Soil Chemistry as a Determining Factor for Riparian Reforestation in Paragominas River, Paragominas, Para, Brazil

Ana Beatriz Matos Rodrigues[1], Nathalia Melo Giuliatti[2], Rodolfo Pereira Brito[3], Antônio Pereira Júnior[4]

[1, 2, 3]State University of Para, Department of Environmental Engineering; Highway PA 125 s/n, Paragominas, Para, Brazil

[4]State University of Para, Department of Environmental Engineering, Environmental Quality Laboratory Highway PA 125, s/n, Paragominas, Para, Brazil

Abstract: ***Changes in riparian forests can be minimized from environmental recovery. However, it is necessary to analyze the soil's chemical attributes before carrying out any recovery measures. Thus, this paper aimed to evaluate the degree of chemical alteration of the land and its ability to supply nutrients to the vegetation for recovery in three areas located in the Permanent Preservation Area (PPA) of the Paragominas River, near three bridges located in the urban area of the municipality of Paragominas,PA. The analytical procedures approach was the deductive one. The research had a quantitative and qualitative technique, besides descriptive objectives. Primary data were obtained in two periods: warm (November) and rainy (February) season, in three areas of 12,000 m² each, located on the banks of the Paragominas River. Regarding soil chemical attributes analysis, we subdivided the areas into 12 quadrants (4 in each region) of 3,000m² each. It was then collected one composite sample (500g) of soil in each quadrant, totalizing 12 samples submitted to laboratory analysis. The chemical attributes analyzed were: hydrogen potential (pH), organic carbon (O.C.), organic matter (O.M.), available phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), potential acidity (H+Al), total cation exchange capacity (CECtotal), the sum of exchangeable bases (E.B.) and base saturation (V%). To calculate the degree of soil chemical alteration, we used Factor Analysis with factor extraction by the Principal Component method. The obtained data indicated that the quadrants presented a low (in 33.33%) to a medium degree (66.67%) of chemical alteration.Nevertheless, according to the results obtained, they are consideredsuitable for reforestation since the chemical attributes present sufficient concentrations, enabling plant recovering. We suggest carrying out complementary physical and microbiological soil analysis and phytosociological studies in preserved areas to ensure recovery effectiveness.***

Keywords: Attributes, Alteration, Recovery

1. Introduction

The soil composition is presented in three phases: solid, liquid, and gaseous. The solid one is related to particle size and structure and is either mineral or organic. The second one is the pore-permeable solution in which most chemical reactions occur because it contains available nutrients to plants. The third one allows the root's respiration and the oxidation of organic matter [1]

Several factors can alter this composition, such as water, which is the leading cause of chemical weathering in the soil. This phenomenon can be due to water availability (mainly in the rainy season). It changes the soil chemical composition from the removal and addition of elements [2]

Thus, soil quality monitoring can be carried out by analyzing chemical attributes. They can indicate the equilibrium, alteration, or degradation state one area is. Thereby, by the soil's characterization, it is verified whether the site is suitable for reforestation what allows propositions to be made to solve problems, such as the absence of riparian forest [3]-[4]

This type of forest encompasses the vegetation on streamflow banks, whether urban, rural, or mixed. It changes due to morphological differences, soil chemical conditions, and climatic variations [5]

These forests are one of the ecosystems most altered by urbanization. Urban sprawl, when significantly disordered, causes their alteration by vegetation cover removal and human activities. Hence, in urban areas, riparian forests generally overlap soils with changes in their chemical, physical, and biological properties [6]-[7]

Therefore, the riparian forest must be reforested when altered or degraded [8]. Altered areas are the ones that, even after being impacted, still have natural regeneration capacity, which reduces the obstacles to environmental recovery [9]. Changes can be minimized or reversed from this recovery with reforestation. It consists of restoring an ecosystem to a stable condition, which may differ from the original [10]

In Brazil, riparian forests are part of Permanent Preservation Areas (PPAs). According to the Forestry Code [11] (Federal Law No. 12.651/12), these are protected areas, with or without vegetation cover, whose function is to protect water resources, biodiversity, besides to ensure the well-being of populations, as well as to promote and facilitate the gene flow of fauna and flora.
Other functions of riparian forests are soil protection from rainfall impact, the purification of the water within the soil, the runoff velocity reduction, the microclimate regulation, and root systems' soil stability. This stability prevents siltation and soil loss, hence conserving chemical elements such as macro-and micronutrients, ensuring plant biomass [12]-[13]-[14]

Regarding the minimum threshold needed to guarantee ecosystems services quality, the Forestry Code determines variable vegetation ranges according to river width: 30 meters (rivers with less than 10 m); 50 meters (between 10 and 50 m); 100 meters (between 50 and 200 m); 200 meters (between 200 and 600 m); 500 meters (more than 600 m). However, human intervention occurs in conflict with these delimitations and may compromise environmental quality [11]-[15]

Before carrying out any recovering measures, it should be assessed soil attributes, especially the chemical ones [16]. This study's purpose is associated with the influence chemical attributes have on the vegetation composition and structure. Therefore, this paper is justified due to the need to verify the soil capacity to provide nutrients to the vegetation, should reforestation be performed.

Thus, the objective of this work was to evaluate the degree of soil chemical alteration in the PPA compared to the natural characteristics of Paragominas plinthosols, and verifying, from the quantitative and qualitative analysis of chemical attributes, the soil's capacity to provide nutrients (chemical support) to the vegetation, should future environmental recovery be performed.

