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Amazonian Fire Events Disturbed the Global Carbon Cycle: A study from 2019 Amazon Wildfire Using Google Earth Engine†

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Abstract: An unprecedented number of wildfire events during 2019 throughout the Brazilian Amazon has caught global attention due to its massive extension and the associated loss in the Amazonian forest- an ecosystem on which the whole world depends. Such devastating wildfire in Amazon has strongly hampered the global carbon cycle and significantly reduced forest productivity. In this study, we have quantified such loss of forest productivity in terms of Gross primary productivity (GPP) applying a comparative approach using Google Earth Engine. A total of 12 wildfire spots have been identified based on its fire extension over the Brazilian Amazon and quantified the loss in productivity between 2018 and 2019. MODIS GPP and MODIS burned area satellite imageries with the revisit time of 8-days and 30-days respectively have been used for this study. We have observed that in comparison to 2018, the number of wildfire events has been increased during 2019. But such wildfire events did not hamper the natural annual trend of GPP of the Amazonian ecosystem. However, a significant drop in forest productivity in terms of GPP has been observed. All 11 sites were recorded with GPP loss ranging from -18.88 gC m^{-2} yr^{-1} to -120.11 gC m^{-2} yr^{-1} except site 3. Such drastic loss in GPP indicates that during 2019 fire events, all of these sites acted as carbon sources rather than carbon sink sites that may hamper the global carbon cycle and terrestrial CO_2 fluxes. So it is assumed that these findings will also fit for the other Amazonian wildfire sites as well as for the tropical forest ecosystem as a whole. We hope this study will provide a significant contribution to global carbon cycle research, terrestrial ecosystem studies, sustainable forest management, and climate change in contemporary environmental sciences.

Keywords: Amazon; 2019 Amazon Fire; GPP; CO_2 fluxes; MODIS; Brazil

1. Introduction

Ecosystem fragmentation due to the countless number of wildfires and the extreme rate of deforestations in the Amazon every year seriously threatens the conservation practices, associated biodiversity, and species richness [1,2]. The Brazilian Amazon landscape is universally recognized for its rich biodiversity, species richness, and also considered as a global repository of ecosystem services [3]. Despite several measures that have been taken to promote the Amazon conservation and its rich biodiversity, several studies have indicated that the loss in forest cover due to wildfires and deforestations are still occurring and running continuously [1,4,5]. Future projections even suggested that such wildfires and deforestation activities will keep on occurring in the Amazon region time to time [6]. Though wildfires are a very regular phenomenon in the Amazonian landscape, an unprecedented number of wildfire events happened during 2019 throughout the Brazilian Amazon that has caught the global attention due to its massive extension and the associated loss, causing serious environmental impacts [7]. Figure 1 shows the number of wildfire events occurred during 2018 and 2019, indicates that the number of wildfire events in 2019 has been increased compared to 2018.

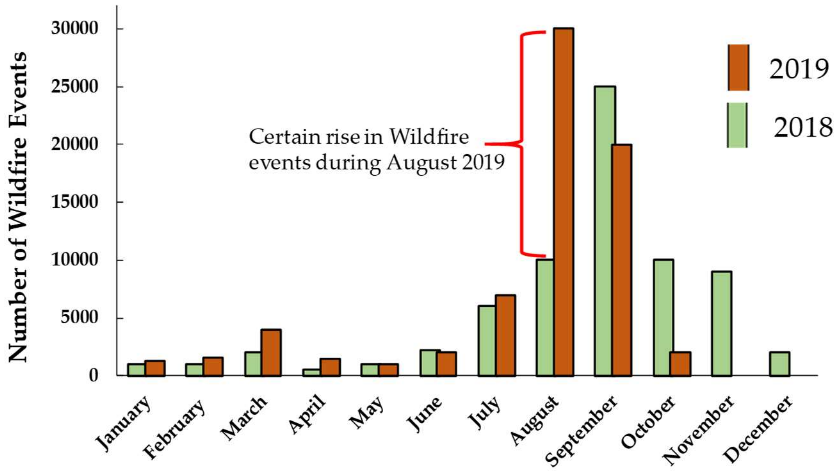

Figure 1. The number of wildfire events in the Brazilian Amazon during 2018 and 2019. A certain spike in wildfire events during August 2019 is visible in the red second bracket. Source: INPE - Brazilian National Institute for Space Research Report. .

