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Assessing land use and cover change, forest degradation and secondary forest databases for better understand airborne CO_2 measurements over the Brazilian Amazon

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Abstract

Tropical forests are essential for ecosystem services provision and for climate change mitigation. Amazon forest, the largest continue tropical forests in the world, have been decreasing due to deforestation and forest degradation. Brazil, a country containing most of the Amazon forests, also presents the highest deforestation rates within the Pan-Amazonian countries. The CARBAM project has been collecting bimonthly CO_2 atmospheric measurements from an airplane since 2010 in the Brazilian Amazon, showing that there is a reduction on the forest capacity to absorb carbon for deforestation and climate change patterns. To understand these CO_2 fluxes, we need to analyze the land use and cover change processes including forest degradation and secondary forest growth. Our goal is to assess different databases to better understand deforestation, degradation and secondary forest dynamics in the Amazon. For this, we merged different databases for the period 2010-2018: MapBiomas for land use and cover change; PRODES for deforestation; Bullock et al. (2020) for degradation; and Silva et al. (2020) for secondary forest. We found that, from the total accumulated deforested area in 2018 (17% of the Brazilian Amazon), pasture represent 69% fallowed by secondary vegetation 21% and agriculture 8%. The annual deforested area, smaller than secondary vegetation area, is increasing since 2012. Degradation has a different area each year. The carbon uptake by secondary forest and degradation dynamics is underestimated in the national communications of greenhouse gases, and its mapping is extremely relevant to policy makers to accomplish the National Determined Contribution. The large pasture areas deserve attention because it may permit the secondary forest to increase and provide agriculture expansion areas, decreasing in this way the pressure for deforestation and degradation of primary forest and contributing to preserve biodiversity and ecosystem services of the Amazon forests.

Keywords: Amazon forests, deforestation, degradation, secondary forests, CO_2 emissions

Introduction

In the last decades, global CO_2 concentrations have reached levels never seen before, with more than 400 ppm. Among the main causes of these are the burning of fossil fuels and the land use and cover change (LUCC) related emissions. In the Amazon region, the main CO_2 emissions (more than 40%) are related to deforestation, degradation and fire. Brazil, a country containing almost 60% of the Amazon forests, presents the highest deforestation rates within the Pan-Amazonian countries (Albuquerque et al., 2020). The CARBAM project has been collecting bimonthly CO_2 atmospheric measurements from an airplane since 2010 in four sites of the Brazilian Amazon, showing that there is a reduction on the forest capacity to absorb carbon for deforestation and climate change patterns (Luciana V. Gatti et al., 2021; L V Gatti et al., 2014).

To understand these CO_2 fluxes, we need to analyze the land use and cover change processes including forest degradation and secondary forest growth. There are comparisons of the multitemporal LUCC datasets of Brazil showing that they have different objectives, temporal and spatial scales (Tejada et al., 2020). The big challenge is to make an annual LUCC that represent different removal and emissions forests carbon pools. Our goal is to assess different databases to better understand deforestation, degradation and secondary forest dynamics in the Amazon, in the intent of having an annual LUCC mask from 2010 to 2018.

Methodology/approach

1. Study area

The study area is the Brazilian Amazon forests biome, as defined by to Olson et al. (2001) including the Planalto region, according to Eva et al. (2005). It has an area of 4,215,763 km^2 (Fig. 1).

Fig. 1: Brazilian Amazon (study area) in red and CARBAM flight sites in yellow airplanes

2. Land use and cover change data mask

We merged different databases in order to have an annual mask for 2010-2018 for the Brazilian Amazon. For land use and land cover we used MapBiomas collection 4.1 (MapBiomas, 2020), for deforestation we used PRODES (INPE, 2019), for degradation we used the data of Bullock et al. (2020) and for secondary forest gain and loss, the data of Silva et al. (2020). Table 1 describes each dataset.

Table 1: Land use and cover change datasets

Process	LUCC dataset	Objective	Scale	Spatial resolution	Temporal scale (years)
Land use and cover	**MapBiomas Brazil c. 4.1**	**Generate annual maps of land cover and use for Brazil**	**Brazil**	**30 m**	**Annual from 1988-2018**
Degradation	**Bullock et al. (2020)**	**Forest degradation**	**Brazil**	**30 m**	**1995-2018**
Secondary forest	**Silva Junior et al. (2020)**	**Secondary forest based on MapBiomas c.4.1**	**Brazil**	**30 m**	**1986-2018**
Deforestation	**PRODES (INPE, 2019)**	**Map annual deforestation**	**Brazilian Legal Amazon**	**30 m**	1988-2019

To make the LUCC mask, we made an spatial overlap analysis between deforestation, degradation and secondary forest. The overlapping was less than 1%, so we merged the different datasets according to Figure 2, assuming that the map layer on the top replaces the pixels in the layer below. We choose the resulting classes of our mask, based on the previous LUCC classes analysis of Tejada et al., (2020).

