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GROSS PRIMARY PRODUCTIVITY IN THE NORTHERN REGION OF PARA STATE, BRAZILIAN AMAZON, FROM MOD17 DATA

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ABSTRACT

This study aimed to characterize and analyze, based on MOD17 data, the spatio-temporal dynamics of GPP in the northern region of Para state, Brazilian Amazon, during a 6-year period (2001 to 2006). The study area encompasses two river basins (Upper Tapajos and Curua-Una) and covers ~74,190 km^2. The spatial variation of GPP was primarily related to the larger presence of forested areas in Upper Tapajos River basin in comparison with Curua-Una River basin. Temporally, GPP varied with the dry and wet seasons in the region. There was a decrease of ~4% in GPP during the dry season, which was related to the fact that the water limitation during the dry season in Amazonia leads to a decrease in photosynthesis, affecting vegetation productivity. It was observed a reasonable interannual variation of GPP in the study area, which corresponded to ~10%.

Index Terms - vegetation productivity, photosynthesis, Amazonia, tropical forest, MOD17.

1. INTRODUCTION

The Amazonian forest has a remarkable influence on climate primarily through by the release or uptake of atmospheric CO2 [1], [2]. As the initial carbon fixed by vegetation through photosynthesis, gross primary productivity (GPP) is a key driver of the global carbon cycle [3]. In this context, knowing the annual and interannual variability of gross primary productivity (GPP) in the Amazon ecosystem is critical for predicting how it will respond to future physical and biological perturbations.

The purpose of this study was to characterize and analyze, based on MOD17 product, the spatio-temporal dynamics of GPP in the northern region of Para state, Brazilian Amazon, during a 6-year period (January 2001 to December 2006).

2. MATERIALS AND METHODS

2.1. Study area

The study area is located in the northern region of the state of Para, Brazil. The study area encompasses two river basins (Upper Tapajos and Curua-Una) and covers ~74,190 km^2 (Fig. 1). The climate according Köppen classification is the AmW, with an annual mean precipitation of ~2000 mm and an annual mean air temperature of ~26 °C. The wet season is from January to June and the dry season lasts from July through December [4]. The main natural vegetation type in the study area is the dense forest [5]. Due to deforestation, it is possible to observe extensive patches of different land cover types such as pasture, secondary succession forest, etc.

2.2. MOD17 data

The MOD17 product [6] is calculated based on the radiation-use efficiency (RUE) concept [7]:

$$GPP = \varepsilon f(T_{ar,min}) f(VPD) APAR \quad (1)$$

where ε is the photosynthetically active radiation (PAR) conversion efficiency; $f(T_{ar,min})$ and f(VPD) are scale factors related to minimum air temperature and vapour pressure deficit, respectively. The algorithm is driven by meteorological information derived from reanalysis (e.g. solar radiation and vapour pressure deficit), and biophysical vegetation parameters retrieved through remote sensing (e.g. fraction of photosynthetically active radiation (fPAR) and leaf area index (LAI)).

We used the product MOD17A2, which provides GPP in a monthly composite at 1 km resolution. The images used encompassed the h12v09 tile, which covers the Upper Tapajos and Curua-Una River basins in the Amazon region, from January to December, over 6 years (2001-2006). First, MODIS images were projected to a geographic coordinate system (lat./long.) based on the WGS 84 datum and converted to the GeoTIFF format using the MODIS Reprojection Tool (MRT). Then, a number of steps were

undertaken using Python Language Reference 2.7. These steps included clipping of the study area, multiplication by scale factors, and application of the land-water mask extracted from product MOD44W over the dataset.

