who demand emission reductions must have an incentive to reduce deforestation to a minimum. It is a level where the reduction marginal cost (the national supply curve of reduced emissions equals the international offset represented by the market price for REDD (REDD credit)).

Based on this, Figure 2 shows the producer's monetary gain (producer's surplus) when participating in the carbon market. The carbon market is a mechanism created by the Kyoto Protocol to help developed countries achieve their GHG reduction targets. GHG-emitting countries can offset their emissions by purchasing emission permits or carbon credits generated elsewhere.

Each carbon credit is equivalent to the sequestration of one ton of CO_2 from the atmosphere, e.g., through its fixation in the biomass of the growing trees. In developing countries such as Brazil, the carbon market is regulated by the Clean Development Mechanism (CDM). That market is setting up projects to sequester or reduce GHGs.

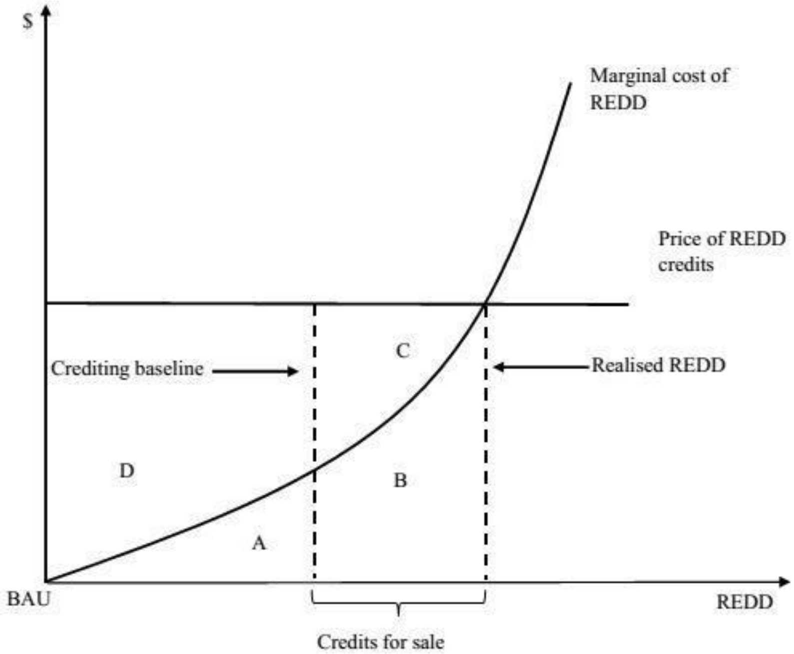
Besides CDM, there are projects developed in the so-called voluntary market. This one permits carbon credits to be purchased by companies interested in offsetting their GHG emissions through the negotiation of credits, e.g., on the Chicago Climate Exchange (CCX) or in contracts signed directly between the parties involved in the project (Pereira et al., 2010).

It is postulated that the marginal cost of reducing deforestation starts at zero and increases as reductions become more expensive. Thus, given an international price for the

REDD credit, a country will reduce emissions from deforestation to the point where the marginal cost equals the price paid for the carbon credit (realized REDD).

Figure 2

Crediting baseline



Source: Angelsen (2008).

Any point above the marginal cost curve and below the marginal benefit curve (REDD credit price) will be a gain for the producer. If the credit baseline is equal to the level of the BAU scenario, the benefit (income) will be D + C (income equals area A + B + C + D, while costs equal figure areas A + B). If the credit line limit is different from the level of the BAU scenario, then the earnings of producers (REDD projects) will be represented by area C - A (income will be area B + C and cost will be area A + B). Thus, the projected income (area C) must be greater than the cost (area A) to obtain positive gains.

Given the theoretical framework, the baseline of the BAU scenario is a reference to provide input to the assessment of the emission reduction impact. The crediting baseline is the benchmark to the potential monetary value with the REDD credits sale. In other words, the latter represents how much can be paid for the REDD result achieved in a given period. From an economical point of view, considering that countries cannot influence the market price of carbon credits, it is assumed that the marginal cost equals the marginal benefit (price paid for the credit) from the sale of this asset. It makes it possible to calculate the potential value associated with the results achieved with the reduced carbon emission from avoided deforestation.

BAU Scenario projection

Based on the fundamentals described in the last section, the methodology proposed in this work estimates the projections of the Business-as-Usual Scenario (BAU scenario) with reference to the projections of RE values in the period from 2006 to 2020 based on the linear regression equation, as described below:

Linear Model:

$$REi = \alpha + \beta ti + ei \qquad (2)$$

Where REi is the variable reduced emissions in period i, which assumes values estimated from the regression equations as a function of the time variable ti in period i, which assumes the values 1,2,3, ... n, according to the chronological order of n RE observations; ei is the random error term; α is the intercept or model constant and β is the regression trend coefficient.

