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ALTERATIONS OF LAND USE AND COVERAGEAND IMPACTS ON THE REGIONAL CLIMATE OF THE EASTERN AMAZON

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Abstract: Extreme weather events have increased in recent years in the Amazon region. According to the Climate Change Panel, the IPCC, the main anthropogenic factors involved in the climate are the use of land in an unsustainable way, and the occupation of this land without planning and environmental ethics, thus causing the most important climate drivers such as deforestation, change in surface albedo, warming of the environment, among others. The present work aimed to characterize the persistent changes in climate patterns and the evolution of land use and cover in Marabá. It was observed a loss of more than 581,624.97 hectares of forest areas in the municipality, which corresponds to 38.44% of the municipality's territorial area, and the increase of 577,982.61 hectares of agricultural area, approximately 38.20% of the area municipal. In the reduced-scale spatial scenario, urbanized and mining areas increased by 3,769.95 (0.24%) and 3,009.61 (0.19%) hectares in the municipal territory, respectively. The climate has also changed in recent decades, with an increase of up to 0.4°C in maximum air temperature and a reduction of up to 31% in monthly precipitation in August.
Keywords: Climate change, Marabá, environmental impact.

INTRODUCTION

The variability of precipitation in the Amazon region is associated with atmospheric and oceanic teleconnections, resulting from periods of heating and cooling of the oceans (Atlantic and Pacific), modulating the main meteorological phenomena in the Amazon, such as the Intertropical Convergence Zone (ITCZ), considered as the main regional precipitation system, determining the duration and intensity of the rainy season in the Amazon (SODRE et al, 2015).

During periods of intense warming of the waters of the Pacific Ocean, the general circulation of atmospheric winds is altered in the region, resulting in a decrease in the intensity of the subtropical trade winds, which normally help to distribute humidity in the Eastern Amazon and Northeast of Brazil, causing periods of droughts in the regions. The opposite case occurs in years of cooling of the Pacific waters (La Niña), when the trade winds are intensified and thus increasing the volume of precipitation in the Amazon region.

The Atlantic Ocean also has high relevance in the Amazon regime, directly impacting the positioning of the ITCZ, thus determining the duration and intensity of rainy periods, droughts and droughts. During periods of cooling of the waters of the tropical Atlantic, the ITCZ establishes itself further north, reducing the volume of precipitation and causing periods of water deficiency, which can lead to severe droughts, as was the case with the droughts of 2005, which affected the southeast. and western Amazon, and that of 2010, which was also associated with ``*El Niño*``.

However, the natural variability of the rainfall regime is affected due to the occurrence of climate extremes. Extreme weather events have increased in recent years in the Amazon region, and include three severe droughts in a decade (ERFANIAN, WANG, & FOMENKO, 2017; JIMENEZ-MUÑOZ et al., 2016; LEWIS, BRANDO, PHILLIPS, VAN DER HEIJDEN, & NEPSTAD, 2011; MARENGO et al., 2011; MARENGO et al., 2008), in addition to several episodes of extreme precipitation, mainly in the eastern portion of the Amazon, which includes the northeast and southeast of Pará and part of Maranhão (ESPINOZA et al., 2014; MARENGO and ESPINOZA, 2016; ERFANIAN, WANG, & FOMENKO, 2017). However, such events are responsible for climate variability, which is altered for a period of a few months and then returns to normal climatological conditions, therefore being a non-persistent event.

According to the IPCC (2021), the main anthropogenic factors involved in the climate are the use of land in an unsustainable way, and the occupation of this land without planning and environmental ethics, thus causing the most important climate drivers such as deforestation, alteration of the albedo surface, environmental heating, among others.

Dynamically, a soil without its vegetation cover, that is, the deforested soil, will heat up more and more, raising the air temperature while the atmospheric humidity, once retained by the natural vegetation, becomes lower due to the intensification of the deforestation process. evaporation, as the amount of remaining vegetation is not sufficient to maintain natural humidity levels, and as a direct effect, precipitation will intensify in periods subsequent to the deforestation process, followed by a gradual reduction in precipitation over the years (MORAES et al, 2022).

