ISSN 2522-9400 **European Modern Studies Journal** *Vol 4 No 2*
available at journal-ems.com

Assessment of the Resilience of Altered Permanent Preservation Areas (App's) from the Occurrence of Precipitation Variations

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Abstract. The urban expansion that assails water bodies in a disorderly way receives environmental impacts that are aggravated when floods and floods occur. The objective of this research was to analyze the changes in vegetation and soil chemistry in 36,000 m^2 (A1, A2 and A3, with 12,000 m^2 each) in the Environmental Protection Areas of the Uraim and Paragominas rivers, southeast Pará. The method used was the deductive one, with quantitative and qualitative scope, of nature applied. The pluviometric data were obtained from the National Water Agency link, from April 2018 (flooding) to March 2019 (flooding). The data obtained were treated statistically as BiosEstat 5.0 software use. The loss of vegetation cover was calculated using the Visible Atmosphericaly Resistat Index with the aid of Unmanned Aerial Vehicle, then the maps were prepared using the electronic tools available in MAPPA Agriculture drone Analysis and Quantum Gis.Soil sampling was performed both in dry and rainy periods in accordance with the Pedology Manual of the Brazilian Institute of Geography and Statistics and the application of the Soil Quality Assessment Index. The analysis of the data obtained indicated that the 2018 flood did not occur only from climatic factors such as La Niña but worsened due to the rupture of dams, the flooding was due to high rainfall rates (March, $\overline{x}$ = 570.0 mm) and may occur again. For the VARI, the data indicated that there was a high alteration in vegetation in Area 1 in different spectral ranges (Q1= 0, 0029%; Q2 = 0,0043%, more intense; Q3 (31,95%) and Q4 (20,79%) less intense, areas with scarce and sparse vegetation coverage and with Housing Units located between 03 and 10 m from the banks. As for IQAS, four quadrants four of them were above the average ($\overline{x}$ = 0.3962), as occurred in: A01Q04, $\overline{x}$ = 0.6323; A0Q01, $\overline{x}$ = 0.5669; A02Q03, $\overline{x}$ = 0.5285 and A02Q02 $\overline{x}$ = 0.4806. Therefore, the alterations in soil chemistry were classified as "low to medium", which is essential for the recomposition of the riparian forest, therefore, it is suggested the isolation of the affected areas, with the planting of native seedlings, and obedience to the marginal vertical radius of 30 m stipulated in the Brazilian Forest Code.

Key words: Climate Change, Forest Code, Urban sprawl

Introduction

The Brazilian Forestry Code was instituted to boost forest activity and preserve the biological diversity and variability of living organisms. In this context, the Forest Code (Federal Law n.12.651/12) defines the Permanent Preservation Area (APP) as a protected area, covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability, and biodiversity, facilitating the gene flow of fauna and flora, protecting the soil and ensuring the well-being of human populations (Brazil, 2012).

However, the function of the APPs is not only based on the preservation and conservation of the biotic and physical environments, but also on the anthropic ones. They are essential to ensure the well-being of human populations because when riparian vegetation is altered, rivers are more susceptible to harmful impacts due to extreme climatic events (such as floods and floods), which can be intensified by episodes such as the rupture of dams (Schäffer, 2011).

As for the meteorological phenomena that can trigger these extreme weather events, the main one is La Niña. The excess rainfall in the Amazon Region may then be associated with the occurrence of this phenomenon. It consists of the abnormal cooling of the surface waters of the Pacific Ocean in the equatorial region, which affects the rainfall regime in the Amazon region and other parts of the world (Higuchi, 2011).

Given the importance of the APP in controlling the adverse effects of these events and all other ecosystem services provided by these areas, they cannot be exploited, except in cases of public utility, social interest, or activities with low environmental impact (Nery et al., 2014). Despite this, they are often altered by urbanization, especially the disorganized. Thus, it is common in urban areas to verify the occurrence of APP's with chemically, physically, and biologically altered soils (Szymczak et al., 2012; Khaledian et al., 2016).

Based on this information, the objective of this research was composed in four phases: (1) To analyze quantitatively and qualitatively the temporal distribution of the rains in March and April (1989-2019).

(2) To detect from the Atmospheric Resistance Index in the Visible Region (VARI), the area of study that was most altered in vegetation and classify the level of alteration according to the percentage of coverage of the VARI intervals.

(3) Assess the chemical modification of the soil in the areas employing the Soil Chemical Alteration Index (IAQS), calculated from laboratory analysis of primary and secondary macronutrient concentrations in the dry and rainy periods.

(4) Suggest two measures for the re-establishment of riparian vegetation and for the prevention of the occurrence of anthropic activities and phenomena that alter the APP.

Methods

Physiography of the municipality

The municipality of Paragominas (Figure 1) is in the southeastern mesoregion of the state of Pará and has an estimated population of 113.145 (Ibge, 2019). The local climate is hot and humid, with an average annual temperature of 26ºC and relative air humidity of 81%. The only two rivers that cross the urban perimeter are the Uraim and Paragominas rivers, both constituting the Microbasin of the Uraim river and the Gurupi river basin (Alves et al., 2014; Pará, 2016).