2. Material and Methods

2.1 Municipality physiography

The research took place in the municipality of Paragominas (Figure 1), Pará state southeastern mesoregion, with an estimated population of 113,145 individuals[17]

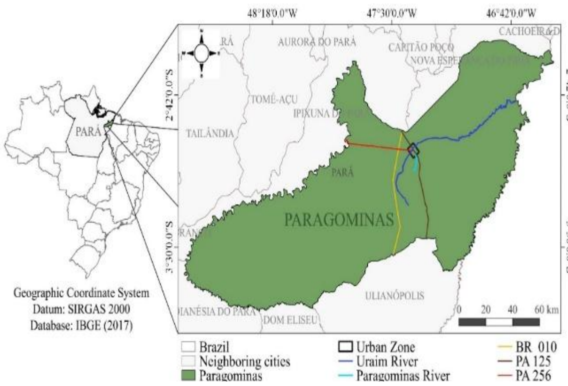


Figure 1: Political-geographical location map of the municipality of Paragominas – Para.
Source: authors (2019).

The city climate is hot and humid, with annual temperatures of approximately 35ºC (maximum) and 22ºC (minimum) and relative humidity of 81%. From July to November, the water availability is low, and from December to June, it is high. The hydrography is composed of Gurupi and Capim river basins, but only the Uraim and Paragominas rivers, part of the Uraim river basin, cross the urban perimeter [18]-[20].

In a pioneering study [21] on the soils of Paragominas, it was identified: Oxisols and Yellow Argisols, Gleysols, Neossols, and Plinthosols. The study areas are located on Plinthosols, mineral soils exposed to excessive moisture's temporary effect in the rainy season[22].

These soils are poorly drained and characterized by expressive plintization, which can occur at a shallow depth (40 cm from the surface) or deeper (from 2m). The plintization consists of accumulations of iron (Fe) and aluminum (Al) or iron oxides (FeOx) in the form of mottled reddish colors.

2.2 Method

The approach method of the logical procedures was the deductive one because, according to the synthesis made by [23], it was based on a general fact (importance of the chemical support provided by the soil to the vegetation recovery) to deduce a particular case (Paragominas river PPA soil capacity to give this chemical support). The research has quantitative and qualitative approaches and descriptive objectives [24]. This method was supplemented by the scientific literature survey in open-access databases such as Google Scholar and Higher Education Personnel Improvement Coordination (CAPES, in Portuguese). For the final selection of this literature, three primary descriptors were used: (1) soil chemical attributes, (2) alteration of urban PPAs, and (3) vegetation recovery of PPAs.

2.3 Studied areas

The research was carried out in three areas located at the Paragominas riverbanks, which flows from the southeast to the north and is 16.4 km long. The sites are 12.000 m² each (60 m x 200 m) and encompass both the river's right and left banks. They have located nearby three bridges within the urban city perimeter, in the Carlos Gomes (1), Caravelas (2), and Bujaru (3) streets, in the Promissão district, on the threshold of Parque da Promissão I and II allotments. On these streets, there is a constant vehicle and pedestrian traffic in both ways.

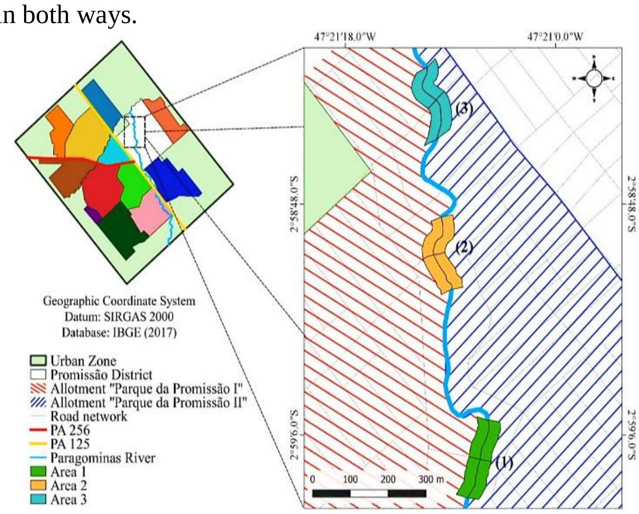


Figure 2: Studied areas location. Paragominas River. Paragominas (PA)

The three areas were delimited based on the following priorities for recovery [25]: primer order rivers [26] PPAs, which is the Paragominas River case, for it has not any tributary rivers; PPAs that have suffered or still suffer from the anthropic activities, which was observed at the chosen areas.

It was also deemed the environmental characteristics (soil, vegetation, and land use) observed on-site. There is altered vegetation (herbaceous, shrub, and arboreal) and, sometimes, bare soil, besides dwellings at some points. Each area is formed by four vertices (P_x), settled in the anticlockwise, starting at the left bank, upstream, which totals 12 vertices (Table 1).

Table 1: The number and geographic coordinates of the vertices of the area. Paragominas, Pará.