Several studies show that in recent decades, repeated drought events and a tendency to reduce precipitation in the south and southeast of the Amazon basin (25% reduction in rainfall between 2000 and 2012) (HILKER et al., 2014), in addition to the record of higher temperatures intensified seasonal evaporative stress throughout the basin (JIMENEZ-MUÑOZ, SOBRINHO, MATTAR, & MALHI, 2013).

The present work aims to characterize soil use and cover and how human activity can cause persistent changes in local climate patterns.

METHODOLOGY

STUDY AREA

The municipality of Marabá (Figure 1) is a city located in the state of Pará, in the North of Brazil. It has a territorial area of approximately 15,678.036 km² (IBGE, 2022) and is located at an average altitude of 71 meters above sea level. Geographically, Marabá is located at the confluence of the Tocantins and Itacaiúnas rivers, which gives the city a strategic position in terms of river transport. The municipality is crossed by the Equator, and part of its territory is located in the Amazon Forest, one of the largest tropical forests in the world.

The Marabá region has a humid tropical climate, with a rainy season between the months of November and April, and a dry season between May and October. The average annual temperature varies between 25°C and 30°C. The predominant vegetation in the area is tropical forest, with a great diversity of plant species. The region also has areas of savannah and flooded fields. The region's biodiversity is rich, housing a variety of fauna and flora typical of the Amazon.

In terms of relief, Marabá is located in a transition region between the Amazon plain and the central Brazilian plateau. The terrain is characterized by plains, hills and low mountains. The presence of the Tocantins and Itacaiúnas rivers offers potential for activities related to the waterway and river tourism. Furthermore, Marabá is known for hosting important mining projects, with emphasis on the extraction of iron ore. This economic activity has a significant impact on the region, contributing to local development, but also raising environmental and social issues.

This municipality was selected as representative of the Eastern Amazon due to its importance within the southeast of Pará, a region that concentrates the largest mining and livestock production enterprises in the Amazon. In addition to being located within the region that has suffered the most changes in the pattern of land use and coverage in the last three decades.

METEOROLOGICAL DATABASE

The *Terra Climate* database (ABATZOGLOU, 2018) was used, covering the monthly period from 1971 to 2021. These data are characterized as being a set of climate and climate water balance data on a global spatial scale, often monthly temporal, with spatial resolution of 4 x 4 km. The data integrates high spatial resolution information from the World Climate dataset, with the Climatic Research Unit database (CRU Ts4.0), in addition to information from the 55-year Japanese Reanalysis (JRA55). *Terra Climate* data is frequently updated and recently added to Google Earth Engine and the threds server, is in the public domain and available in netCDF format at https://www.climatologylab.org/terraclimate.html.

The climatological periods used to evaluate changes in climate patterns were those between 1981 to 2010 and 1991 to 2020, called past and current climate, respectively.

The analysis of the change in climatological patterns consisted of calculating the difference between the two database periods (1981 to 2010 and 1991 to 2020) of the meteorological variables of precipitation and maximum and minimum air temperature, through a simple arithmetic difference, generating thus the patterns of climate anomalies.

To evaluate the dynamics of soil anthropization, data available on the MapBiomas Project platform, a multi-institutional initiative to generate annual maps of land use and cover, were used based on automatic classification processes applied to satellite images. The complete description of the project can be found at http://mapbiomas.org and in the reference article by Souza at. al. (2020).