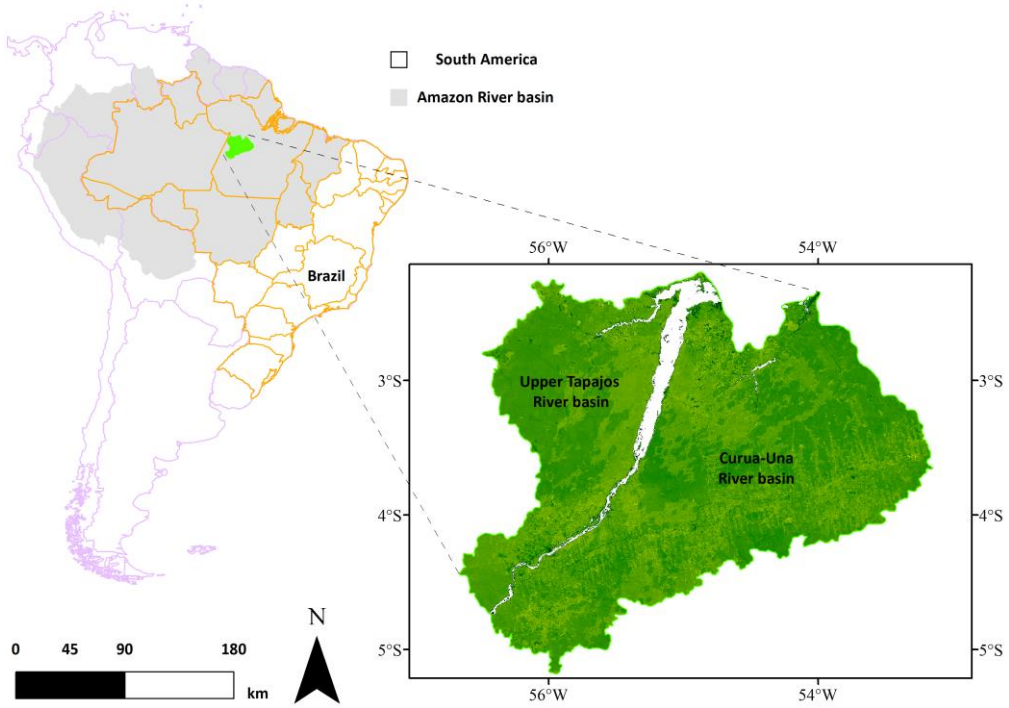

Fig. 1. Map showing the location of the study area.

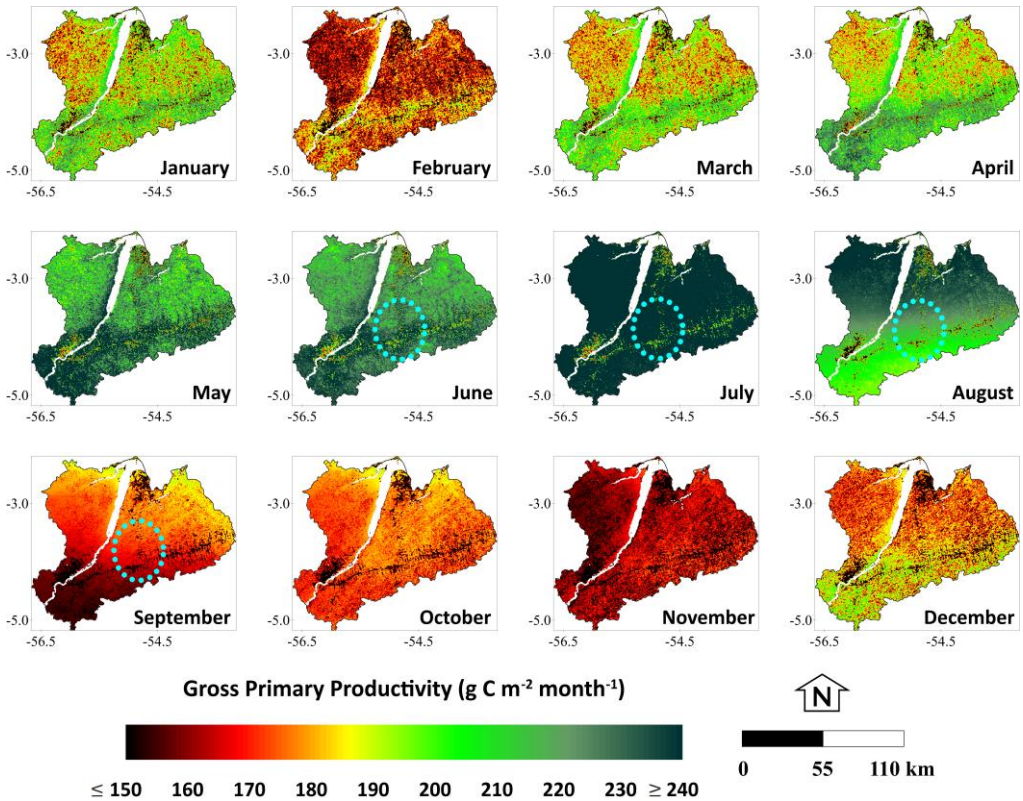

Fig. 2. Monthly averages of GPP (g C m^{-2} $month^{-1}$), between the years of 2001 and 2006.