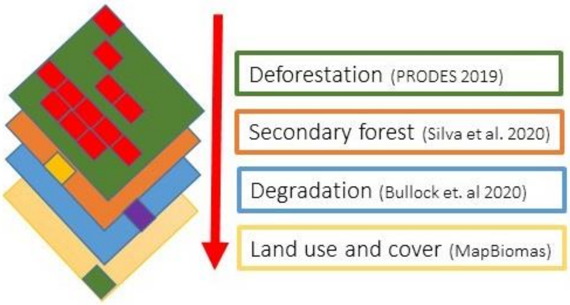

Fig. 2: Land use and cover dataset overlapping order

Results

The resulting classes (and combinations) of our land use cover mask are in Table 2. Forest is the predominant class with 78% in 2018. From the anthropogenic impact classes pasture and agriculture have a greater extent (11 and 1.3%). From the natural vegetation classes, grassland has 3.3%. Secondary forest has 3.4%. In the context of the Brazilian Amazon biome, degradation and deforestation have a small area, but the impact is great. For this we show the percentages of the accumulated deforested area according to PRODES, that is 17% in 2018, where are the classes: secondary forest, degradation, deforestation, planted forest, pasture and agriculture (see Fig. 3).

Table 2: Land use and cover change classes

Selected classes	MapBiomas	Total area (2018)		LUCC data
Class name	Grouped subclasses (%)	km²	%	
1. Forest	Forest (81.1)			
	Mangrove (0.1)	3,282,001	77.9	MapBiomas c4.1
	Savanna (0.7)			
2. Secondary forest	Secondary vegetation	143008	3.4	Silva et al. 2020 based on MapBiomas c4.1
3. Degradation	Degradation	5588	0.1	Bullock et al. 2020
4. Deforestation	Primary forest /Secondary forest?	7154	0.2	PRODES-mask
5. Planted forest	Forest plantation (0.001)	737	0.02	MapBiomas 4.1
6. Grassland	Grassland (0.1)			
	Other non-forest natural formation (3.2)	140378	3.3	MapBiomas 4.1
7. Pasture	Pasture (11.4)	468215	11.1	MapBiomas 4.1
8. Agriculture	Annual and perennial crop (0.7)			
	Semi-perennial crop (0.001)	56100	1.3	MapBiomas 4.1
9. Other non-forest natural formation	Urban infrastructure	3328	0.1	MapBiomas 4.1
	Other non-forest natural formation (0.004)			
	Beach and dune (0.0003)			MapBiomas 4.1
	Salt flat (0.005)			
	Mining (0.002)			
10. Water bodies	River, Lake and Ocean (2.4)	100872	2.4	MapBiomas 4.1
11. Non-Observed	Not observed (0.2)	4248	0.1	MapBiomas 4.1

We found that, from the total accumulated deforested area in 2018 (17% of the Brazilian Amazon), pasture represent 69% fallowed by secondary vegetation 21% and agriculture 8%.

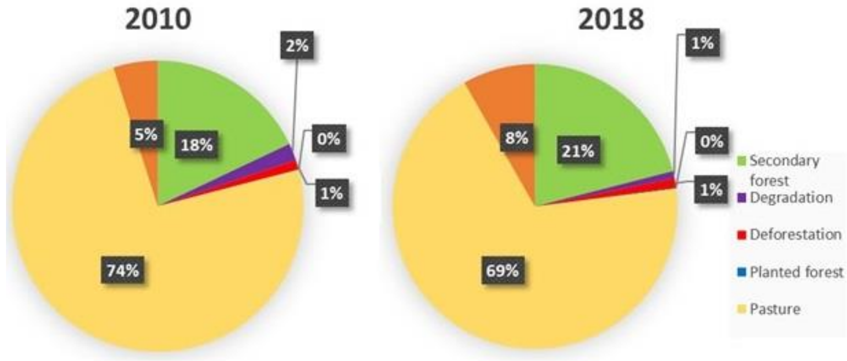

Fig. 4: Classes in the cumulated deforested area

The map of land use and cover classes (Fig. 5) show some of the LUCC dynamics, degradation and deforestation end on pasture or agriculture, or in secondary vegetation. The different year LUCC map show clearly the so called deforestation arc (Aguiar et al., 2016) in the southeast, but also how LUCC have increase in areas of Amapá and Acre states.