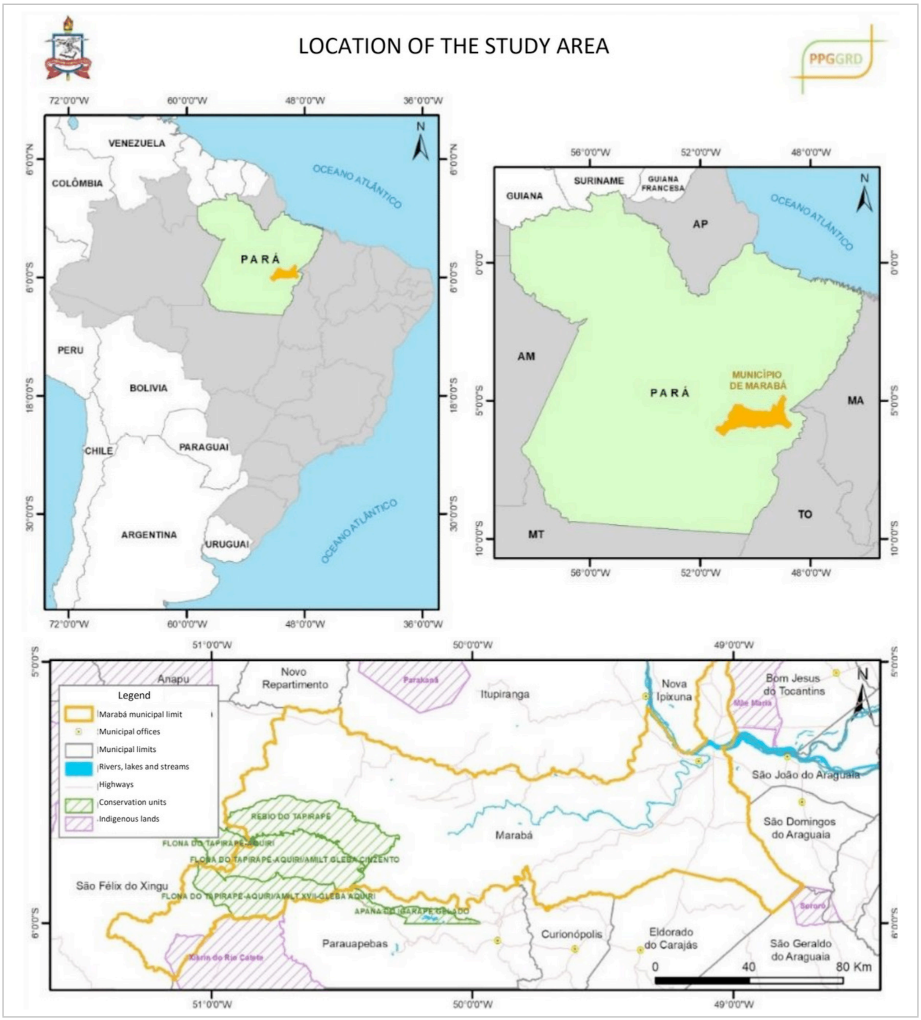

Figure 1: Geographic location of the municipality of Marabá.

Source: IBGE, 2022 and LABRD-IG-UFPA, (2022).

The Map biomes project employs cloud processing and automated classifiers developed and operated from the Google Earth Engine platform, to generate a historical series of annual maps of Brazil's land cover and use, using the 2004 IBGE Brazilian Biomes maps, originally at a scale of 1:5,000,000, subsequently refined based on the RADAM phytophysiognomies map at a scale of 1:1,000,000 and based on the 2013 IBGE state limits at a scale of 1:250,000.

The annual mapping data, made available on the platform, begins in 1985 and extends until 2021, and was generated based on Landsat images with a spatial resolution of 30 m (meters) and a spatial generalization that discards isolated areas with less of 0.5 ha (hectares).

Another important feature is the use of all available images from each year, as well as spectral indices, texture indices and relief information, as a form of machine learning, enabling the classifier to differentiate all mapped classes, thus aiming to generate of consistent maps to characterize the dynamics of changes in land use and vegetation cover (Souza at. al., 2020).

For decadal analyses, the data series was subdivided into four periods. The 1st decade-1D (1985-1994), 2nd decade-2D (1995-2004), 3rd decade-3D (2005-2014) and present time-TP (2015-2020), respectively.