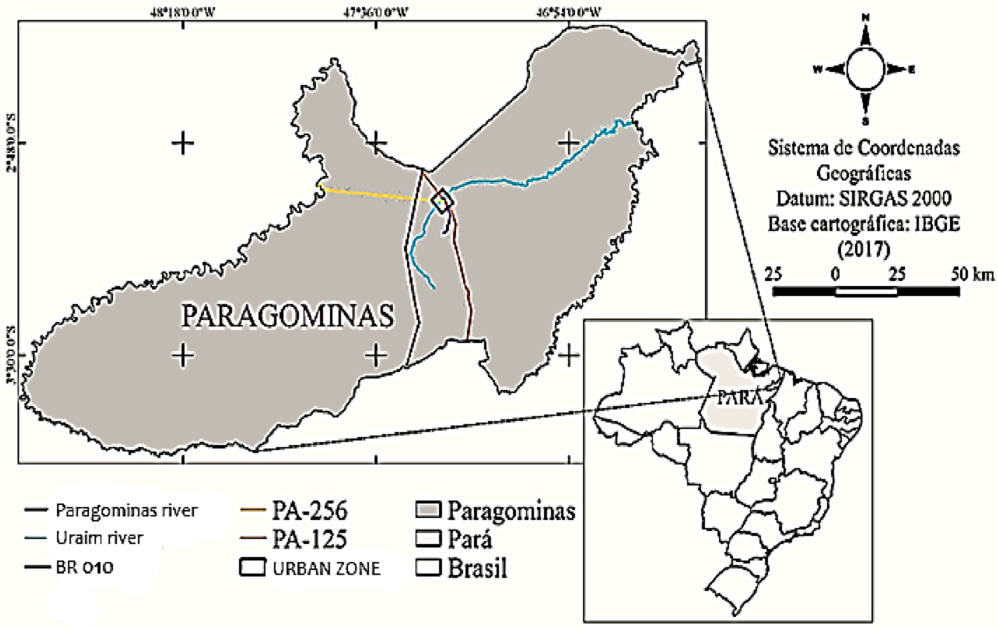

Figure 1. Political and geographical location of the municipality. Paragominas- PA. Source: authors (2020)

Areas of study

There are three study areas, and they are in the urban area of the municipality of Paragominas, on the banks (left and right) of the Paragominas River. They are in the surroundings of three bridges, in Carlos Gomes, Caravelas, and Bujaru streets, respectively. The presentation of data, each area, was subdivided into four quadrants (Figure 2), of 100m x 30m each, and named according to the area of which it is part and its numbering concerning that area, for example, A01Q01 refers to Quadrant 1 (Q01) of Area 1 (A01).

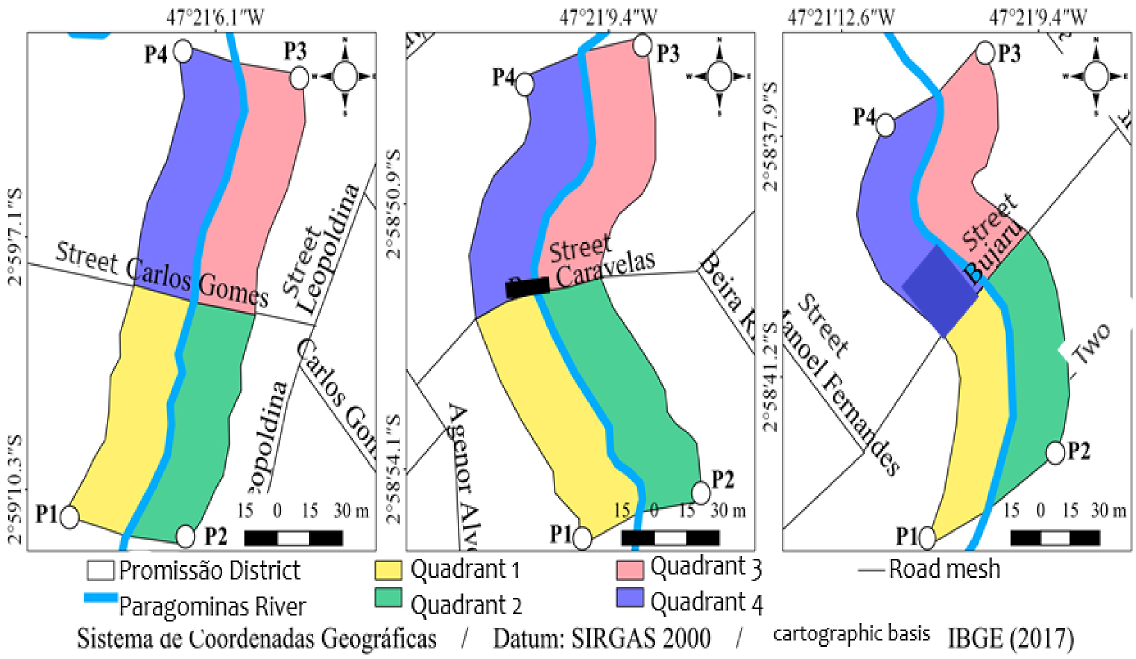

Figure 2. Study areas and their subdivision into quadrants. Source: authors (2020)

The vertices of each area were identified counterclockwise and total four in each (Table 1).