The wildfire events that occurred during June to September 2019 have caught the global media attention due to its massive expansion and devastations. According to INEP, the wildfire events had an increase of 17% in 2019 compared to 2018[1]. The number of active fires in August 2019 was nearly three times higher than in August 2018 and the highest since 2010 [8]. The belch smoke and soot emitted from the wildfire zones polluted the air massively and disturbed the wildlife along their path, destroying a significant part of one of the most important carbon storehouse left on the planet. However, after September 2019 the intensity of these wildfires decreased over time, but such a huge wildfire in the Brazilian Amazon in 2019 considerably disturbed the global carbon cycle.

In this study, we have compared the carbon sequestration in terms of GPP between 2018 and 2019 from 12 wildlife spots to understand whether such a massive fire event occurred in 2019 has any impact on carbon sequestration and GPP. The 12 wildfire spots at the Brazilian Amazon were selected based on the spatial extension of the 2019 wildfire incident. Several studies such as Gerwing JJ. [9], Kauffman et al. [10], Hughes et al. [11], Cochrane, and Schulze [12], Nepstad et al. [13] have significantly covered the Brazilian Amazon wildfire events since long time. However, no such study was found on the 2019 Amazon wildfire that particularly addresses the impact on the carbon cycle in terms of GPP. This study was conducted in open source Google Earth Engine (GEE) platform.

2. Study Area

This study was conducted at 12 pilot spots spread over the different parts of the Brazilian Amazon. The detailed locations of these spots were provided in Table 1 and Figure 2

Table 1. Location of the 12 pilot spots located at different parts of the Brazilian Amazon.

Spots	Coordinate (W, S)	Reference places
P1	−51.45, −11.14	Luciará (Mato Grosso, Brazil)
P2	−51.21, −10.74	Porto Alegre o Norte (Mato Groso, Brazil)

[1] https://www.bbc.com/news/world-latin-america-49971563

P3	−50.33, −10.90	Inawebohona (Tocantis, Brazil)
P4	−51.22, −12.74	Ribeirão Cascalheira (Mato Grosso, Brazil)
P5	−52.68, −15.02	Novo Sao Joaquim (Mato Grosso, Brazil)
P6	−48.04, −12.90	Paraná (Tocantis, Brazil)
P7	−59.14, −17.02	San Matías (Brazil-Bolivia border)
P8	−59.12, −16.53	San Matías (Brazil-Bolivia border)
P9	−59.29, −15.95	Porto Esperidião (Mato Grosso, Brazil)
P10	−57.84, −20.41	Corumbá (Mato Grosso del Sur,Brazil)
P11	−56.31, −19.88	Miranda (Mato Grosso del Sur, Brazil)
P12	−57.26, −20.60	Kadiwéu (Porto Murtinho - Mato Grosso del Sur, Brazil)

3. Materials and Methods

3.1. Datasets

This study incorporated 2018 and 2019 MODIS GPP and MODIS burned area data obtained using the cloud-based geospatial processing platform GEE. MODIS cumulative 8-day composite GPP products (MOD17A2H) with a 500m resolution have been used to estimate the plant productivity for both of the years. The MOD17A2 product derived from the MODIS sensor provides the accumulated value of GPP based on the concept of efficiency of solar radiation used by vegetation [14]. Similarly, MODIS Terra and Aqua combined burned Area monthly data products (MCD64A1 Version 6) with a 500m resolution has been used to map the burned areas for both of the years.

3.2. Methods

To understand the trend of GPP for 2018 and 2019, each overpass record of MODIS GPP with the interval of 8 days have been considered for all 12 pilot points. Furthermore, the annual mean of each pilot spot has been calculated. To understand the gap between 2018 and 2019 GPP, the annual mean for each spot has been compared. The total operation has been conducted in open source GEE platform, accessed from the Earth Engine home page (https://earthengine.google.com/).