Area	Vertex	Latitude	Longitude
Area 1	P_1	2° 59'10.64" S	47° 21'8.49" W
	P_2	2° 59'11.03" S	47° 21'6.60" W
	P_3	2° 59'4.99" S	47° 21'4.81 "W
	P_4	2°59'4.60"S	47°21'6.72"W
Area 2	P_1	2°58'55.06"S	47°21'9.79"W
	P_2	2°58'54.52"S	47°21'7.96"W
	P_3	2°58'48.84"S	47°21'8.80"W
	P_4	2°58'49.34"S	47°21'10.65"W
Area 3	P_1	2°58'43.46"S	47°21'11.22"W
	P_2	2°58'42.19"S	47°21'9.06"W
	P_3	2°58'36.67"S	47°21'10.30"W
	P_4	2°58'37.77"S	47°21'11.90"W

The horizontal segments (P1-P2 e P3-P4) represent river PPA width, with 60 m length each one (30 m PPA in each bank); the vertical ones (P1-P4 e P2-P3) represent each area length, with 200 m (100 m upstream and 100 m downstream). To the better results exposition and deem the different characteristics (soil, vegetation, and land use) observed in each area, they were subdivided into four quadrants each (Figure 3).

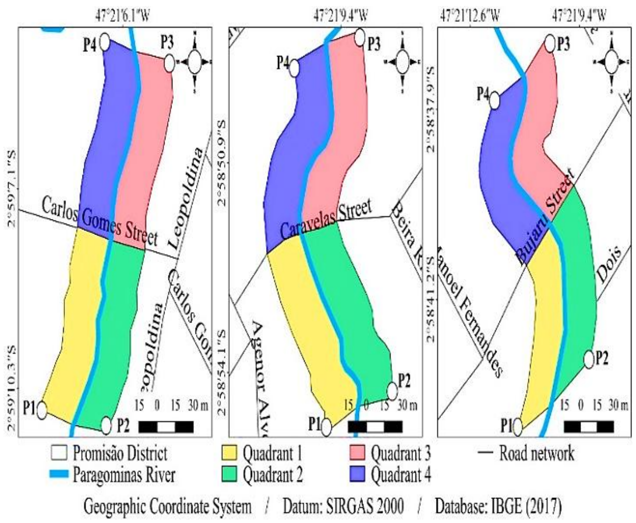


Figure 3: Quadrant location within the three studied areas. Paragominas (P.A.)

The three quadrants' dimensions are 30m x 100m, equivalent to 3000 m² each. They were numbered from 1 to 4 according to the area they are part of, for instance: A01Q01 (Area 01 and Quadrant 01).

The areas' soils are classified as Plinthosols, with very clayey texture. These soils have a concretionary horizon, where the plintization can be evidenced between 0.8 and 1.0-meter depth from the surface [27]. This soil order is usually weathered, which may be a consequence of many factors, as high rainfall rates in Amazon [25]-[28].

2.4 Soil sampling and analysis

The chemical analysis followed the Manual of Methods for Soil Analysis [4]. The sampling was executed in two periods: (1) warm season, in November, when the mean rainfall is 46.1 mm, and (2) rainy season, in February, when the mean rainfall is 285.8 mm [29].

The sampling was carried out through trenches; likewise, it was done [29] in Roraima Plinthosols. It was open five trenches in each quadrant in the warm season and five in the rainy one, with 40 cm sides dimension and 0-20 cm depth. The five deformed samples (100g), collected in each quadrant, were homogenized to yield a composite model, with 500g [22]. Summing up, a total of 12 composite samples (one for each quadrant) was analyzed in the laboratory each season (Figure 4).

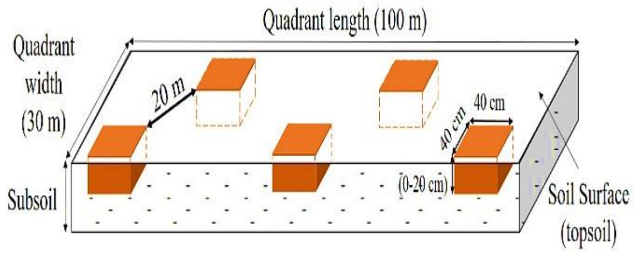


Figure 4: Croqui of soil sampling in each quadrant. Paragominas (PA)

The samples of air-dried fine earth were analyzed in the Amazon Federal Rural University Soil Laboratory (warm season) and in the Emilio Goeldi Paraense Museum Chemical Analysis Laboratory (rainy season), both located in Belém (P.A.). It was analyzed, each period, the same chemical attributes [29] (Table 2).

Table 2: Soil chemical parameters are analyzed in the laboratory

Parameters	Symbols	Units of measurement
pH in water	pH_{H2O}	--
pH in Potassium chloride	pH_{KCl}	--
Organic Carbon	OC	g/kg
Organic Matter	OM	g/kg
Phosphorus	P	mg/dm³
Potassium	K^+	$cmol_c/dm^3$
Calcium	Ca^{2+}	$cmol_c/dm^3$
Magnesium	Mg^{2+}	$cmol_c/dm^3$
Potential acidity	H + Al	$cmol_c/dm^3$
Total Cation Exchange Capacity*	CEC_{total}	$cmol_c/dm^3$
Sum of Bases*	SB	$cmol_c/dm^3$
Bases saturation*	V%	%

2.5 Soil Chemical Alteration Index (SCAI)

The SCAI was calculated to analyze soil chemical alteration degree. It was based on one pioneering method [30] and its adaptation by other authors (Table 3).

Authors	Factor Analysis	SCAI equation
[30]	X	--
[31]	X	--
[32]	X	X
[33]	X	X
[34]	X	--
[8]	X	--
[35]	X	X
[36]	X	X

The software used to perform the calculation were: BioEstat 5.0 [31], Microsoft Excel [32], and Statistical Package for the Social Sciences (SPSS), version 22.0 [33]. The authors calculated a degradation index based on the data acquired at the agricultural and livestock census executed by IBGE. However, this dataset was not used in this paper due to the areas' location and dimensions.