Table 1. Numbers and geographic coordinates of the vertices of the studied areas. Paragominas (PA)

Area	Vertexes	Latitude	Longitude
1	P1	2°59'10.64 "S	47°21'8.49 "O
	P2	2°59'11.03 "S	47°21'6.60 "O
	P3	2°59'4.99 "S	47°21'4.81 "O
	P4	2°59'4.60 "S	47°21'6.72 "O
2	P1	2°58'55.06 "S	47°21'9.79 "O
	P2	2°58'54.52 "S	47°21'7.96 "O
	P3	2°58'48.84 "S	47°21'8.80 "O
	P4	2°58'49.34 "S	47°21'10.65 "O
3	P1	2°58'43.46 "S	47°21'11.22 "O
	P2	2°58'42.19 "S	47°21'9.06 "O
	P3	2°58'36.67 "S	47°21'10.30 "O
	P4	2°58'37.77 "S	47°21'11.90 "O

Source: authors (2020).

Research method

The method of approaching the logical procedures was the deductive one, according to a synthesis prepared by Prodanov and Freitas (2013). This method consists in the analysis of particular facts (soil and vegetation changes that occurred in the APP of the Paragominas River) from the observation of general effects (the changes that anthropic activities and climatic events can cause about the APP's). The research also had both quantitative and qualitative approaches and clear objectives, according to a synthesis prepared by Sakamoto and Silveira (2014).

Collection of pluviometric data

For the analysis of rainfall in Paragominas/PA, rainfall data were collected on the HidroWeb digital platform of the National Water Agency (ANA, 2018). The months of march and April were analyzed with emphasis because of the occurrence of two climatic events in the municipality: the flooding in April 2018 and the flooding in March 2019.

The selection data of the pluviometric station was made based on three factors: (1) the more excellent proximity to the urban area and, consequently, to the Paragominas River; (2) the availability of data; and (3) the amount of time series failures. Based on this, the station "Paragominas 2" (03° 00' 36" S and 47° 20' 36" W), administered by ANA and identified by code 00347000, was selected. It is located about 300 meters from the bank of the Paragominas River and 2.8 km (in a straight line) from Study Area 1.

Only four failures were observed in the series (Mar./1991, Apr./1991, Apr./2014 and Mar./2015), which were filled from the simple linear regression (Nascimento et al., 2009) between the stations "Paragominas 2" and "Capim River." This last station was selected to fill the gaps, as it is between the two (Capim River and Cafezal stations) closest to the "Paragominas 2" station, besides having few differences in the filling and having historical series available from 1989 to 2019.

Also, the adjustment coefficient (R^2) between her data and "Paragominas 2" is 0.7437, while the adjustment between her data and those of the "Cafezal" station is 0.0782. The equation for filling in the gaps by the Capim River pluviometric station (code 00247006) was y = 0.9368x + 37.091, where x is the monthly total measured by "Capim River" and y was the value that filled in the gap.

The historical series collected was analyzed in two ways: from 1989 to 2018 for the annual totals and from 1989 to 2019 for the March and April PRP. Because in both stations considered ("Paragominas 2" and "Capim River") on the platform, for the year 2019, the values are only available from January to April, which made it impossible to analyze the annual rates.

Based on the faults duly filled, a graph showing the behavior of the rainfall indexes in March and April during the last 31 years in the municipality (1989 to 2019) was plotted. The data were treated statistically, with the help of BioEstat 5.0 software (Ayres et al., 2007) to identify the arithmetic mean of precipitation in both months, as well as the maximum and minimum recorded rainfall values (Costa, 2011).

An atmosphere-resistant index in the visible region (VARI)

Visible Atmospherically Resistant Index) was calculated to map the percentage of green cover per unit area (i.e., the Plant Fraction). It was used to identify which of the study areas were more altered in terms of vegetation and to classify the level of alteration from the percentage of coverage (Torres-Sánchez et al., 2014). For its calculation, Equation 2 was used. In it, the reflections of the visible red, green, and blue bands (Red, Green, and Blue - RGB) sensitive to the presence of vegetation cover were considered primordial for the selection of this tool for vegetation analysis (Gitelson et al., 2002):

$$VARI\,\frac{(Rgreen - Rred)}{(Rgreen + Rred - Rbue)}$$

The calculation of the VARI was made from aerial images of the three areas captured using UAV (Unmanned Aerial Vehicle). Index calculation and map generation were performed using the MAPPA Agriculture Drone Analysis online platform and the processing and post-processing tools contained in the Quantum Gis (QGis) software, respectively.

To facilitate the analysis of the obtained data and thus to qualify the level of alteration of the areas regarding vegetation, the classification "high," "medium" and "low" were used, according to the intervals closest to -1, 0 and +1, respectively, according to the VARI intervals indicated in the legend of each of the tables exposed in the results. The quadrants with the highest percentages of coverage for a given range were highlighted with the colors corresponding to the intervals and the level of vegetal alteration (Table 2).

