IMPROVING BIOMASS BURNING ESTIMATES BY UPDATING LAND USE AND LAND COVER INFORMATION

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ABSTRACT

Biomass burning (BB) emissions are often related to broad detrimental impacts including climate change and endangering human health. The combination of orbital remote sensing and modelling enables the estimate of BB emissions on regional to global scales. However, these estimates are often linked to very high uncertainties. This work aimed at improving BB emissions estimates from the PREP-CHEM-SRC emissions preprocessing tool by updating the Land Use and Land Cover (LULC) information based on the MapBiomas annual LULC maps. We have run the tool for the 2002-2020 period and then analyzed the difference in the annual estimates of fine particulate matter ($PM_{2.5}$) emitted from BB in the Amazon and Cerrado biomes. In the Amazon biome, annual emissions decreased, on average, 2.0% with the new LULC information. At the Cerrado biome, annual emissions increased, on average, by 2.4%. Other improvements, such as updated emission factors, can improve the accuracy of estimates derived from PREP-CHEM-SRC.

Key words *— Biomass burning, LULC, Amazon, Cerrado.*

1. INTRODUCTION

Biomass burning (BB) emissions play a key role on the biosphere-atmosphere interaction. Among broad detrimental impacts, they change the atmospheric composition [1], regional climate [2], alter the hydrological cycle [3], and endanger human health [4]. Therefore, it is necessary to quantify BB emissions accurately for assessing their impact on the environment and human life.

Considering the extension of BB worldwide, the combination of orbital remote sensing and modelling is the only viable approach to estimate BB emissions on regional to global scales [5,6]. Satellite-based BB emissions estimates are traditionally based on the relationship between burned biomass and the emission factor (EF - mass emitted of a given species during a BB event per mass of dry matter). Burned biomass can be estimated from two approaches: based on burned area [7] or Fire Radiative Power (FRP), a quantitative measurement that is directly related to the rate of burned biomass [8]. Comparative studies have shown that estimates obtained with the FRP approach are better correlated with reference data than estimates based on burned area [9].

Considering both approaches, the Land Use and Land Cover (LULC) information is critical to accurately estimate BB emissions since the EFs are LULC-based. For example, when estimating BB emissions using the burned area approach the combined effects of LULC and above ground biomass (AGB) lead to substantial differences in the estimates of up to 3 times [10].

Currently, we have tools specifically designed to estimate BB emissions on regional scale offering more accurate parametrization than global BB emission inventories such as the Global Fire Emissions Database (GFED) [11]. Regarding South America, we can highlight the PREP-CHEM-SRC tool, which provides emissions estimates from distinct sources, such as BB, in flexible spatial resolutions [12].

Although the recent improvements made on PREP-CHEM-SRC 1.8.3 [12], an important gap in this tool is the outdated LULC information [13]. Currently, LULC information on PREP-CHEM-SRC 1.8.3 is based on the global MCD12Q1 collection 5.1 product, which has consistent inaccuracies on regional scale [13]. Moreover, the product is made available until 2013; therefore, all estimates from PREP-CHEM-SRC 1.8.3 after this year considers the 2013 LULC information.

This work aimed at improving the BB emissions estimates from PREP-CHEM-SRC 1.8.3 by updating the LULC information on the tool following the annual LULC maps made available for Brazil by MapBiomas collection 6.0 [14]. We have run the tool for the 2002-2020 period and then analyzed the difference in the annual estimates of fine particulate matter ($PM_{2.5}$) emitted from BB in the Amazon and Cerrado biomes.

2. MATERIALS AND METHODS

Annual estimates of $PM_{2.5}$ emitted from BB during the 2002-2020 period were obtained using the Brazilian Biomass Burning emission model with Fire Radiative Power (3BEM_FRP) [12] implemented on the PREP-CHEM-SRC emissions preprocessing tool version 1.8.3. The 3BEM_FRP model is based on the FRP approach to estimate the emissions associated with BB. Fires were the only activated source of emission in PREP-CHEM-SRC 1.8.3 and Moderate Resolution Imaging Spectroradiometer (MODIS) sensors

ISBN: 978-65-89159-04-9

active fires products (MOD14 and MYD14) [15] were used as inputs in 3BEM_FRP.