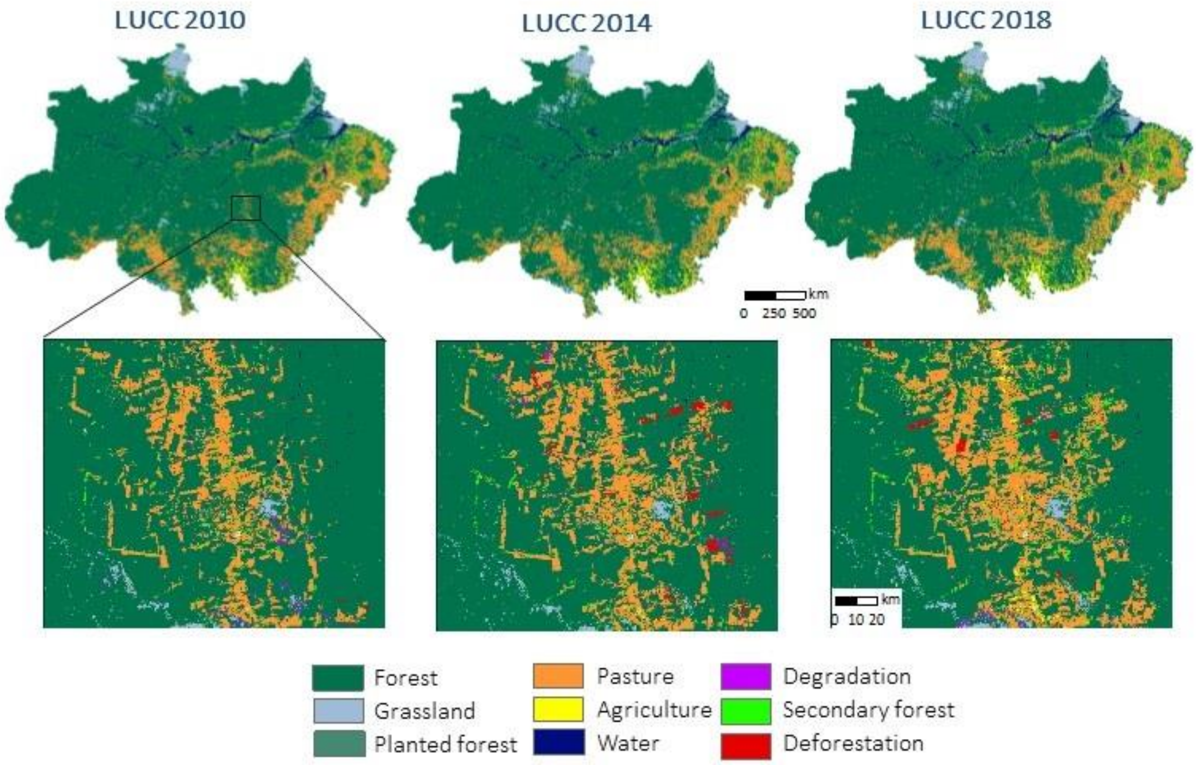

Fig. 5: Map of land use and cover change in 2010, 2014 and 2014

The annual dynamics of LUCC (Fig. 6) show that annual deforestation, secondary forest, pasture and agriculture are increasing since 2012. Degradation has a different area each year, but in 2015 and 2016 the degraded area was considerable larger than the deforested area.