4. Result and Discussion

4.1. Result

Figure 2 shows the distribution of wildfire zones during 2018 and 2019 over the Brazilian Amazonian landscape. As clearly visualized in Figure 2, the wildfire intensities and spread have been significantly increased during 2019 compared to the previous year.

Even though several wildfire events took place in the Brazilian Amazon landscape, we have observed a common general trend of GPP for the year 2018 and 2019 (see Figure 3). Such condition indicates that the wildfire events did not hamper the general trend of GPP of the Amazon forest but do affect the productivity negatively in small-scale scenarios. The highest GPP has been observed at site 2 with 507.05 gC m^{-2} yr^{-1} and the lowest GPP has been observed at site 1 with 181.88 gC m^{-2} yr^{-1} during 2018, whereas the highest GPP and lowest GPP for the year 2019 have been recorded at site 2 and site 4 with 457.67 gC m^{-2} yr^{-1} and 147.38 gC m^{-2} yr^{-1} respectively (See Figure 4). However, a significant drop has been observed in GPP in terms of productivity for the year 2019 in comparison to 2018 in all other 11 pilot spots except spot 3 (See Figure 5). Site 11, site 12, and site 8 have been recorded the highest decrease in GPP with the rate of -120.11 gC m^{-2} yr^{-1}, -99.32 gC m^{-2} yr^{-1}, -79.70 gC m^{-2} yr^{-1} respectively. The details of site-wise decrease in GPP in 2019 compared to 2018 have been provided in Figure 5.

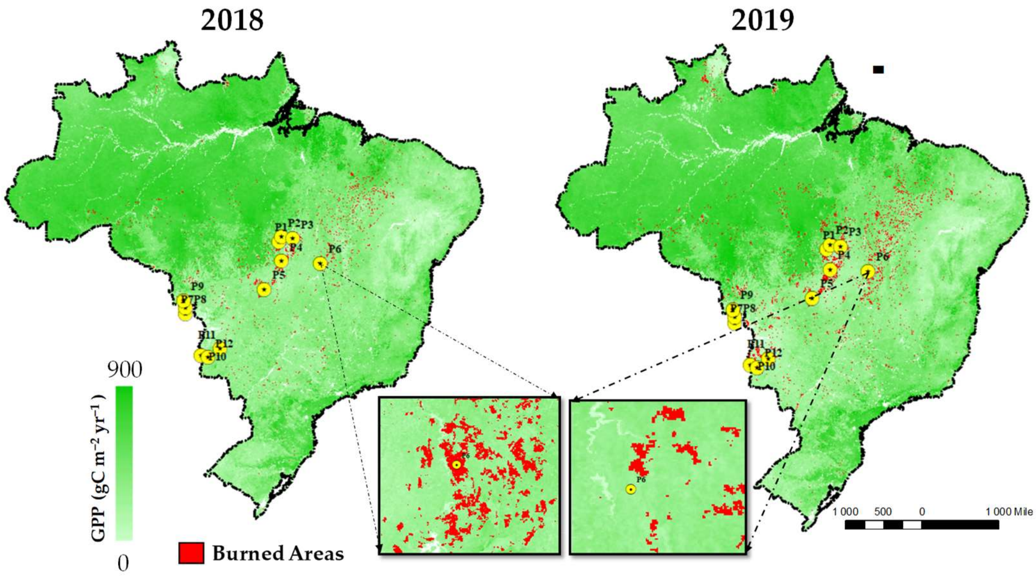

Figure 2. Distribution and spread of wildfire zones over Brazilian Amazon during 2018 and 2019. Yellow dots represents the pilot study areas considered in this study.