We have run PREP-CHEM-SRC under two scenarios: (i) considering the current LULC information and (ii) altering the LULC information based on MapBiomas annual maps (2002-2020). The preparation of the new LULC information consisted of (i) downloading the LULC maps from Google Earth Engine (GEE), (ii) resampling the LULC maps (30 meters) to the spatial resolution of 500 meters, which is the one of the LULC information in PREP-CHEM-SRC, based on the majority of the LULC at the coarser spatial resolution, (iii) reclassifying the LULC categories of MapBiomas to match the International Geosphere-Biosphere Programme (IGBP) classification scheme (since PREP-CHEM-SRC follows this classification scheme), and (iv) converting the new LULC information to the format read in PREP-CHEM-SRC.

Model outputs consisted of the daily emission of $PM_{2.5}$ associated with BB at the spatial resolution of 0.1º, subsequently aggregated into annual estimates and clipped to the delimitation of the Amazon and Cerrado biomes. More details on the method applied are described in Pereira et al. [12].

3. RESULTS

Figure 1 shows the LULC in the Amazon and Cerrado biomes for the year 2020 considering the old (MCD12Q1 collection 5.1 – year 2013) and new (MapBiomas collection 6 – year 2020) LULC information in PREP-CHEM-SRC. When comparing the maps, we observe that the new LULC information better represents the deforestation process in the Amazon biome (forest formations decreased 3.64%, while savanna and grasslands increased 5.02%). Regarding the Cerrado biome, croplands are also better represented (increase of 8.01%), especially at the MATOPIBA agricultural frontier, as well as forest formations in Northern Cerrado (increase of 10.72%).

Figure 2 shows the spatial distribution of the $PM_{2.5}$ emitted from BB in the Amazon and Cerrado biomes for the year 2020 considering the new LULC information implemented on PREP-CHEM-SRC 1.8.3. We observed that, in the Amazon biome, we have higher values of emissions than in the Cerrado biome (reaching up to 0.090 kg m^{-2}). These higher values are concentrated in the "Arc of the Deforestation" region, the most anthropized portion of the biome. As opposed to the Amazon, in the Cerrado biome we found emission values higher than zero in almost the entire biome, with highest estimate reaching 0.046 kg m^{-2}. These higher estimates in the Cerrado are concentrated in the ecotones between the Amazon and Cerrado biomes, where we have higher incidence of forest formations.

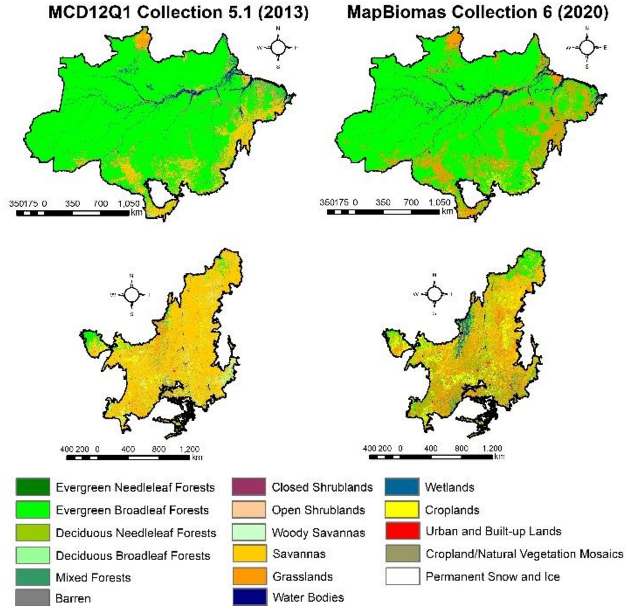

Figure 1. LULC in the Amazon and Cerrado biomes for the year 2020 considering the old (MCD12Q1 collection 5.1 – year 2013) and new (MapBiomas collection 6 – year 2020) LULC information in PREP-CHEM-SRC.