The possible paths of RE supply projected for the Amazon are estimated considering the reductions in GHG emissions, which have historically been associated with Land Use Change, especially deforestation.

The results of the projected values are compared to the expected CO_2 emission reduction levels with the decline in Amazon deforestation rates, considering the reduction targets defined by the government. The calculation of the drop in emissions for the Amazon for the years 2025 and 2030 considers the percentages of variation published in the MMA (2016) based on data generated by the Greenhouse Emissions Estimation System (SEEG, 2019).

Finally, using the projections of the BAU scenario, a key factor to consider is the valuation of CO_2 emission reductions from the MUT sector, which represents the trajectories for the supply curve of credits for emission reductions in the Amazon until 2030. For this calculation used the minimum value of US$ 5 and the maximum value of US$ 15 per ton of CO_2. These values are based on the standard price of five US dollars per ton of carbon dioxide corresponding to the emissions avoided in the country used in negotiations with international donors, mediated by the National Bank for Economic and Social Development (BNDES) to raise funds for the Amazon Fund (SFB, 2013). Furthermore, Moutinho et al. (2011) also calculate the fundraising potential for the national contribution to reducing emissions converted into “reduced emissions certificates” or REDD credits equivalent to 1 ton of carbon dioxide, using the range of values between US$ 5 and US$ 15 dollars per ton.

Results and discussion

The estimated RE (or avoided emissions) for the period 2006 to 2020 totaled 3.5 billion tCO_2, which could be allocated to "emission reduction certificates", or REDD credits (Table 1). The commercialization of the credits would generate a potential amount of financial resources between 17.8 and 53.3 billion dollars, considering a minimum value of US$ 5 and a maximum value of US$ 15. These values indirectly represent an estimate of the cost of deforestation avoided in the Amazon by 2020.

By the end of 2017, the Amazon Fund had received around US$ 1 billion in donations, 93.3% from the Norwegian government, 6.2% from the German government and 0.5% from the company, Petróleo Brasileiro S.A., Petrobras (Amazon Fund, 2017). Thus, in comparative terms, it is inferred that the fundraising potential related to avoided emissions for the Amazon exceeds the volume of financial resources that were raised by the Fund.

Table 1

Average deforestation rate (km²), deforestation rate (km²), reduced deforestation (km²) and reduced carbon emissions (millions of tons) in the Amazon biome

Year	Average Deforestation Rate	Deforestation Rate	Reduced Deforestation	Reduced Emission
2006	19,625.30	14,286.00	5,339.30	196
2007	19,625.30	11,651.00	7,974.30	292.7
2008	19,625.30	12,911.00	6,714.30	246.4
2009	19,625.30	7,464.00	12,161.30	446.3
2010	19,625.30	7,000.00	12,625.30	463.3
2011	16,530.90	6,418.00	10,112.90	371.1
2012	16,530.90	4,571.00	11,959.90	438.9
2013	16,530.90	5,891.00	10,639.90	390.5
2014	16,530.90	5,012.00	11,518.90	422.7
2015	16,530.90	6,207.00	10,323.90	378.9
2016	8,141.10	7,893.00	248.1	9.1
2017	8,141.10	6,624.00	1,517.10	55.7
2018	8,141.10	7,536.00	605.1	22.2
2019	8,141.10	10,129.00	-1,987.90	-73
2020	8,141.10	11,088.00	-2,946.90	-108.2
Total	221,486.50	124,681.00	96,805.50	3,552.70

Source: Own elaboration (2020).

The achievement of the Brazilian goal of reducing the rate of deforestation in the Amazon to a level equal to or less than 3,925 km² by 2020, defined by the PNMC, would imply a drop in emissions of the order of 154.7 $MtCO_2$ [(8,141.1 - 3925) x 100 x 367]. However, the deforestation rate in 2020 was around 11,000 km², as shown by INPE data (2020). In this manner, the goal of reducing deforestation by 80% in relation to the average from 1996 to 2005 was not met in 2020.

It is asserted that, in 2020, the deforestation rate was above the average for the period 2016 - 2020, resulting in a negative estimate of RE (-108.2 $MtCO_2$), which can be understood as an inflection of the mitigation trend of deforestation emissions achieved with avoided deforestation since 2006, representing increases in emissions from 2019.