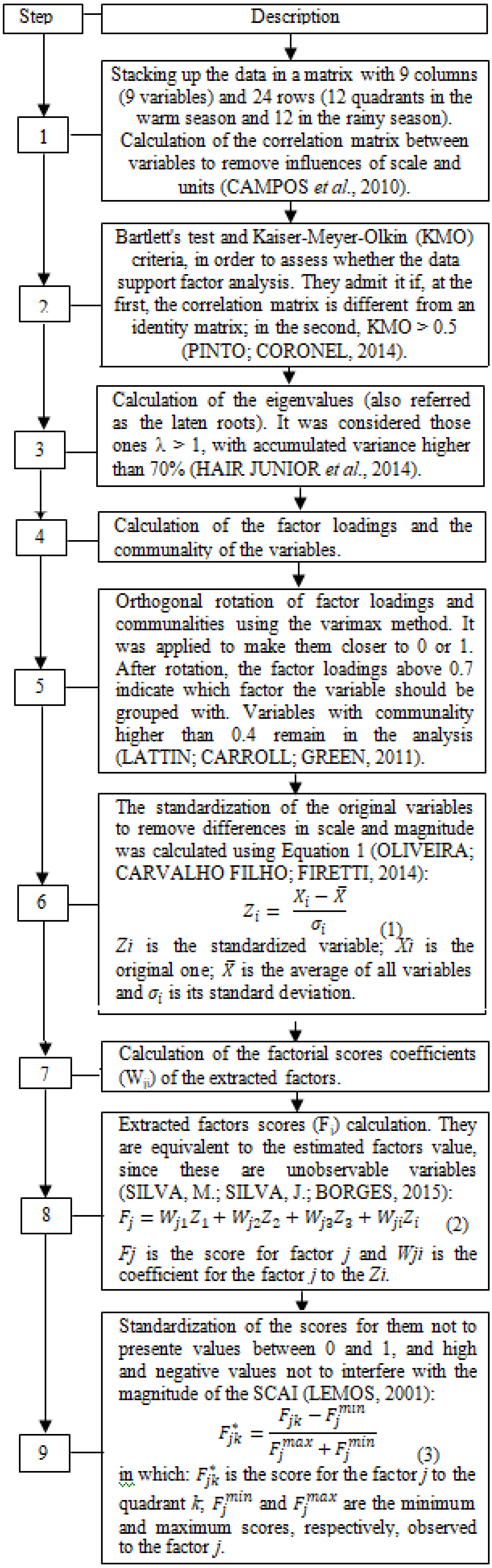
It was limited only to the methods applied by those authors. Therefore, to calculate SCAI has reckoned the same attributes as [6]. The authors used them to perform the factor analysis of their influence on the soil chemical quality in small urban areas. Thus, it was possible to use them in this research to analyze the index's first step, followed by its application.

From the 12 chemical parameters analyzed in this research, nine were incorporated into the index. It would be statistically impossible to use CEC_{total}, SB, and V% since they are dependent variables and not independent like the other ones (Table 4).

Table 4: Soil chemical parameters are used to calculate SCAI

Parameters	Symbologies	Measurement units
pH in water	pH_{H2O}	--
pH in Potassium chloride	pH_{KCl}	--
Organic Carbon	OC	g/kg
Organic Matter	OM	g/kg
Phosphorus	P	mg/dm³
Potassium	K^+	$cmol_c/dm^3$
Calcium	Ca^{2+}	$cmol_c/dm^3$
Magnesium	Mg^{2+}	$cmol_c/dm^3$
Potential acidity	H + Al	$cmol_c/dm^3$

These variables were considered because [6] claim that anthropic interference could alter soil chemical characteristics. Therefore, the metabolism and vegetal function might be injured [34]. The SCAI calculation was carried out in two main steps: **1)** factor analysis, the extraction of the factor by the Principal Components method, highlighted in white; **2)** SCAI equation application, highlighted in gray (Figure 5).



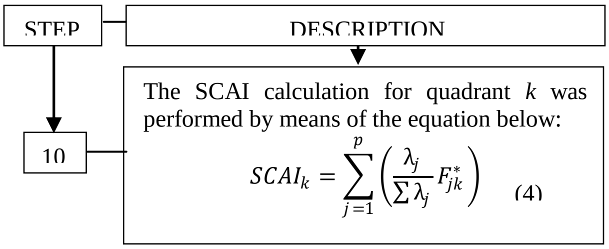


Figure 5: Flow chart of the method for calculating the Soil Chemical Alteration Index

The interpretation was performed based on the legend composed by [42]. This research combined two intervals from all three considered by the authors, which resulted in code with three numeric gaps to read the index (Table 5).

Table 5: Legend used to read the SCAI.

[32]		Authors (2019)	
Interval/Legend	Q1	Interval/Legend	Q2
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	Medium-high	0.70 a 1.00	High
0.70 a 1.00	High		

Legends: Q1 – Qualification; Q2 – Qualification.

SCAI data were statistically treated by applying electronic spreadsheets at BioEstat, version 5.0. It was identified: maximum and minimum values, arithmetic mean, standard deviation, and variation coefficient [31];[43].

2.6 Interpretation of the soil nutritional status

The laboratory results interpretation was executed aided by fertility manuals and soil analysis interpretation guides. These are the pioneer and current studies that qualify the chemical attributes concentrations in tropical soils. The pioneer one [44] divides the intervals into five classes (Table 6).

Table 6: Qualifications of the chemical attribute concentration intervals.