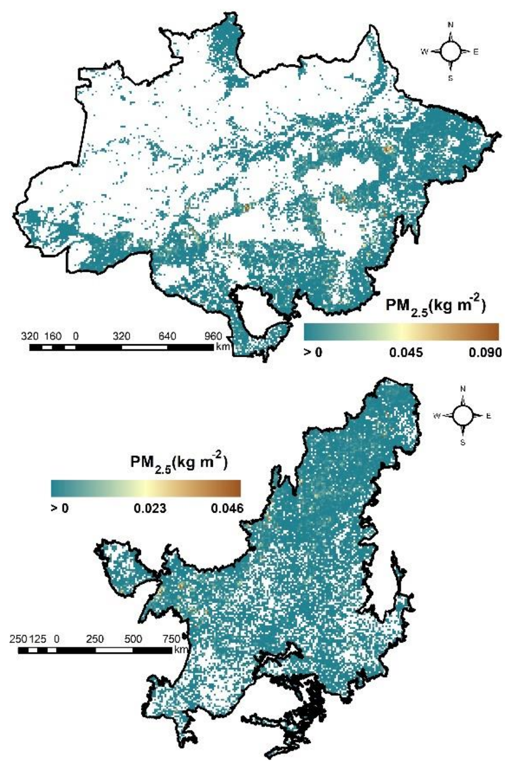

Figure 2. Spatial distribution of the $PM_{2.5}$ emitted from BB in the Amazon and Cerrado biomes for the year 2020 considering the new LULC information implemented on PREP-CHEM-SRC 1.8.3.

Figure 3 shows the annual estimates of $PM_{2.5}$ emitted from BB in the Amazon and Cerrado biomes with the distinct

ISBN: 978-65-89159-04-9

LULC information during the 2002-2020 period. Considering the estimates using the new LULC information, average annual $PM_{2.5}$ emitted from BB in the Amazon biome was 2,127,373 Mg year^{-1}, while in the Cerrado biome the annual average value reached 821,754 Mg year^{-1}.

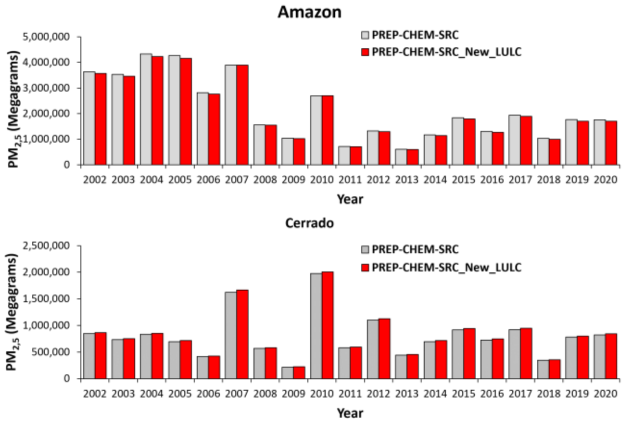

Figure 3. Annual estimates of $PM_{2.5}$ emitted from biomass burning in the Amazon and Cerrado biomes between 2002 and 2020. Estimates were obtained using the 3BEM_FRP model implemented on PREP-CHEM-SRC 1.8.3 considering the old (MCD12Q1 collection 5.1) and new (MapBiomas collection 6) LULC information.

Still considering the estimates obtained using the new LULC information, the year 2004 had the highest emission of $PM_{2.5}$ associated with BB in the Amazon biome during the 2002–2020 interval (4,227,503 Mg), while the year 2013 had the lowest one (595,968 Mg). In the Cerrado biome, annual estimates ranged between 223,712 Mg (2009) and 2,008,383 Mg (2010).