RESULTS AND DISCUSSIONS

EVOLUTION OF LAND USE AND COVER

The municipal forest area of Marabá (Figure 2) decreased considerably in recent decades, around 140,016.39 hectares (-10.14%) only in the first decade of study, between 1985 and 1994, while the areas of agricultural activities increased by 141,087.22 hectares (129.69%), urbanized areas expanded by 1,029.49 hectares (45.45%) and areas of mining activities by 143.56 hectares (161.56%). In the following decade (1995-2004) the scenario of suppression of forest areas intensified, with a decrease of 326,892.24 hectares (-27.38%), a period in which spatial increases occurred in agricultural areas, 327,073.92 hectares (110 .29%), urbanized areas, 801 hectares (22.98%) and mining with an increase of 61 hectares (28.3%) (Figure 2).

In the 3rd decade of study (2005-2014) the deletions of forest areas continued, with losses of 79,222.45 hectares (-9.5%), and a spatial increase of 76,197.07; 1,683.41 and 1,590.05 hectares in the areas of agricultural (11.60%), urban (38.10%) and mining (380.97%) activities respectively, thus explaining the abrupt expansion of mining activities in the municipality in this period. The last six years were also characterized by adverse conditions in land use and coverage, with a decrease in forests by 35,493.89 hectares (-4.8%), an increase in agricultural regions by 33,624.41 hectares (4.5%), urban areas in 255.65 hectares (4.15%) and with emphasis on mining, with an increase of 1,215.52 hectares (58.66%).

The general scenario was the loss of more than 581,624.97 hectares of forest areas in the municipality, which corresponds to 38.44% of the municipality's territorial area, and the increase of 577,982.61 hectares of agricultural area, around 38 .20% of the municipal area. In the reduced-scale spatial scenario, urbanized and mining areas (Figure 3) increased by 3,769.95 (0.24%) and 3,009.61 (0.19%) hectares in the municipal territory, respectively (Figures 2).

Agricultural data from the municipality of Marabá, according to IBGE (2022), indicate that cassava cultivation in 2004, the beginning of the historical series, occupied an area of 1500 ha, equivalent to 0.1% of the municipality's area, from in 2014 it occupied 0.34% equivalent to an area of 5,200ha remaining unchanged until 2021, this increase in area represents an increase of 246% in 18 years.

Soybeans, despite occupying a smaller area than Cassava, showed a significant increase in its cultivation area. In 2004 it occupied just 30 ha, equivalent to 0.001% of the municipal area, increasing in 2014 to 500 ha and in 2021 to 525 ha, equivalent to 0.03% of the total area of the municipality of Marabá, which represents an increase of 1,655% in 18 years. In relation to livestock, in 2004 Marabá had a herd of 816,730 head of cattle, rising to 900,000 heads in 2014 and 1,479,450 heads of cattle in 2021, an increase of 81.02% in 18 years.

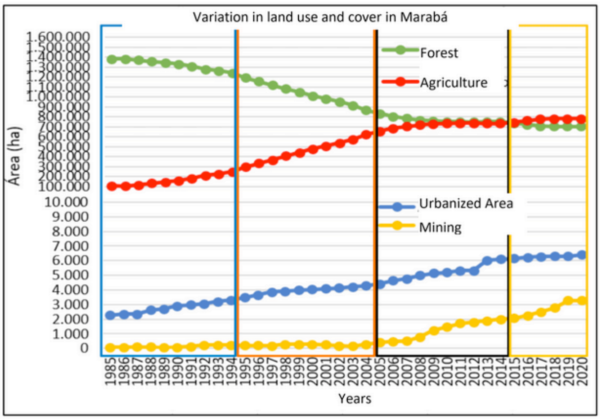

Figure 2. temporal variation in land use and occupation in the municipality of Marabá over the last 37 years. The blue, brown, black and yellow boxes represent the 1st decade-1D (1985-1994), 2nd decade-2D (1995-2004), 3rd decade-3D (2005-2014) and present time-TP (2015-2020), respectively.

Source: Authors (2023).

TEMPORAL VARIATION OF PRECIPITATION AND AIR TEMPERATURE

It was observed, through the climatological series of the time period between the years 1991 and 2020 of Marabá, a great variability in the monthly precipitation patterns throughout the year, with precipitation reaching 321 mm in the month of March and can reach just 17 mm in July. The wettest quarter is concentrated between the months of January and March with a total volume of precipitation of 876 mm, while the dry period begins in June and ends in August, totaling only 69 mm (Figure 3).