Table 2. Classification of the percentage of coverage to characterize the level of plant alteration

Interval number	Colors	Level of plant alteration
1		High
2		
3		Medium
4		
5		Low
6		

Source: authors (2020).

Also, it is essential to note that the flow of electromagnetic radiation (REM) that reaches the objects (incident energy) undergoes various types of modification when it meets these objects. The adjustments vary according to the relationship between the type of REM and the capacity of the targets to absorb, transmit, or reflect energy. The reflectance of vegetation, for example, varies according to the parts of the plant, the entire plant, a set of plants, and several collections of plants spatially distributed (Abreu and Coutinho, 2014).

In this sense, when using the interval -1 to 1 for interpretation of the VARI intervals, it was considered that the closer to 1, the higher the percent coverage and the lower the vegetation change level and the higher the percent coverage in the VARI interval close to -1, the higher the vegetation change level.

Soil data collection

The methodologies used to perform the soil chemical laboratory analyses were those described in the Manual of Chemical Analysis for Soil Fertility Assessment (Teixeira et al., 2017). As for soil sampling, it was performed in two periods: dry and rainy (Table 3).

Table 3. Period of soil collection in the study areas. Paragominas - PA

Period	Period of collection
The first collection - Dry	3rd week of November 2018.
Second collection - Rainy	4th week of February 2019.

Source: authors (2020).

Soil sampling occurred with the use of a randomized experimental design (zigzag) with the aid of a drill (stainless material) at a depth of 0-20 cm. Five simples (deformed) samples containing 100g were collected in each quadrant, which totaled 12 composite samples (one in each quadrant) of 500g each, which were submitted to laboratory analysis (Table 4), according to the Manual of Pedology (Ibge, 2019).

Table 4. Chemical parameters of soil analyzed in the laboratory

Parameters	Symbologies	Units of measurement
Hydrogenic potential in water	pH_{H2O}	--
Hydrogenic Potential in Potassium Chloride	pH_{KCl}	--
Organic carbon	Corg.	g/kg
Organic matter	MO	g/kg
Available phosphorus	P	mg/dm^3
Potassium	K^+	$cmol_c/dm^3$
Calcium	Ca^{2+}	$cmol_c/dm^3$
Magnesium	Mg^{2+}	$cmol_c/dm^3$
Potential acidity	H + Al	$cmol_c/dm^3$

Source: authors (2020).

The soil analysis related to the collection of the dry period was performed at the Soil Laboratory of the Federal Rural University of the Amazon (UFRA), Campus Belém. The analysis of the collection of the rainy season was carried out at the Laboratory of Chemical Analysis of the Emílio Goeldi Museum of Pará (MPEG), Coordination of Earth Science, and Ecology (CCTE). The soil collected is of the order of Plinthosols, which is characterized by presenting plinization (accumulations of iron and aluminum or iron oxides in the form of moths). These soils are subject to the temporary effect of humidity, which occurs mainly in the rainy season (Santos et al., 2018).

Calculation of the chemical alteration index of the soil (IAQS)

The calculation of the IAQS occurred in two stages: 1) factor analysis, with the extraction of factors from the Main Components method; 2) application of the equation of the soil chemical alteration index.

Stage 1:

a) Stacking data in a 9-column matrix for the same number of variables; 24 rows for 12 quadrant composition for dry and rainy period data. The technique recommended by Campos et al. (2010). According to his synthesized, this allows removing influences of scale and units.

b) Effect of two tests: Bartlett and Kaiser-Meyer-Oikon (KMO) criteria, purpose: possible admission that the correlation matrix is different from the identity matrix. For KMO>0.5, according to Pinto and Coronel (2014).

c) Calculation of characteristic roots λ (auto values or eigenvalues). We considered in factor analysis the λ >1, with accumulated variance >70%, as exposed by Hair Júnior et al. (2017).

d) Calculation of factor loads and commonalities of variables.

e) Orthogonal rotation of factor loads and commonalities using the "varimax" method. The objective was to make them closer to 0 or 1. Then, the loads were verified whose values were above 0.7 (indicates a need for grouping). Those with communalities > 0.4 remain in the analysis.

f) Orthogonal rotation of factor loads and commonalities using the "varimax" method. The objective was to make them closer to 0 or 1. Then, the loads were verified whose values were above 0.7 (indicates a need for grouping). Those with communalities > 0.4 remain in the analysis, in obedience to what was described in Lattin, Carroll, and Green (2011).

g) The standardization of variables to remove differences in scale and magnitude was calculated using Equation 1, contained in Oliveira et al. (2014).

$$Z_i = \frac{Xi - \bar{x}}{\sigma_i} \quad (1)$$

in which: Zi = standardized variable; Xi = original; $\bar{x}$= average of all variables; σ = standard deviation.

h) Calculation of the factor score coefficients (*Wji*) of the extracted factors.

i) Factor scores (*Fj*) of extracted factors. They are equivalent to the estimated value of the elements (Equator 2), since these are unobservable variables, as exposed by Silva et al. (2015) using the Equation 2.

$$Fj = W_{J1}Z_1 + W_{J2}Z_2 + W_{J3}Z_3 + W_{Ji}Z_i \quad (2)$$

Fj is the j-th factor score, and *Wji* is the j-th factor coefficient for *Zi*.