3. RESULTS AND DISCUSSIONS

Fig. 2 presents the spatial distribution of the monthly average GPP (January to December), from 2001 and 2006, in the Upper Tapajos and Curua-Una River basins. The images from January to August presented higher values of GPP in comparison with the images from September to December. This pattern is related to the characteristics of the dry and wet seasons in the eastern part of Amazonia. The dry season can vary interannually, but typically occurs between July and December. The wet season typically occurs between January and June. The degree of water limitation predicts seasonal patterns of photosynthesis in the southern Amazon. The low water availability and increased vapour pressure deficit during the dry period induces stomatal closure, which leads to a decline in the photosynthesis rate [8]. Thus, the decrease of GPP in the dry season occurred as expected and it is corroborated by several studies conducted in the region [2], [9]. The highest values of GPP are shown to be situated in the western part of the study area (Upper Tapajos river basin), which has experienced less deforestation compared with the eastern region (Curua-Una river basin). It is interesting to note in the cyan dashed circles over the images of June, July, August and September the spatial pattern of deforestation in the Amazon, known as the fish bone. It is possible to verify the difference of GPP values between logged and forested areas, with the later presenting higher values. This is because herbaceous ecosystems are less productive than forest ecosystems [10].

The monthly GPP ranged between 103.2 and 263.0 g C m^{-2} $month^{-1}$, representing an absolute difference of 159.8 g C m^{-2} (Fig. 3). These values were observed in September 2006 and July 2005, respectively. On average for the whole period, the monthly GPP was 193.4 g C m^{-2} $month^{-1}$. The monthly average GPP varied between 158.1 and 246.0 g C m^{-2} $month^{-1}$. November presented the lowest values of GPP while July presented the highest ones. The monthly average GPP in the wet season was 197.5 g C m^{-2} $month^{-1}$ while in the dry season it was 189.3 g C m^{-2} $month^{-1}$, which means a decrease in GPP during the dry season of ~4%. The annual GPP values ranged from 2223.7 (2005) to 2446.3 g C m^{-2} $year^{-1}$ (2003), which corresponds to a variation of ~10%.

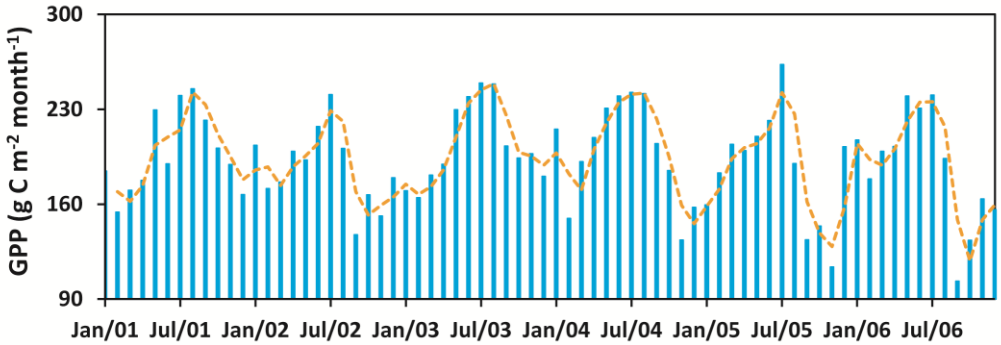

Fig. 3. Monthly GPP between January 2001 and December 2006 over the study area. The dashed orange line represents the moving average of time series (period=2).

4. CONCLUDING REMARKS

The use of MOD17 data enabled mapping the spatial distribution and evaluating GPP in the northern region of Para state, as well as analyzing the temporal dynamics of this variable in Amazon rainforest remnants for the period between 2001 and 2006. The spatial variation of GPP was primarily related to the larger presence of forested areas in Upper Tapajos River basin (western part) in comparison with Curua-Una River basin (eastern part), which is situated within the so-called arc of deforestation. Temporally, GPP varied with the dry and wet seasons in the region. There was a decrease in GPP during the dry season, corresponding to ~4%. It occurred as expected and it was related, among others, to the fact that the water limitation during the dry season in Amazonia leads to a decrease in photosynthesis, affecting vegetation productivity. It was observed a reasonable interannual variation of GPP in the study area, which corresponded to ~10%.

5. ACKNOWLEDGEMENT

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