New study from the Brazilian Institute of Space Research (INPE) quantifies the role of deforestation and forest degradation in the CO_2 emissions until 2050.

INPE presents updated scenarios of land use and greenhouse gas emissions for the Brazilian Amazon region, combining quantitative and qualitative elements in a study that has just been published by CCST (Earth System Science Center) researchers. Here the on-line version of the article.

The study helps to clarify the potential and limitations of the targets proposed by Brazil for the iNDC (Intended Nationally Determined Contribution), subsidizing the discussions to the COP 21 in Paris.

Ana Paula Aguiar, a researcher at CCST/INPE and one of the study leaders, explains that the need for development of new scenarios emerged from the changes observed in the region in the last decade. "Several studies discussed the future of the Amazon region in the 2000s, with a primary focus on the issue of deforestation. However, those studies were developed based on a socio-economic and institutional context of total lack of deforestation control – and even their most optimistic scenarios would be considered very pessimistic today. The situation changed and then there was a need to update the scenarios. But the region's future remains very uncertain. For example, while the deforestation rates in the Amazon region have fallen since 2004, they have stabilized at around 6,000 km²/year over the past 5 years. Will they fall further, stabilize or rise again? Will the Forest Code be fulfilled? How will environmental liabilities be settled? Will the present high levels of forest degradation be reversed? The answers depend on a number of both external and internal factors – in special on how the governments and the society will deal with the demand for land and commodities in the coming decades. But the new scenarios we propose are not limited to the issues of natural resources and land use. They are comprehensive, explicitly including the social dimension as an axis of the discussion. Relevant issues such as the chaotic urbanization and the inequality in access to resources of the region have also been addressed", says the researcher.

In this context, contrasting narrative scenarios about the future were built in a participatory manner, through workshops with representatives of civil society and government, under the AMAZALERT project, in partnership with EMBRAPA, the Emilio Goeldi Museum and several other organizations. Elements of these narratives relating to the use of natural resources were quantified using computational models capable of predicting the regional CO_2 balance - considering alternative trajectories of *deforestation*, *secondary vegetation dynamics* and also *forest degradation*.

"It is the first work that includes these three processes in the carbon balance of the Amazon in a spatially explicit way. The scenarios represent contrasting stories, but feasible ones, and include a number of assumptions on policies for the region - in particular on whether or not the Forest Code will be fulfilled, "says Jean Ometto, head of the CCST / INPE and one of the research leaders.

This study integrates datasets produced by INPE's monitoring systems (PRODES, DEGRAD e TerraClass and uses the open source modelling tools LuccME and INPE-EM also developed by INPE.

Summary of scenarios

The most optimistic scenario (Scenario A - Sustainability) represents a future with significant progress in socio-economic and environmental dimensions. In this scenario, the Restoration and Conservation measures provided in the Forest Code are not only met, but exceeded. The region would become a carbon sink after 2020 due to the end of both clear-cut deforestation and forest degradation processes, combined with an increase in the secondary vegetation area (and its length of stay), leading to a process of Forest Transition.

The opposite scenario, rather pessimistic (Scenario C – Fragmentation), assumes a setback in the environmental and social advancements in the last decade, with a return to higher rates of deforestation and disrespect to the Forest Code, together with a chaotic urbanization process and intensification of social problems.

Finally, an intermediate scenario (Scenario B – Middle-of-the-road), combines assumptions of the two more extreme scenarios. This scenario also considers the enforcement of the Forest Code, with legal deforestation rates at around 4,000 km²/year after 2020. The Legal Reserves are regulated, primarily by the compensation mechanism in the same biome and the secondary vegetation maintains the same current dynamics of abandonment and cyclical cut in the less consolidated areas. In this scenario, perhaps the most plausible one, the region remains a source of CO_2 emissions.