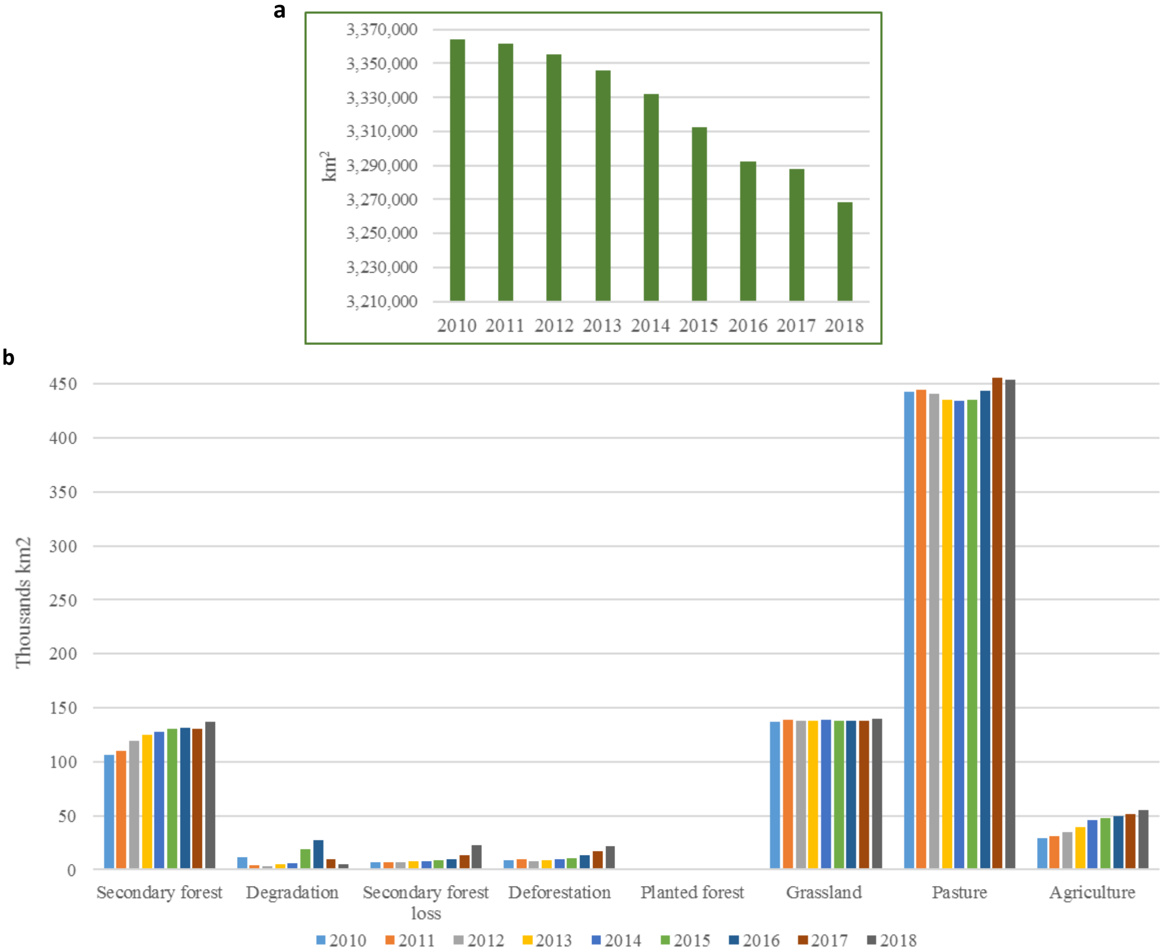

Fig. 6: a. Forest area from 2010 to 2018; b. Land use and cover change from 2010 to 2018

Discussion

After analyzing the land use and cover change datasets for Brazil, we found that is really important to consider degradation and secondary forest, since it represent a considerable area each year. Degradation and secondary vegetation are not being correctly accounted in the national communication on greenhouse gases (Albuquerque et al., 2020; MCTI, 2020). Indeed, degradation area could represent a greater CO_2 emission, when compared with deforestation in some years. Secondary vegetation is an important CO_2 removal when is preserved (Heinrich et al., 2021). Thus, mapping both processes might be a relevant information for policy makers and contribute to accomplish the National Determined Contribution. The large pasture areas deserve attention because it may permit the secondary forest to increase and provide agriculture expansion areas, decreasing in this way the pressure for deforestation and degradation of primary forest.

The fact that the PRODES deforestation data use a hydrological year (August – July) in instead of a normal January to December calendar, as the CARBAM CO_2 measurements does, it makes difficult to compare both data sets. To tackle this, we should considered to make a LUCC mask using only MapBiomas data, running a script similar of the one used for secondary forest loss of Silva Junior et al. (2020) for deforestation.

The next step will be assign emission factors each LUCC class, considering also the forest biomass

Conclusions

The annual LUCC mask, product of joining many LUCC databases was possible and showed the relevance of mapping not only deforestation but secondary forest and degradation, since they have a representative area. The carbon uptake by secondary forest and degradation dynamics is underestimated in the national communications of greenhouse gases, and mapping these processes is extremely relevant to policy makers in the context of the National Determined Contribution. Also, large pasture areas should be managed to permit the secondary forest to increase and provide space for agriculture expansion. In this way the pressure for deforestation and degradation of primary forest may be decreased, contributing to preserve biodiversity and ecosystem services of the Amazon forests.

In further research we will assign emission factors for each annual LUCC, in order to compare with the atmospheric CO_2 measurements, considering also forest biomass data.

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