I	II	Qualification				
		V.L.	L	MD	G	V.G.
OC	g/kg	≤4	4.1a11.6	11.7a23.2	23.3a40.6	>40.6
OM	g/kg	≤7.00	7.1a20	20.1a40	40.1a70	>70
Ca^{2+}	$cmol_c/dm^3$	≤0.40	0.41a1.20	1.21a2.40	2.41a4.0	>4.00
H+Al	$cmol_c/dm^3$	≤1.00	1.01a2.50	2.51a5.00	5.01a9.0*	>9.00*
SB	$cmol_c/dm^3$	≤0.60	0.61a1.80	1.81a3.60	3.61a6.0	>6.00
CEC total	$cmol_c/dm^3$	≤1.60	1.61a4.30	4.31a8.60	8.61a15.	>15.00

Legends: I – Attributes; II – Units; V.L. – Very Low; L – Low; M.D. – Medium; G – Good; V.G. – Very Good.*The H+Al interpretation must be read as high and very highinstead of right and very good.

The area deemed satisfactory the intervals qualified as a medium, right, and very good, except for H+Al. This one was considered acceptable when very low and low, injuring vegetal functions when it is exceeding. Regarding the current studies [45]-[46], they qualify the intervals of pH_{H2O}, Mg^{2+}, $K^{+,}$ and V% into three classes (Table 7).

Table 7: Qualification of the chemical attribute's concentration intervals

Attributes	Units	Qualification			Authors
		Low	Medium	High	
pH_{H2O}	--nits	< 5.0	5.0 a 6.0	> 6	1
Mg^{2+}	$cmol_c/dm^3$	< 0.4	0.4 a 1.0	> 1.0	1
K^+	$cmol_c/dm^3$	< 0.15	0.15 a 0.38	> 0.38	[45]
V%	%	< 50	50 a 70	> 70	1

.: [43]-[44].

These values were deemed satisfactory when medium and high. Regarding pH, the "high" interval was considered acceptable only if inferior to 7.5 since soils with pH between 7.5 and 8.5 are calcareous ones [47]. The phosphorus fissionability results were interpreted based on the six classes (Table 8).

Table 8: Vegetation types that better develop themselves due to the phosphorus responsible

Qualification	Interval (mg/dm^3)
Many cultivars grown in soil with this much phosphorus are more likely to present low productivity due to the soft element responsible.	< 5
In this case, just a few perennial cultivars could maintain its mean productivity, like, for instance, forestry species.	Five a 10
It satisfies most of the perennial cultivars' demand, but it limits many annual cultivars and vegetables.	Ten a 20
The adequate interval for the majority of perennial cultivars and limiting for vegetables.	20 a 40
Good disponible for annual and perennial cultivars limits some high productivity vegetable development such as tomato e potato.	40 an 80
Adequate concentration for most cultivars.	> 80

Composed based on[45].

3. Results and Discussions

3.1 Soil chemical alteration index

By calculating SCAI, it was verified that none of the three analyzed areas suffered high soil chemical alteration. Their alteration was low at four quadrants (33.33%) and medium at eight (66.67%). Amid these, it is the most altered one: 0.6323 (Table 9).

Table 9: Ranking between all of the studied quadrants regarding the soil chemical alteration

Ranking	A/Q	SCAI	Q
1º	A01 Q04	0.6323	M
2º	A01 Q01	0.5669	M
3º	A02 Q03	0.5285	M
4º	A02 Q02	0.4806	M
5º	A03 Q03	0.4709	M
6º	A02 Q01	0.4619	M
7º	A01 Q03	0.4286	M
8º	A01 Q02	0.4049	M
9º	A03 Q02	0.2453	L
10º	A03 Q01	0.2167	L
11º	A03 Q04	0.1834	L
12º	A02 Q04	0.1342	L
Maximum		0.6323	
Minimum		0.1342	
Arithmetic mean		0.3962	

Standard deviation	0.1622	
Variation coefficient	40.94%	

Legends: A/Q – Area/Quadrant; Q – Qualification.

The data analysis and the seven on-site visits showed that the four quadrants (A01Q04, A01Q01, A02Q03, and A02Q02) more altered were the ones with sparse and scarcevegetal cover (arboreal, shrub, and herbaceous) or dwellings nearby the river, between 3 and 10 meters (Figure 6).

Figure 6. Quadrants with the four higher SCAI: a) A01Q04 (0.6323); b) A01Q01 (0.5669); c) A02Q03 (0.5285); and d) A02Q02 (0.4806)

This alteration is due to anthropic activities (like dams) onto the urban soils and resulted in low and medium indexes (0.1342 to 0.6323), with a 0.3942 arithmetic mean (medium degree). According to a study [6] carried out over clayey urban soils in Santa Maria, RS, this intervention can cause alkalinity and nutrition imbalance in the ground, injuring the vegetal development.

Other research is also performed in urban soils; in Pato Branco, PR, [48] claimed that this injuring occurs because soil conditions interfere directly with the tree's vitality. As for the current research, it was possible to pinpoint the alteration in the three studied areas by comparing each attribute's values found with the natural characteristics of the Paragominas Plinthosols (Table 10).