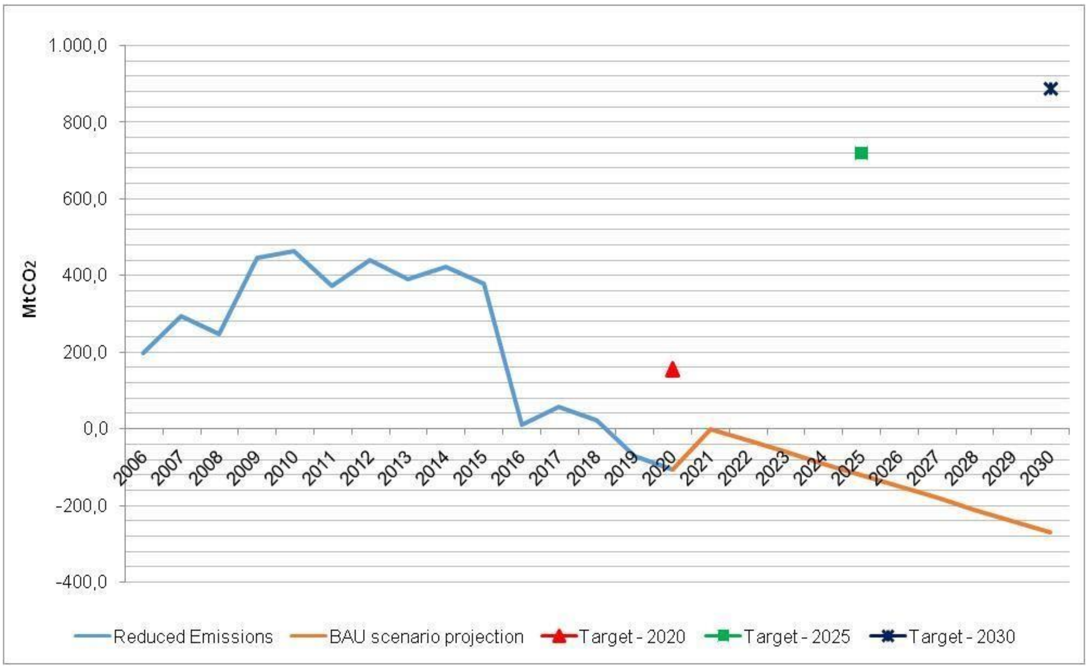
Regarding the Brazilian emission reduction targets, according to the Nationally Determined Contribution, a reduction of 90% (1,699.5 $MtCO_2$) of net emissions is expected by 2025, and a reduction of 111% (2,096.05 $MtCO_2$) by 2030, compared to 2005 levels (1.8 $GtCO_2$) (MMA, 2016). Thus, Brazilian emissions from Land Use Change would reach 188.8 $MtCO_2$ in 2025 and -207.71 $MtCO_2$ in 2030.

Regarding the Amazon, in 2005, the region accounted for 63.49% (1.2 $GtCO_2$) of emissions from the national MUT sector (SEEG, 2019), therefore, a target for RE in the region is estimated 719 $MtCO_2$ in 2025 and 887 $MtCO_2$ in 2030.

Due to the increase in forest losses observed in the Amazon from 2012 onwards, being a potential barrier to the reduction of future emissions, it is evident that in a pessimistic scenario, a scenario of high deforestation, represented by the trajectory resulting from the BAU Scenario Projection, the RE estimates would be equivalent to –121.85 and –271.31 $MtCO_2$ in 2025 and 2030, respectively (Figure 3).

Figure 3

Reduced Emissions, BAU Scenario projection, and reduction targets for 2020, 2025 and 2030



Source: Own elaboration (2020).

From the linear regression of the reduced emissions data – RE, the results were obtained for the linear trend model: REi = -29.89 + 475.98ti, R^2 = 0.43 and p-value of 0.000 and 0.008 for α and β, respectively. The results indicate that, in the period from 2006 to 2020, on average, there were increases in RE at an absolute rate of 475.98 million tons, indicating a positive trend. That is, each year, RE increased by about 476 million.

Furthermore, with the decreasing trend in RE, with negative values starting in 2019, which may mean an increasing volume of CO_2 in the atmosphere, and, consequently, that the RE target for the year 2020 (154, 7 $MtCO_2$); 2025 (719 $MtCO_2$) and 2030 (887 $MtCO_2$) would be overestimated, considering the persistence of high deforestation rates. And so, contradicting the emission mitigation objectives intended by Brazil in the context of the Paris Agreement.

Finally, as an exercise in estimating the cost of reducing emissions based on projected CO_2 values, it is inferred that in the year 2025, this cost would be equivalent to 609.2 million and 1.827 billion dollars, considering values of 5 and 15 dollars per ton of CO_2, respectively. In 2030, these values would reach US$ 1.356 and US$ 4.069 billion.

Considering the targets for these years, it is evident that the potential for reducing emissions (RE according to the target per year minus the RE projected by the BAU Scenario) by results achieved would be 597.16 $MtCO_2$ and 615.71 $MtCO_2$ in 2025 and 2030, respectively.