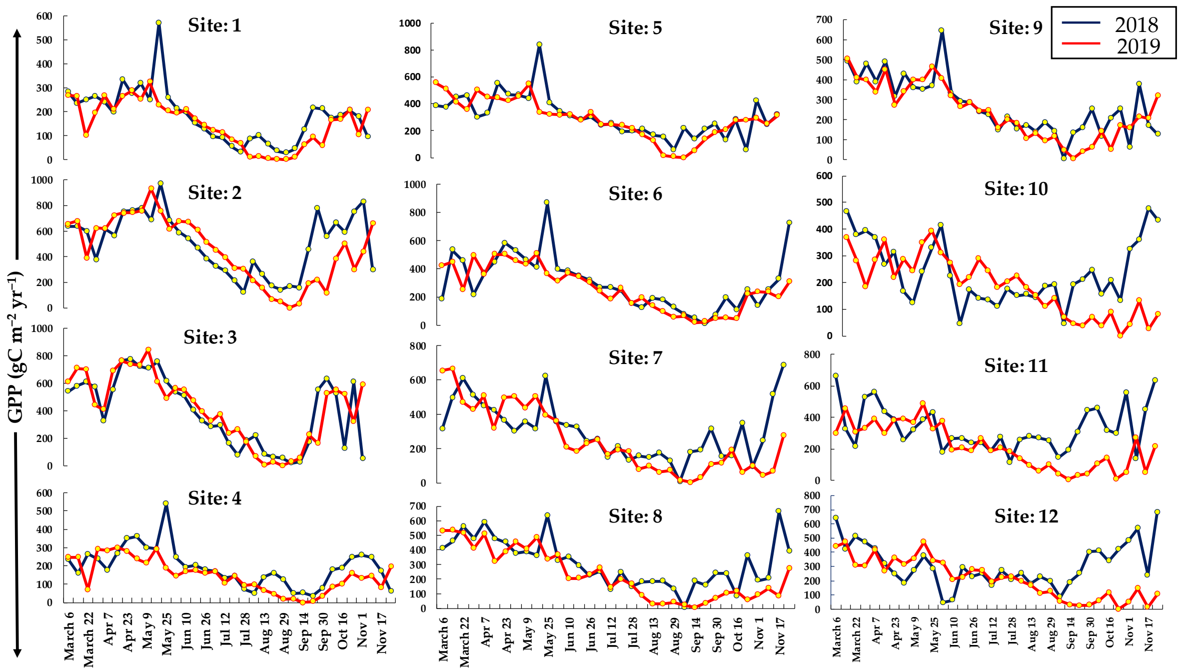

Figure 3. GPP trend at 12 pilot sites observed from MODIS 8-day composite GPP data over the Brazilian Amazon for the year 2018 and 2019.

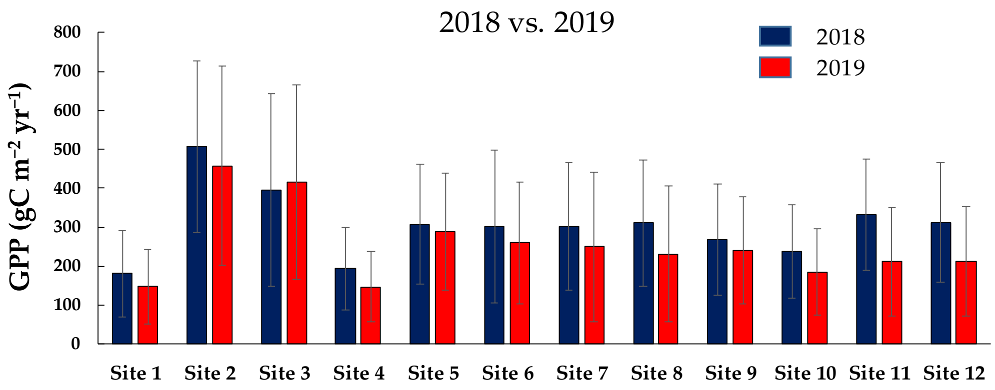

Figure 4. Site wise comparison of GPP between 2018 and 2019. Black straight lines on the bars show the standard deviations.