Table 10: Minimum e maximum values are common to Paragominas' Plintossolos and the studied areas

Paragominas Plinthosols*			
	Units	Minimum	Maximum
pH_{H20}	--	3,9	4,2
pH_{KCl}	--	3,7	3,9
OC	g/kg	28,0	67,9
OM		48,3	117,0
P	mg/dm³	1,0	7,0
Ca^{2+}	--$cmol_c/dm^3$--	2,1	3,0
Mg^{2+}		1,1	2,0
K^+		1,1	3,5
H+Al		120,0	228,0
SB		6,9	51,2
CECtotal		126,1	277,5
V	%	5,0	18,0
AREA 1			
	Units	Minimum	Maximum
pH_{H20}	--	6,00	7,60
pH_{KCl}	--	6,30	7,30
OC	g/kg	4,20	22,10
OM		7,20	38,00
P	mg/dm³	17,10	145,00
Ca^{2+}	--$cmol_c/dm^3$--	4,10	8,50
Mg^{2+}		0,50	1,60
K^+		0,04	0,63
H+Al		0,00	1,64
SB		5,11	10,63
CECtotal		6,75	10,63
V	%	76,0	100,00
AREA 2			
	Units	Minimum	Maximum
pH_{H20}	--	6,50	7,30
pH_{KCl}	--	4,70	6,80
OC	g/kg	1,70	25,20
OM		3,00	43,40
P	mg/dm³	25,2	294,70
Ca^{2+}	- $cmol_c/dm^3$ -	2,5	8,50
Mg^{2+}		0,7	1,60
K^+		0,03	0,78
H+Al		0	6,44
SB		4,55	10,88
CECtotal		5,38	14,77
V	%	34,00	100,00
AREA 3			
	Units	Minimum	Maximum
pH_{H20}	--	5,80	6,90
pH_{KCl}	--	4,70	6,80
OC	g/kg	8,00	23,20
OM		13,80	40,00
P	--cmolc/dm^3---	37,50	162,53
Ca^{2+}		3,40	9,15
Mg^{2+}		0,60	1,10
K^+		0,15	1,00
H+Al		0,84	5,78
SB		4,19	10,4
CECtotal		8,02	14,54
V	%	42,00	90,00

*Data obtained by IBGE (2017) at a depth of 0-20cm.
Legend: pH_{H2O}: pH in water; pH_{KCl}: pH in potassium chloride; O.C.: Organic Carbon; O.M.: Organic Matter; P: Phosphorus; Ca^{2+}: Calcium; Mg^{2+}: Magnesium; K^+: Potassium; H+Al: Potential acidity; S.B.: Sum of Bases; CEC_{total}: Total Cation Exchange Capacity; V%: Bases Saturation.

We found that the soils' chemical alterationcompared with the city plinthosols was beneficial because the earth currently presents eutrophic characteristics. Regarding the trophism, it is an indication of a eutrophic and fertile soil the predominance (in the sorptive complex - CEC_{total}) of Ca^{2+}, $Mg^{2+,}$ and K^+ over H^+ and Al^{3+}[49].

This study confirmed this scenario by the lower H+Al values associated with, the higher Ca^{2+} costs (sorptive complex main component) than the plinthosols natural concentrations. This adequacy is paramount. In research in tropical soil in Manaus (AM), it wasobserved that the soil chemical characteristics could directly interfere with the floristic composition and the vegetation structure [34].

Moreover, according to a study conducted [50] in Boa Vista, R.R., plinthosols, these characteristics work out from the seedling establishment to the forestry maintenance. Overall, the indexes are satisfactory, but it must be avoided other interventions into the PPA so that the indexes might not be impaired and make the reforestation impossible since the PPA is a sensitive area and easily damageable.

3.2 Soil nutritional status analysis

The laboratory analysis verified the PPA's soil chemical alteration degree and its modification compared with the city plinthosols. After that, we observed the chemical attributes concentration in the soil nutritional system (Table 11).

Table 11: Datesof the laboratory analysis of the soil chemical attributes from the studied areas

Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
WARM-SEASON					
ÁREA 1					
Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
pH_{H20}	--	**7.3**	**7.4**	**7.2**	7,6
OC	g/kg	**11,8**	**11,8**	4,2	7,0
OM		**20,4**	**20,4**	7,2	12,0
P	mg/dm³	**27,0**	**145,0**	**29,3**	**17,1**
Ca^{2+}	$cmol_c/dm^3$	**7,40**	**5,50**	**8,00**	**1,00**
Mg		**1,60**	**1,50**	**1,00**	**1,50**
K^+		**0,44**	**0,28**	**0,28**	**0,63**
H+Al		**0,00**	**0,00**	**0,00**	**0,00**
SB		**9,44**	**7,28**	**9,28**	**10,63**
CECtotal		**9,44**	**7,28**	**9,28**	**10,63**
V	%	**100**	**100**	**100**	**100**
AREA 2					
Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
pH_{H20}	--	**6,8**	**7,3**	**7,0**	**6,5**
OC	g/kg	**22,3**	1,7	8,7	**14,6**
O.M.		**38,4**	3,0	15,0	**25,2**
P	mg/dm³	**294,7**	**110,9**	**129,0**	**25,2**
Ca^{2+}	$cmol_c/dm^3$	**8,5**	**5,9**	**3,5**	**2,5**
Mg		**1,6**	**1,0**	**1,5**	**0,7**
K^+		**0,78**	**0,18**	**0,38**	0,14
H+Al		**3,89**	0,0	0,0	6,44
SB		**10,88**	**7,08**	**5,38**	**3,34**
CECtotal		**14,77**	**7,08**	**5,38**	**9,78**
V	%	**74**	**100**	**100**	**14**
ÁREA 3					
Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
pH_{H20}	--	**5,8**	**6,1**	**6,8**	**6,4**
OC	g/kg	**13,6**	8,0	10,1	**16,7**
OM		**23,4**	13,8	17,4	**28,8**
P	mg/dm³	**97,8**	**90,2**	**39,1**	**37,5**
Ca^{2+}	$cmol_c/dm^3$	**4,0**	**5,5**	**4,0**	**3,4**
Mg		**1,0**	**0,7**	**0,8**	**0,6**
K^+		**0,19**	**0,29**	**0,22**	**0,19**
H+Al		5,22	**3,11**	**3,0**	5,78
SB		**5,19**	**6,49**	**5,02**	**4,19**
CECtotal		**10,41**	**9,6**	**8,02**	**9,97**
V	%	**50**	**68**	**63**	42
RAINY SEASON					
AREA 1					
Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
pH_{H20}	--	**7,01**	**6,7**	**6,78**	**7,08**
OC	g/kg	**20,11**	**18,16**	**13,08**	**22,07**
O.M.		**34,67**	**31,31**	**22,56**	**38,04**
P	mg/dm³	**39,57**	**54,06**	**35,19**	**56,18**
Ca^{2+}	$cmol_c/dm^3$	**6,9**	**4,1**	**4,85**	**6,79**
Mg		**0,65**	**0,9**	**0,6**	**0,45**
K^+		0,04	0,11	**0,19**	**0,19**
H+Al		**0**	**1,64**	**1,34**	**0**
SB		**7,59**	**5,11**	**5,64**	**7,43**
CECtotal		**7,59**	**6,75**	**6,98**	**7,43**
V	%	**100**	**76**	**81**	**100**
AREA 2					
Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
pH_{H20}	--	**6,55**	**6,34**	**7,3**	**6,68**
OC	g/kg	**25,19**	**23,63**	**16,99**	**12,3**
O.M.		**43,43**	**40,73**	**29,29**	**21,21**
P	mg/dm³	**151,93**	**272,07**	**91,87**	**74,2**
Ca^{2+}	$cmol_c/dm^3$	**5,3**	**6,2**	**5,5**	**3,7**
Mg		**1,3**	**1,0**	**1,0**	**0,75**
K^+		0,11	0,03	**0,2**	0,1
H+Al		**3,14**	**1,14**	**0,0**	**3,44**
SB		**6,71**	**7,23**	**6,7**	**4,55**
CECtotal		**9,85**	**8,37**	**6,7**	**7,99**
V	%	**68**	**86**	**100**	**57**
AREA 3					
Analyzed Variables	Units	A01 Q01	A01 Q02	A01 Q03	A01 Q04
pH_{H20}	--	**5,99**	**6,32**	**6,88**	**6,64**
OC	g/kg	**18,16**	**15,82**	9,57	23,24
O.M.		**3131**	**27,27**	16,5	**40,06**
P	mg/dm³	**81,27**	**159,0**	**42,4**	**162,53**
Ca^{2+}	$cmol_c/dm^3$	**9,15**	**5,45**	**5,55**	**5,4**
Mg		**1,1**	**,65**	**1,04**	**1,05**
K^+		**0,15**	**0,17**	**1,0**	**0,15**
H+Al		**4,14**	**244**	**0,84**	**1,64**
SB		**10,4**	**6,27**	**7,6**	**6,6**
CECtotal		**14,54**	**8,71**	**8,44**	**8,24**
V	%	**72,0**	**72,0**	**90,0**	**80,0**

Note: The bold-highlighted values are satisfactory to the vegetation growth and development.

Legend: pH_{H2O}: pH in water; O.C.: Organic Carbon; O.M.: Organic Matter: P: Phosphorus; Ca^{2+}: Calcium; Mg^{2+}: Magnesium; K^+: Potassium; H+Al: Potential Acidity; S.B.: Sum of Bases; CEC_{total}: Total Cation Exchange Capacity; V%: Bases Saturation.

From the data analysis regarding the pH_{H2O}, it was verified that these attribute values are satisfactory. In other words, they are adequate to the vegetation development within 11 quadrants (91.66%) in the warm season, and within 12 quadrants (100%), in the rainy season. The only pH_{H2O}value was not satisfactory was obtained from the A01Q04, which was 7.6 in the warm season.

According to a study about nutritional problems at the plant cultivation in calcareous soils [47], this pH value might reduce the availability of nutrients such as Fe^{3+}, thus negatively affecting the plant growth. Nonetheless, this value is not a barrier to reforestation since it was obtained just in one of the two samplings. It is approximately 7.5 (calcareous soil characteristics pH: 7.5 to 8.5), which does not reflect high alkalinity or salinity.

Amid the values, it was deemed ideal within the interval suggested by [49] by the International Plant Nutrition Institute [51]. Both claim that most cultivars show good productivity when soil pH is between 6.0 and 6.5. These ideal values were observed for the pH_{H2O} within three quadrants (25%) in the warm season and two quadrants (16,66%) in the rainy season. Therefore, it was verified that, regarding the acidity, the soil is suitable for reforestation.

Concerning the **O.C.** and the **O.M.**, both presented sufficient concentrations within six quadrants (50%) in the warm season, and within 11 quadrants (91.66%), in the rainy season. A study carried out [52] in Amazon allocates that both the attributes are linked to the high temperatures and humidity in tropical climates. This type of weather leads to O.M. decomposition, which releases nutrients into the soil, besides it contributes to the cation retention and its subsequent absorption by the plants.