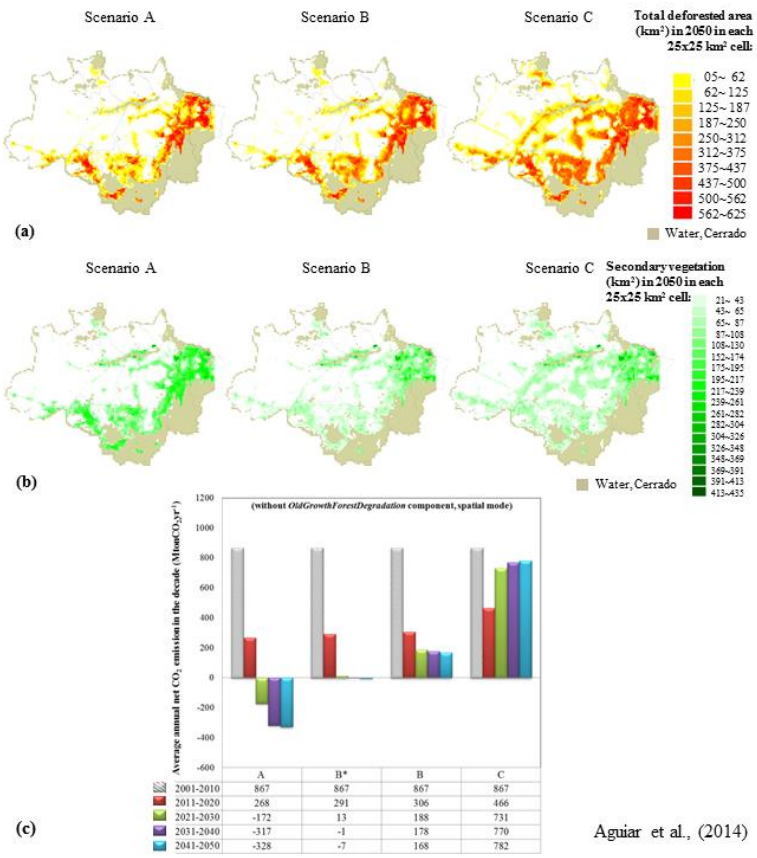

Figure 1: (a) Total deforestation by 2050; (b) Secondary vegetation area by 2050; (c) Net emission estimates per decade.

About the plausibility of the scenarios, the study's authors warn: "Scenarios are not forecasts. To say that the Amazon will become a carbon sink, as in Scenario A, without clarifying all the underlying assumptions would be a mistake. Scenarios are only internally consistent stories about how the future may develop. Scenario techniques are applied precisely when uncertainty about the future is very big. Moreover, the future depends on our actions today. Whether it will be closer to scenario A or C, will depend on the organization of society in one direction or another. Fostering this discussion is the main objective of the proposed method.

Scenarios and Brazil's iNDC

In the land use change and forests sector, the iNDC provides for, among other aspects: "strengthening policies and measures with a view to achieve, in the Brazilian Amazonia, zero illegal deforestation by 2030 and compensating for greenhouse gas emissions from legal suppression of vegetation by 2030". In other words, Brazil is proposing zero net emissions from deforestation by 2030 – in a situation between the scenarios A and B described above. Some aspects of the CCST/INPE study can help in the analysis of the challenges of such targets:

1. ***Zero illegal deforestation in the Brazilian Amazon* - What does it mean?** Several recent papers published in the scientific literature have estimated the area that can be legally cleared in accordance with the Forest Code, obtaining values from 86,000 km^2 to 290,000 km^2 (Martini *et al.*, 2015; Soares-Filho *et al.*, 2014; Sparovek *et al.*, 2015). Scenario B in Aguiar et al. (2015) considers a deforestation rate (legal) around 4,000 km^2 / year after 2020 (ie, a loss of approximately 140,000 km^2 in the period 2015-2050). An important source of uncertainty relates to how these studies considered public lands without destination, especially in the state of Amazonas. The options in relation to these areas are (i) the creation of protected areas or (ii) making them intended for agricultural production. The creation of protected areas in these areas could substantially reduce the potential for legal deforestation. On the other hand, the literature indicates (which has also been widely discussed in the participatory process of building scenarios) the fragility of existing protected areas, including unconsolidated conservation areas and the pressure on indigenous lands (Ferreira et al., 2014). Finally, it is worth noting that, deforestation rates fell significantly after 2004, but stabilized at 6,000 km2 in recent years. Therefore, the maintenance and improvement of the set of actions of *PPCDAM* (Plan for Prevention and Control of Deforestation in the Legal Amazon) and the strengthening of institutional frameworks (to avoid setbacks) are essential, so that, deforestation rates remain at the maximum within legal limits and not increase again towards Scenario C (Table S1.1 of the supplementary material of the article presents an overview of required actions resulting from the participatory process of building the scenarios).
2. ***Compensation of emissions from legal deforestation:* (a) The role of secondary vegetation in the carbon balance.** One way to offset emissions from legal deforestation in the Amazon would be the absorption of CO_2 through the regeneration of secondary vegetation. According to the TerraClass system, in 2008 there was approximately 150,000 km2 of secondary vegetation in areas previously cleared. This area has been increasing in recent surveys of the system. The process of secondary vegetation growth could, potentially, compensate the emissions from clear-cut deforestation. However, the literature data and the TerraClass itself show that a considerable part of this vegetation is cut cyclically (e.g., about 25% of the area identified in 2008 had been cut in 2012). The new scenarios discuss the potential role of secondary vegetation in the carbon balance in the future, through models that represent the dynamics of abandonment, growth and the cyclical