Stage 2:

a) Standardization of the scores so that they present values between 0 and 1, and negative ratings with high modular costs do not interfere with the magnitude of IQAS (Equation 3), as described by Lemos (2001).

$$F_{jk} \frac{F_{jk} - F_j^{min}}{F_j^{máx.} + F_j^{min}} \quad (3)$$

Where F_{jk}= j-th factor score for the kth quadrant, F_j^{min} and $F_j^{máx.}$ Scores observed for a j-th factor.

b) The calculation of the IAQS for k - ésimo quadrant was done with the application of Equation 4.

$$IAQS_k = \sum_{j=1}^{p} \left(\frac{\lambda_j}{\Sigma_{\lambda_j}} (F_{JK}^{*})\right) \quad (4)$$

The legend used to interpret the IAQS is the one composed of Cunha et al. (2008). In this research, we chose to mix two of the four strata used by them, has adapted for three numerical intervals as a legend for interpretation of the index (Table 5).

Table 5. Legends for interpretation of IAQS. Paragominas-PA

Cunha et al. (2008)		Adaptation made	
Interval/Legends	**Qualification**	**Interval/Legends**	**Qualification**
0.00 a 0.30	Low	0.00 a 0.30	Low
0.30 a 0.50	Medium-Low	0.30 a 0.70	Medium
0.50 a 0.70	Higt Low	0.70 a 1.00	Higt
0.70 a 1.00	Higt	-----------------	----------------

Adapted the dates in Cunha et al. (2008)

The IAQS data were treated statistically using spreadsheets contained in BioEstat 5.0 software (Ayres et al., 2007). From it, the maximum and minimum values of the data of each analysis were identified, and the arithmetic means, standard deviation, and coefficient of variation (Costa, 2011) were calculated.

Interpretation of laboratory analyzed attributes

According to Santos et al. (2018), plinthosol's are naturally acidic and of low fertility. Therefore, among all the characteristics explained in the laboratory and used to calculate the IAQS, emphasis will be given to the hydrogen ion potential in water (pH_{H2O}) and to base saturation (V%), which are indicators of soil acidity/alkalinity and fertility, respectively (Table 5).

Table 6. Qualification of concentration ranges of chemical attributes

Attributes	Units	Qualification		
		Low	Medium	High
pH_{H2O}	--	< 5.0	5.0 a 6.0	> 6
V%	%	< 50	50 a 70	> 70

Source: Sobral et al. (2015).

The above values were considered satisfactory when medium and high. In the case of pH, the "high" range was deemed to be adequate if it is below 7.5 since soils with pH between 7.5 and 8.5 are calcareous (Pestana et al., 2015).

Photographic memorial

Support of soil and vegetation analyses carried out after the climatic events occurred in the municipality, a photographic material was prepared to demonstrate the effects of the flooding on the APP in the study areas: (1) day 19/04/2018 (seven days after the flooding); and (2) day 25/03/2019 (two days after the flooding).

Results and Discussion

Temporal distribution of rainfall

The average annual rainfall rate recorded in Paragominas (AP), for the time series from 1989 to 2018, was 1745.65 mm. In 2018, the year of occurrence of the flood, the annual total was 2163.40 mm, being the third highest in the time series, lower only than 2716.27 (in 2009) and 2503.50 (in 1989).

About the rainy period in Paragominas, Pinto et al. (2009) and Andrade (2011) identified that it occurs from December to May, which was evident in this study. The rainy period in the municipality can be characterized as high rainfall and many days ($\overline{x}$=145.79) of rain. As for the 1989-2019 series, the months with the highest rainfall rates in the last 31 years were March ($\overline{x}$ = 355.9 mm) and April ($\overline{x}$ = 364.0 mm).

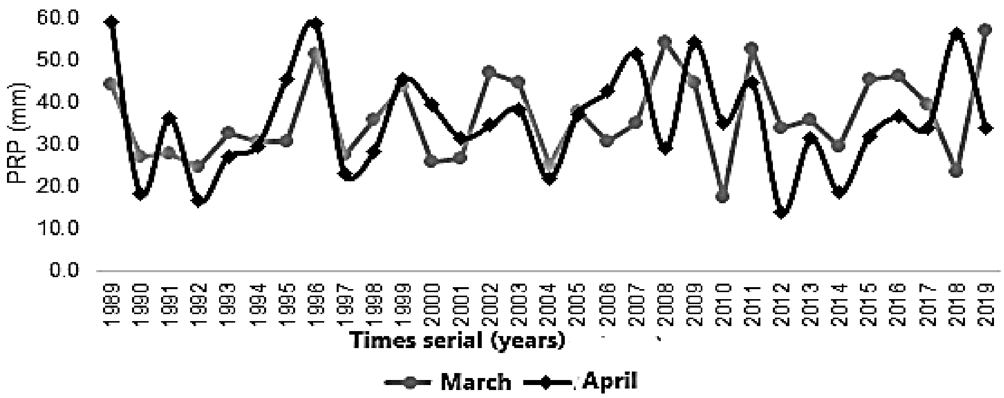

Figure 4. Rain rates in March and April, recorded in the municipality of Paragominas-PA during the last 30 years (1989 to 2019). Source: authors (2020)

From the data obtained, it was also verified that the highest average rate in March ($\overline{x}$ = 570.0 mm) occurred in 2019, precisely the month and year of flooding; in April ($\overline{x}$ = 589.8 mm), it happened in 1989, which was the year of the second-highest rainfall in the series. After the analysis of available data for the series (1989-2018), March was the wettest month in 13 (43.33%) of the 30 years studied and April the most humid in 7 years (23.33%). The maximum rainfall for the remaining ten years was recorded in February (20%), May (10%), and January (3.34%).