Therefore, the hypothesis of maintaining the current trend of increasing forest clearing, or Business-as-Usual, implies increasing levels of emissions, which restricts the potential for capturing financial resources due to results achieved by reducing emissions from avoided deforestation. In this direction, the challenge of encouraging deforestation becomes even more critical given the inefficiency and mismanagement of the current government's environmental policy, which has been carrying out deliberate actions to dismantle control and prevention bodies created in recent decades in Brazil.

Considering that actions to mitigate deforestation in the Amazon have a cost of environmental governance, the value estimates express the cost attributed to the conservation of the ecosystem function of carbon sequestration provided by the Amazon Forest, which represents the quantification of values to keep the forest standing.

Conclusion

The objective of this work was to analyze the scenario for reduced CO_2 emissions from avoided deforestation due to Land Use Changes. It was found that the commercialization of credits from reduced emissions in the Amazon in the period between 2006 and 2020 would generate a potential number of financial resources between 17.8 and 53.3 billion dollars. These values represent an estimate of the cost of avoided deforestation in the Amazon until 2020, which exceeds the volume of financial resources that were raised by the Amazon Fund.

In 2020, the deforestation rate was above the average for the period from 2016 to 2020, in other words, there was an inflection of the trend towards mitigating emissions from avoided deforestation observed in the second half of the 2000s. In this sense, due to the increase in forest losses observed in the Amazon from 2012 onwards, it was inferred that, in a pessimistic scenario with high deforestation rates, the estimates, according to a linear growth trajectory of the RE in the perspective of the BAU Scenario, would be equivalent to -121.85 and -271 .31 $MtCO_2$ in 2025 and 2030, respectively.

The results also indicate that, in the period from 2006 to 2020, on average, there were increases in RE at an absolute rate of 475.98 million tons, indicating a positive trend. However, it was observed that from 2019 onwards the ER estimates started to assume negative values. In addition, the RE targets for the years: 2020 (154.7 $MtCO_2$); 2025 (719 $MtCO_2$) and 2030 (887 $MtCO_2$) would be overestimated, considering the persistence of high rates of deforestation, thus contradicting the intended emissions mitigation objectives in the context of the Paris Agreement.

Finally, regarding the estimation of the cost of reducing emissions based on the projected CO_2 values, it was inferred that in the year 2025, this cost would be between 609.2

million and 1.827 billion dollars. In 2030, these values would reach US$ 1.356 and US$ 4.069 billion.

Considering the emission reduction targets, it is evident that the potential net value for results achieved would be 597.16 and 615.71 million tons of CO_2 in 2025 and 2030, respectively. In this direction, environmental governance actions with a view to combating forest destruction would play a key role in increasing the potential for capitation of financial resources for results achieved with emission reductions from avoided deforestation.

Considering that actions to mitigate deforestation in the Amazon have a cost of environmental governance, the value estimates express the cost attributed to the conservation of the ecosystem function of carbon sequestration provided by the Amazon Forest, which represents the quantification of values to keep the forest standing.

Regarding the dynamics of deforestation in the region, it is understood that the environmental damage associated with Land Use Changes, being the main source of Brazilian emissions, is a major barrier to promoting a significant drop in future emissions in the country.

In addition, despite the remarkable results with the decrease in deforestation, which made it possible to generate an enormous environmental asset with the reduction of emissions from 2004 onwards, the high rates of forest loss in recent years are well above the desired level to meet to environmental policies in the context of climate change.

The variations in emissions may differ from the desired levels according to the goals defined by the government, since the scenarios for future deforestation are linked to the country's political and economic situation. In this sense, the development of future research on the topic addressed in the article must follow the changes in the usual scenario regarding the trajectories of deforestation rates and CO_2 emissions released by official statistics in the coming years in order to verify to what extent they are converging to the desired levels.

Furthermore, the estimate of carbon stock per hectare of forest, used in the methodology for calculating Reduced Emissions (RE), can be refined by obtaining an annual historical series of carbon stock data, considering annual emissions, to measure the net carbon stock per representative hectare of forest.

The study of REDD credits valuation could have been thought of in a disaggregated way through estimates for the Amazonian states, considering that they have their state emission reduction plans. In particular, this challenge comes up against limitations in collecting accurate carbon stock data due to many variations associated with the spatial heterogeneity of the region, considering the various peculiarities of different locations, with the actual amounts of carbon present in the entire region being very little known.

In light of the foregoing, the changes observed in the country's political, environmental and economic conjuncture that move towards weakening environmental governance for protecting forests can negatively influence future deforestation and, consequently, the drop in

Brazilian emissions. For all the aspects discussed in the article, it is emphasized that Brazil still has a great challenge to reach the desired levels of GHG emissions.

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