We observe that, in the Amazon biome, annual emissions decreased, on average, 2.0% with the new LULC information. At the Cerrado biome annual emissions increased, on average, by 2.4%. In 2020, when the LULC information is more critically outdated, emissions were 3.20% lower with the new LULC information in the Amazon biome, while in the Cerrado biome they were 2.55% higher.

4. DISCUSSIONS

LULC is critical to estimate BB emissions, as both emission and combustion factors are LULC-based. For example, in PREP-CHEM-SRC 1.8.3 the $PM_{2.5}$ emission factor for fire events occurring in evergreen broadleaf forest is 9.4 g emitted per kg of dry matter, while the $PM_{2.5}$ emission factor for fires occurring in savanna is 4.0 g emitted per kg of dry matter [13]. Therefore, we can much more than double the estimated emission of a savanna area incorrectly classified as evergreen broadleaf forest.

This explains the decrease in the $PM_{2.5}$ emissions associated with BB in the Amazon biome during the 2002-2020 period when considering the new LULC information, since we have less forest areas that have higher emission factor than savannas or croplands. This difference is clearer in consolidated deforestation frontiers such as the “Arc of Deforestation”.

In the Cerrado biome, the opposite process was found as MapBiomas identified more forest formations, especially in Northern Cerrado at the Maranhão state. Forest fires are a major disturbance in this region that burn, on average, 1,680 km^2 yearly with 60% of the events occurring in forest edges [16].

Based on the new LULC information, other important parametrizations of PREP-CHEM-SRC, such as the EFs, can be improved. As opposed to GFED and other global BB inventories, PREP-CHEM-SRC considers the same EF for both savanna and croplands LULCs (4.0 g of $PM_{2.5}$ emitted per kg of dry matter) [13]. This update could be performed based on Andreae [17], who evaluated EFs from over 370 published studies and integrated them into consistent average values that include standard deviations. In the case of $PM_{2.5}$, the EF proposed for burning events occurring in savannas is 6.7 ± 3.3 g kg^{-1}, while the value for burning events in croplands is 8.1 ± 4.4 g kg^{-1} [17].

Other potential improvement in the estimates obtained using PREP-CHEM-SRC is related to the degradation process necessary to match the spatial resolution of the new LULC maps (30 meters) with the spatial resolution of the LULC information defined by the tool (500 meters). This process hinders one of the advantages of MapBiomas that is the more detailed information regarding LULC. A possibility to solve this issue is to calculate the rate of emission for each active fire prior to the clusterization process that integrates all active fires in a grid cell to estimate the daily emission (see Pereira et al. [12]).

5. CONCLUSIONS

We have estimated $PM_{2.5}$ emissions associated with BB in the Amazon and Cerrado biomes during the 2002-2020 period using the PREP-CHEM-SRC tool version 1.8.3 under two LULC scenarios: based on the MCD12Q1 product collection 5.1 and the MapBiomas collection 6. Such a framework was able to characterize the influence of LULC on the emissions associated with BB.

Substantial changes were identified when comparing the distinct LULC information, mostly associated with the better representation of the deforestation process in the Amazon and the increase of forest formations in Northern Cerrado. These changes have led to decreased emissions of $PM_{2.5}$ associated with BB in the Amazon biome, while in the Cerrado biome annual estimates have increased.

The updated LULC information is a major improvement on PREP-CHEM-SRC. We hope that this update is implemented for all users of the tool in the near future. Nevertheless, other important updates, following the LULC, can be implanted in PREP-CHEM-SRC. New emission factors based on Andreae [17] will better represent the BB emissions in South America, especially because we have distinct values for the savanna and cropland LULCs. Overall, we expect increased BB emissions in South America with these new emission factor values.

6. ACKNOWLEDGEMENTS

This research was financially supported by the São Paulo Research Foundation (FAPESP, grants 2019/25701-8, 2016/02018-2 and 2020/15230-5) and the National Council for Scientific and Technological Development (CNPq, grants 350820/2022-8 and 314416/2020-0).

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