However, it is noticeable that the flooding that occurred in April 2018 may not have been due only to climatic factors, since there were already periods (1989 and 1996, the latter with 585.4 mm) when the rainfall recorded in that month was higher than that in 2018 (561.7 mm).

Regarding these variations, Fonseca and Miyagawa (2018) conducted a study on the areas at risk of flooding in the municipality. They confirmed that the high rate of PRP (110 mm in one hour) recorded on April 11, 2018, caused significant flooding. This precipitation contributed to the high rates recorded in April, observed in this survey. However, the authors conclude that the effects of rainfall were aggravated by the rupture of three dams located in rural properties upstream of the Uraim and Paragominas rivers.

The high rainfall recorded in April 2018, although not the highest in the series, was further intensified by the La Niña phenomenon (of moderate intensity), recorded by Inpe (2019) for the period 2017-2018. According to Reboita and Santos (2018), this phenomenon promotes the intensification of convective activity in the Amazon. It favors the increase of rainfall in the region, which, according to Fraga (2014) and Borma et al. (2013), may cause urban flooding, as observed in the municipality subject of this research.

The atmosphere-resistant index in the visible region (VARI)

From arithmetic combinations of spectral bands, it was possible to obtain the percentage coverage of the three study areas. The maps were illustrating the intervals detected for the indices (VARI) equivalent to the colors identified in zones 1, 2, and 3.

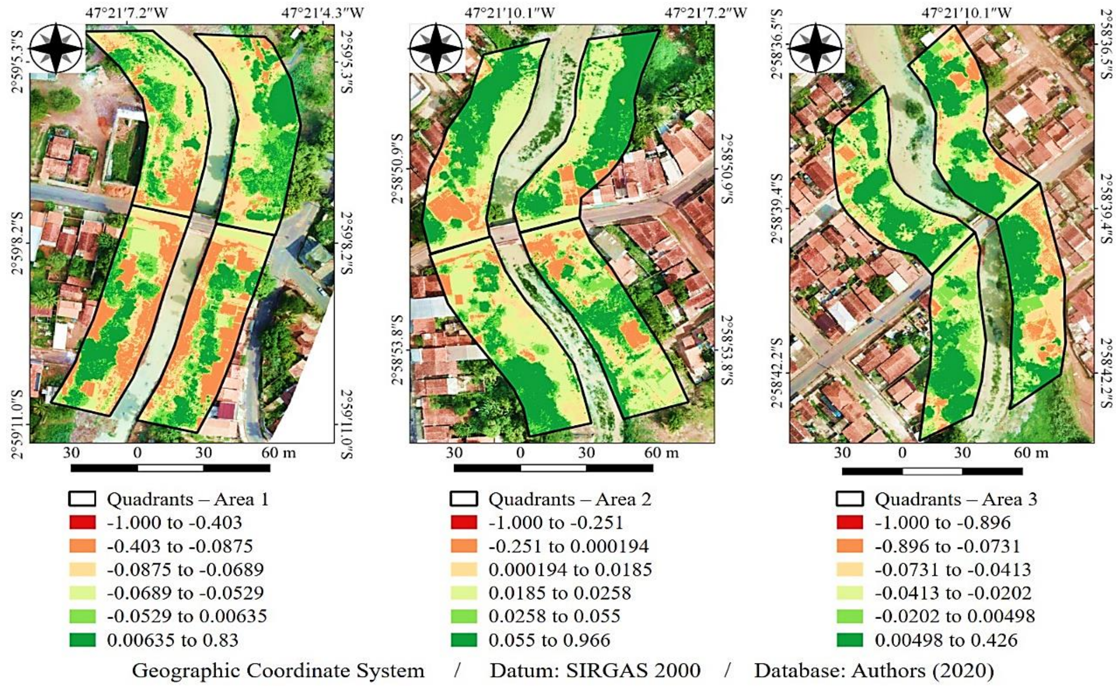

Figure 5. VARI maps in areas 1, 2, and 3. Source: authors (2020)

The data obtained and analyzed in terms of the percentage of coverage of the intervals were arranged in tables corresponding to each mapped area (Table 7).