cut in deforested areas. The results of scenario B show that if the current dynamics were maintained, emission rates would remain positive (see Figure 1). It is important to note that the existing secondary vegetation in the region was produced by the historical process of occupation of the region (extensive cattle raising, lack of technical support, shifting cultivation, land speculation, etc.), initially unrelated to the latest issue of regularization of environmental liabilities under the Forest Code. Measures aiming at using these areas for the settlement of legal reserves shall include - in addition to adequate monitoring systems and specific legislation that guides their need for cyclical suppression - the availability of alternative technologies so that the secondary vegetation may be part of the productive system of the farmers in the region such as systems that integrate pasture /agriculture and forestry. **(b) Regularization of Legal Reserves (RL).** The works mentioned above (Martini *et al.*, 2015; Soares-Filho *et al.*, 2014; Sparovek *et al.*, 2015) also estimate the area of legal reserve to be restored (environmental liability) as long as the new Forest Code is actually enforced. The work of Soares-Filho *et al*. (2014), for example, estimated about 80,000 km^2 of environmental liability. The Forest Code provides two main mechanisms of regulation: effective restoration of legal reserve within the rural property or compensation in another area of the biome (through the Environmental Reserve Quota - CRA). There is much uncertainty as to which mechanism will be adopted by different actors. In all these works the environmental liability area is considerably smaller than the surpluses (area legally available for conversion), in many cases, less than half. The compensation mechanism can protect pristine forest (reducing the surpluses), whereas the restoration mechanism may favor the increase of areas of secondary forests. There is therefore a need for a broad discussion on the most appropriate regulating mechanisms in different contexts - considering not only the net carbon emissions, but the loss of biodiversity, the provision of ecosystem services and impacts on the actors involved. Results in Aguiar *et al* (2015) indicate that, in terms of emissions, even if the regularization of 80,000 km^2 of liability were to occur by the restoration mechanism (unlikely in the view of the authors as, in many cases, it would bring the abandonment of production areas), emissions would remain positive - because of the balance between areas susceptible to be legally cleared (surpluses) and the growth curve of vegetation in the areas of restoration. On the other hand, the simulation B results show that the regeneration of an area of more than 150 000 km^2 would be required to zero net emissions by 2030. Therefore, only the enforcement of the code is unlikely to be able to zero emissions in the Amazon by 2030 regardless the Legal Reserves regulation mechanism used by the different actors. Further measures are needed to keep the clear-cut deforestation rates below the "legal" levels.

3. ***Other important points:*** **(a) Emissions from forest degradation.** The paper presents the quantification of emissions from the forest degradation process - an important component of the regional carbon balance not considered in the Brazilian targets. Using data from DEGRAD INPE system, the paper estimates that gross emissions from degradation in the period were on average about 47% of the emissions by clear-cut deforestation. On the other hand, the process of post-disturbance regeneration can compensate, in part, these emissions. (b) Emissions in other biomes. The iNDC refers only to the Amazon biome. However, both works of economic modeling (Dalla-Nora 2014), and the estimates of the area that can be legally cleared according to the Forest Code in the Cerrado (about 400,000 km^2 according to Soares-Filho *et al*. 2014) indicate high rates of deforestation in this biome in the coming decades, due to its productive potential for agriculture and lower degree of protection. If compliance with the Forest Code is the sole requirement used to take actions to protect the Cerrado, we can anticipate considerable impact on national emissions and in terms of

biodiversity loss. As for the Caatinga biome, although it also presents high surpluses (about 258,000 km^2, according to Soares-Filho *et al.* (2014)), it does not present climate and soil conditions for the expansion of grain farming. This biome is, however, subject to other deforestation vectors, particularly the predatory exploitation to meet demand for charcoal and firewood for energy purposes.

In sum, our results indicate the need for a broad discussion about: (i) the premises and modelling assumptions adopted by government to calculate the 1.2 $GtCO_2e$ iNDC target in 2030, especially about expected CO_2 absorption coming from the land use and forest sector; (ii) how the Forest Code will actually be implemented – and monitored and enforced – especially regarding the restoration measures; (iii) the consolidation of the existing protected areas and the fate of the public lands without destination.

Technological innovation

From a technological point of view, the work brings a number of advances incorporated to the INPE-EM systems (emission modeling) and LuccME (land use change modeling) for the representation of deforestation, secondary vegetation and forest degradation processes. Improvement of LuccME and INPE-EM tools is being financed by the INPE project with the Amazon Fund (MSA/BNDES – Component 6).

The results, models and databases used in the study are available for download at http://luccme.ccst.inpe.br/conteudo_en/projetos.html

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