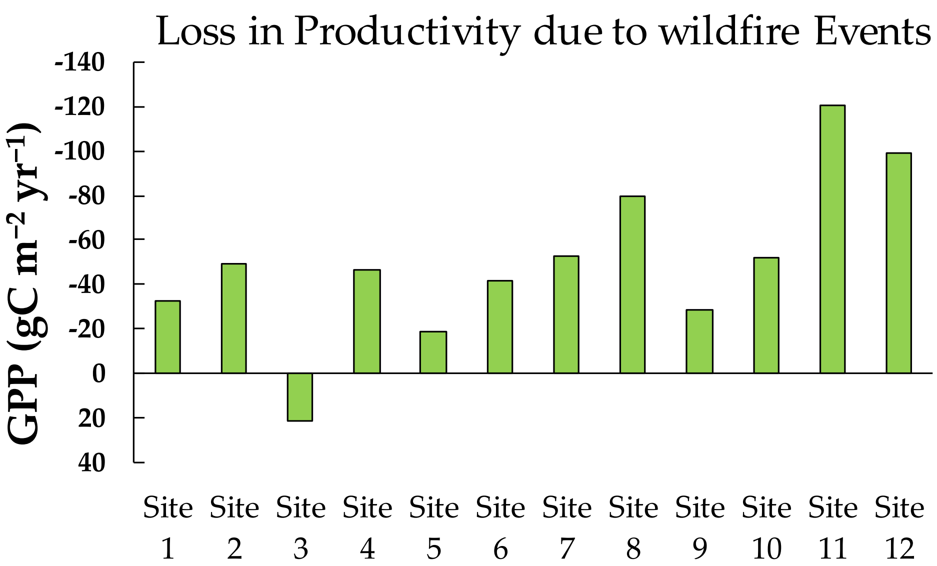

Figure 5. Loss in productivity in term sof GPP during 2019 compared to 2018 at all 12 pilot study sites.

4.2. Discussion

Our study demonstrated that the wildfire events that occurred in 2019 at the Brazilian Amazon significantly impacted the primary productivity of the forest as well as the Amazonian ecosystem, in comparison to 2018. We estimated an 8.95 percent reduction in GPP during 2019 at 12 pilot study plots at Brazilan Amazon than 2018. Amazon forest is globally recognized as a prime producer of oxygen and receiver of carbon. However, such destructive wildfire events often turn this carbon sink zone into carbon sources due to wildfires. It has also been observed that though wildfire events do not hamper the general trend of GPP for the forest ecosystem, but significantly reduces forest productivity resulted in low consumption of carbon for photosynthetic activity as well as a decrease in autotrophic and heterotrophic respiration [15]. Thus, it can be assumed that the ecosystem respiration over the different wildfire zones of the Amazon forest during 2019 has been decreased due to forest fire and induced extreme heat. Such disturbances, particularly extreme wildfires events like 2019, significantly hampers the structure and diversity of the landscape over time by exerting selection pressure, controlling succession, and affecting the ecosystem functioning, including the carbon and nutrient cycles [16]. Thus, it is evident that the wildfire events not only disturbed the structure, composition, and functionality of the terrestrial ecosystem but also influenced the global CO_2 fluxes and its feedbacks to the global climate system as a whole [17].

5. Conclusion

The intensity and number of wildfires have been significantly increased globally over time due to climate change and global warming. Such situations accelerated the possibilities of tree mortality, destruction of forest ecosystems, and loss of biodiversity. Quantifying such trends are highly necessary to detect the early signs of ecosystem degradation. Advanced satellite remote sensing technology provides us such a great opportunity to monitor, measure, and take required mitigation measures on a timely basis. However, more advanced vegetation signals like Sun-induced fluorescence (SIF) can be incorporated with modern machine learning models to monitor, predict and quantify productivity losses in real-time and implement sustainable management techniques to restore the forest ecosystem and biodiversity [18]. We assume that an increase in future wildfire events could turn forest ecosystems into carbon sources contributing towards positive carbon-climate feedbacks which is already anticipated in the tropics [19].

Author Contributions: conceptualization, S.B.. and D.A.; methodology, S.B.; software, D.A.; formal analysis, S.B.; investigation, S.B.; resources, S.B. and D.A.; data curation, S.B. and D.A.; writing—original draft preparation, S.B.; writing—review and editing, S.B. and D.A.; visualization, S.B. and D.A.; supervision, S.B. and D.A.

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Conflicts of Interest: The authors declare no conflict of interest.

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