Table 7. Percentage of coverage of areas 1, 2, and 3 quadrants

Area 01				
VARI	**Q01 (%)**	**Q02 (%)**	**Q03 (%)**	**Q04 (%)**
-1 a -0.403	0.00029	0.0043	0	0
-0.403 a -0.0875	30.31	34.22	6.28	14.11
-0.0875 a -0.0689	16.35	15.70	23.93	25.06
-0.0689 a -0.0529	15.08	14.83	18.84	23.10
-0.0529 a 0.00635	13.73	15.88	18.99	20.97
0.00635 a 0.83	24.55	19.37	31.95	16.76
Area 02				
VARI	**Q01 (%)**	**Q02 (%)**	**Q03 (%)**	**Q04 (%)**
-1 a -0.251	0	0	0	0
-0.251 a 0.000194	6.22	13.25	5.75	12.12
0.000194 a 0.0185	14.39	14.48	7.55	9.15
0.0185 a 0.0258	36.11	28.33	28.69	29.94
0.0258 a 0.055	13.72	18.71	11.99	11.67
0.055 a 0.966	29.56	25.23	46.02	37.12
Area 03				
VARI	**Q01 (%)**	**Q02 (%)**	**Q03 (%)**	**Q04 (%)**
-1 a -0.896	0	0	0	0
-0.896 a -0.0731	4.12	13.47	9.81	6.01
-0.0731 a -0.0413	9.44	22.92	20.09	12.27
-0.0413 a -0.0202	21.53	10.48	17.90	28.86
-0.0202 a 0.00498	28.55	14.25	13.75	14.23
0.00498 a 0.426	36.35	38.87	38.44	38.64

Obs*: The colors arranged are the same as indicated in the methodology, in Table 2. Source: authors (2020).

After the analysis (Figure 4 and Table 7), it was possible to identify that among the areas, area 1 proved to be the most altered. Because only in it occurred the highest percentages of coverage in orange and yellow, which characterize a high and medium level of alteration, respectively. The other areas (2 and 3) obtained higher percentages of coverage in colors compatible with a low level of adjustment. Coverage of quadrants in Area 1, as well as the highlighted quadrants that obtained "high," "medium," and "low" values concerning the level of vegetal alteration (Table 8).

Table 8. Percentage of coverage of Area 1

VARI	Q01 (%)	Q02 (%)	Q03 (%)	Q04 (%)
-1 a -0.403	0.00029	0.0043	0	0
-0.403 a -0.0875	30.31	34.22	6.28	14.11
-0.0875 a -0.0689	16.35	15.70	23.93	25.06
-0.0689 a -0.0529	15.08	14.83	18.84	23.10
-0.0529 a 0.00635	13.73	15.88	18.99	20.97
0.00635 a 0.83	24.55	19.37	31.95	16.76

Source: authors (2020).

Regarding the percentage of coverage of the red color, between quadrants 1 and 2, the highest rate reached was 0.0043%. This value indicates that the vegetal alteration that occurred in quadrant 2 was the most senior and that this influenced the chlorophyll content. According to research carried out by Ponzoni (2001), the existing pigments in the leaves dominate the spectral reflectance.

The author reiterates that these pigments, generally found in chloroplasts, are chlorophyll (65%), xanthophylls (29%) and carotenes (6%), with percentage values that vary according to the different species. Still, on quadrant 2, it also obtained the highest percentage coverage for the orange color (34.22%), which ratifies the change in vegetation that occurred in this quadrant.

As for quadrant 3, it was shown, among the quadrants analyzed, with the highest percentage of coverage for the color "dark green" (31.95%), which characterized a low vegetation alteration in the quadrant. According to research conducted in the Amazon by the authors Nunes et al. (2012), this high value was due to the presence of vegetations with the arboreal extract. Therefore, these present a greater photosynthetic and water stability, which consequently leads to higher reflectance.

On the other hand, in quadrant 04, among the colors identified, the color that reached the highest percentage of coverage was beige with 25.06%, so there was a change in the average level in the quadrant. In this perspective, the authors Ferreira et al. (2006) reveal that vegetations with herbaceous arbustive extract are highly susceptible to variations caused by the alternation of water regimes, besides not having photosynthetic and water stability, which contributed to the average reflectance's.

For these reasons, it was decided to analyze the levels of change that occurred in Area 1 and not in the others. Because the other areas obtained better percentages of coverage, in which the levels of variation were low due to the amount of arboreal vegetation and more significant portions of allocated green biomass. Such standards may be associated with the fact that in Areas 2 and 3, there is a lower presence of housing units within the delimited quadrants compared to Area 1.

Chemical alteration index of the soil (IAQS)

From the IAQS calculation, it can be verified that there was no area with high chemical alteration of the soil, only low (in 4 quadrants - 33.33%) and medium alterations (in 8 quadrants - 66.67%), the most significant being 0.6323 (Table 9).

Table 9. Ranking of study quadrants regarding the soil chemical alteration

Ranking position	Area/Quadrant	IAQS	Qualification
1º	A01 Q04	0.6323	Medium
2º	A01 Q01	0.5669	Medium
3º	A02 Q03	0.5285	Medium
4º	A02 Q02	0.4806	Medium
5º	A03 Q03	0.4709	Medium
6º	A02 Q01	0.4619	Medium
7º	A01 Q03	0.4286	Medium
8º	A01 Q02	0.4049	Medium
9º	A03 Q02	0.2453	Low
10º	A03 Q01	0.2167	Low
11º	A03 Q04	0.1834	Low
12º	A02 Q04	0.1342	Low
Maximum		**0.6323**	
Medium		**0.1342**	
Arithmetic mean		**0.3962**	
Standard deviation		**0.1622**	

Coefficient of variation	**40.94%**	

Source: authors (2020).