The maximum air temperature can reach an extreme of 34°C in August, fluctuating between this value and 30°C throughout the months of the year. The minimum air temperature varies between 21.9°C and 23.6C° throughout the year.

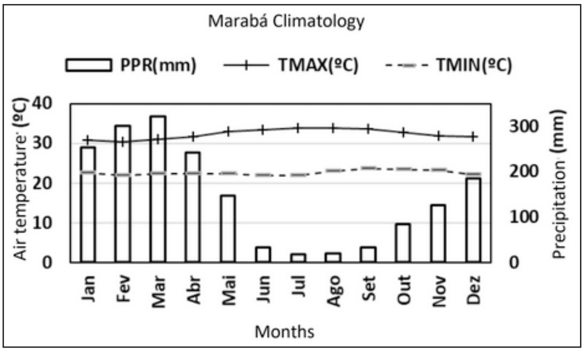

Figure 3: Monthly variability of precipitation and air temperature in the municipality of Marabá.

Source: Authors (2023).

CHANGES IN WEATHER PATTERNS

The difference between the maximum and minimum temperatures of the past climate and the current one shows an increase of 0.2°C in both air temperatures, in the months of January to May, July and November (Figure 4). The greatest value of change was observed in the maximum air temperature in September, with a value of 0.4°C.

Precipitation also showed a change in climatological pattern, with more significant percentage values in the months of August and September, months of low rainfall volumes. In these months, a reduction of 31% and 27% in monthly precipitation volumes was observed, in the months of August and September, respectively (Figure 5).

This scenario can be intensified in years of climate anomalies, as previously described.

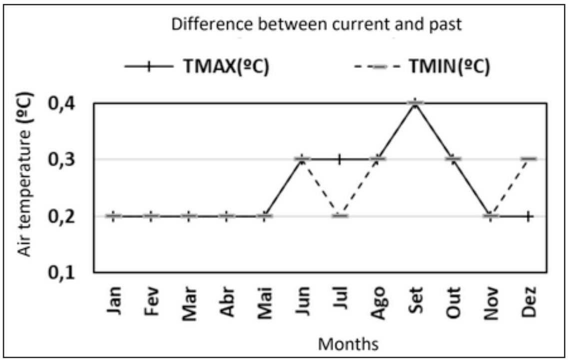

Figure 4: Monthly anomaly of maximum and minimum air temperature. Difference between the current (1991 to 2020) and past (1981 to 2010) climatological periods.

Source: Authors (2023).

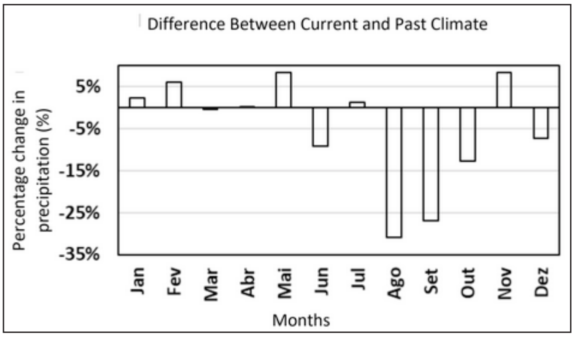

Figure 5: Monthly anomalies in the percentage of precipitation. Difference between current and past (1991 to 2020) and past (1981 to 2010) climatological periods.

Source: Authors (2023).

FINAL CONSIDERATIONS

The expansion of the agricultural cultivation area, increased grain production, as well as the increase in cattle herds demand greater environmental pressure in the territory, causing greater impact on the processes of soil change, use and coverage. These characteristics require greater demands on natural resources, especially water, which without due planning and irrational use for the use of these natural resources, associated with the lack of adequate infrastructure such as: irrigation management, regulation of water use, environmental inspection, certainly will produce periods of greater agro-climatic risks for the region, especially in years of El Niño climate anomaly and positive SST in the Atlantic Ocean, as previously described.

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