From the analysis of the data obtained, it was found that the four highest rates of alteration are related to the quadrants with sparse and scarce vegetation coverage and the presence of housing units (UA's) closer (between 3 and 10 meters) to the left and right margins of the water body.

Figure 6. a) 1st in the IAQS ranking: Area 01, Quadrant 04; b) 2nd in the IAQS ranking: Area 01, Quadrant 01; c) 3rd in the IAQS ranking: Area 02, Quadrant 03; d) 4th in the IAQS ranking: Area 02, Quadrant 02. Source: authors (2020).

This relationship occurs, according to research conducted by Szymczak et al. (2012), in urban soils of Santa Maria (RS), since anthropic activities on urban lands can cause several changes, such as alkalinity and nutritional imbalance, besides hindering plant development.

This plant development is hampered because, according to Cadorin et al. (2013), in a study carried out on urban soils in Pato Branco (PR), the most critical environmental factor for the vitality of trees is the condition of the land in which they grow.

However, the changes that occurred were not detrimental to the chemical quality of the soil. The values obtained for the alteration indexes allowed the classification as low and medium (0.1342 to 0.6323), the analysis of the concentrations of the attributes used for the IAQS calculation confirms this fact (Table 10).

Table 10. pH_{H2O} and V% in the study quadrants. Paragominas - PA

Season	Área 01				Área 02				Área 03			
	01	02	03	04	01	02	03	04	01	02	03	04
pH_{H2O}												
Dry	7.3	7.4	7.2	7.6	6.8	7.3	7.0	6.5	5.8	6.1	6.8	6.4
Wet	7.01	6.7	6.78	7.08	6.55	6.34	7.3	6.68	5.99	6.32	6.88	6.64
V%												
Dry	100	100	100	100	74	100	100	34	50	68	63	42
Wet	100	76	81	100	68	86	100	57	72	72	90	80

Source: authors (2019).

From the data obtained, it was observed that the chemical alteration of the soil in the studied areas was beneficial since the pH. V % values obtained are satisfactory, and now the land has eutrophic characteristics: pH is no longer acid, and soil fertility has increased (V > 50% in 22 (n = 91.7%, of the 24 samples). Regarding soil trophic, Ronquin (2010) describes as indicative of eutrophic and fertile soil, the predominance in CTC_{total} of Ca^{2+}, $Mg^{2+,}$ and K^{+} over H^{+} and $Al^{3+.}$

The values obtained for soil fertility then indicate its suitability for plant recovery, although altered. The municipality's plinthosol's naturally present low costs for V% (5 to 18%), according to a data survey carried out by Ibge (2017), for mapping of natural resources in Paragominas (PA). In the areas, however, they presented values between 34% and 100%, with only two values (34 and 42%) below 50% (dystrophic soil).

The same behavior was observed by Cadorin et al. (2013), in their study in Pato Branco (PR). The authors showed that urban soils had undergone chemical changes with urbanization, but currently have better quality in terms of fertility. Thus, it is inferred that the ground analyzed in this research still can provide chemical support to the development of vegetation, planted, or in regeneration.

According to the analyses carried out in Manaus (AM), by Barroco Neta and Nishiwaki (2018), and in Boa Vista (RR), by Feitosa et al. (2016), this support is essential, because the chemical quality of the soil can directly interfere in the floristic composition and in the structure of the vegetation that needs it from the establishment of the seedlings to the maintenance of the forests. In the research conducted in Paragominas, the chemical conditions of the analyzed soil maintain requirements for the recovery of vegetation that has been dragged by flooding and inundation.

Measures for the reestablishment of vegetation and protection of the app

It is suggested as measures for the re-establishment of vegetation in the areas of their isolation and the planting of native seedlings for recovery. As for the protection of the APP from the prevention of anthropic activities in it, it is suggested the removal of residents with residences within 30 m from the river banks, as well as the environmental education of the surrounding population so that they become aware and act consciously, without degrading the environment.

Conclusion

Regarding the temporal distribution of rainfall rates, it was observed that the flooding in 2018 was not only due to climatic factors such as La Niña and the frequent high rainfall in that month but was aggravated by the rupture of dams located in the municipality. In the following year, another event (flooding) of natural cause, which indicates the possibility of future recurrence of them, given the high rainfall recorded in the municipality.

Thus, from the collections made, it was possible to identify that the occurrence of the phenomena was influenced by high rainfall rates, but that they are not extraordinary. Thus, measures should be taken to recover the APP understudy, aiming at reducing the socio-environmental and economic impacts that may result from them.

Regarding the Atmosphere-resistant Index in the visible region (VARI), this was essential to verify that the most altered area among the three was area 1. Besides characterizing the levels of change that occurred in this area, the quadrants of the most or least changed were, Q2>Q1>Q4>Q3.

As for the chemical alteration of the soil, it was verified that it is from low to medium, and it is not harmful to the development of vegetation, because of the quality that the soil still presents in terms of fertility.

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