As for these attributes' concentration, the A03Q03 (Figure 7a) quadrant was the only one that presented inadequate values in both sampling periods, despite the presence of arboreal vegetation. It may arise from the cleansings periodically performed by dwellers from nearby areas, reducing the organic matter accumulation on the soil (Figure 7b).

Figure 7:a) and b) Low litter accumulation onto the A03Q03 quadrant

About this reduction,in Manaus, AM, it was verified that it is essential not to remove soil litter. It is deposited in the warm season in tropical regions and decomposed in the rainy one [34]. This process helps the cycling maintenance of nutrients such as K and P., Thereby, and the periodic cleansing must be halted.

Furthermore, in a study about Amazon forestry species, the researchers found thatlitter deposition happens typically in the warm seasons because it is a strategy to minimize the low water availability effects [53]. Thus, with a low rate of leaves, the plant reduces its water losses during transpiration. Regarding the **P**, it was satisfactory in all (100%) quadrants in both sampling periods. In the rainy season, the phosphorus concentrations in Seropedica, RJ, appear in a higher availability in tropical areas in tropical areas soil litter [54]. It is a result of the lesser uptake by the plant in this season. In the warm season, the vegetation's hydric stress is exposed to requires a higher uptake of phosphorus to its translocation throughout the plant.

Among those values deemed satisfactory, some quadrants showed concentrations far above 80 mg/dm^3, such as A02Q01 (294,7 mg/dm^3, in the warm season) and A02Q02 (272,07 mg/dm^3, in the rainy season). It should be warned that some nutrients excess in the environment, like P, could cause a lack of other ones, like Ca^{2+} and Mg^{2+}, since it favors these' uptakes and movement [55]. Furthermore, the P excess might lead to phytopathology as ferric chlorosis.

Such values might arise from untreated domestic wastewater effluent discharges into the soil, as in it there are high concentrations of P. In research about the anthropic activities impacts over the P dynamics, it was described that the phosphorus is in the sewer in the form of both organic (proteins) and mineral compounds (synthetic detergents) [56].

In a studyabout the trophic status of the Paciência River in Minas Gerais [57], the authors found that the P concentrations increase in the river due to the domestic wastewater effluent discharge. Thus, to reduce such attention in the soil and avoid the river contamination, the bursts observed on-site must be halted.

Concerning the **Ca^{2+}** and P, its concentrations were satisfactory (good and very good) in all 12 (100%) quadrants in both sampling periods. Amid the excellent values, some very high ones were verified, as in A03Q01 (9.15 $cmol_c/dm^3$). The concentrations are similar to those found in the Paraíba state [58].

This high value (9.15 $cmolc/dm^3$) can be associated with the açai lumps observed in this quadrant, which were deposited irregularly in previous cultivars executed by a nearby dweller. According to a [59] study performed in Rio Branco, AC, these lumps (an açai processing waste) contribute to the rise of soil nutrientsavailability from the increment of calcium elements.

Another factor that might raise Ca^{2+} concentrations in the presence of construction and demolition wastes (CDW), just as cement powder and roof tiles. About that, in Pato Branco, PR,the high levels of Ca^{2+} (a mean of 7.6 $cmol_c/dm^3$) in the soil were justified by the insertion of calcareous materials from constructions [48].

It was verified within the A01Q01, A01Q03, A01Q04, and A02Q01 quadrants, in the warm season A01Q01 and A01Q04 quadrants, in the rainy season, due to the taken place embankment onto them, which contained CDW. Moreover, such values could arise from the dwelling constructions' wastes, which was observed on-site, less than 30 meters from the river (Figure 8).

Figure 8: a) A01Q01 and b) A01Q04. Dwellings in construction and CDW were disposed of onto the soil

When the calcium is present in high concentrations, it might injure the adsorption and absorption processes of Mg^{2+}. About this relation between both cations, a survey performed in Arapoti, PR, found that the two have chemical properties very similar to each other (degree of valence and mobility) [60]. Therefore, there is a competition for the soil adsorption sites and the roots to absorb them. This way, the excessive presence of one may injure those processes.

However, it was observed that it did not occur in the areas since the **Mg^{2+}** values, despite the variability, showed themselves satisfactory (medium and high) in all 12 (100%) quadrants in both samplings' periods. In a study performed in Jacuí, MG, it was observed the adequacy of this element contributes to photosynthesis because it is part of the chlorophyll molecule, which absorbs the luminous energy used in the photosynthesis [61].

The lower concentrations of Mg^{2+} verified in both the samplings within the A02Q04 (0.70 and 0.75), and the A03Q02 (0.70 and 0.65) might result from the soil drainage. During both warm and rainy seasons, the soil was swamped. The flash flood (2018) in the municipality could have contributed to this element's leaching and the consequent reduction of its concentration in the soil.

Concerning the **K^{+}**, in the warm season, this cation presented sufficient concentrations in all 12 quadrants, except for A02Q04, in which it was observed a low value (0.14 $cmol_c/dm^3$). In the rainy season, seven quadrants (58,33%) presented gooddeals, with 6 (50%) of them in medium availability and 1 (8,33%) in high availability.

Regarding K+'s low concentrations (non-satisfactory) in 5 quadrants (41,66%), they might be related to the rainfall in the rainy season. In the Amazon Rainforest, the K^{+} is the most mobile nutrient in the soil [62]. Therefore, in tropical regions, the high rainfall rate raises the likelihood of its leaching due to its low "adsorption force" to the soil colloids, as verified about Mg^{2+}.

Another factor that interferes with the K^{+} availability is the presence of dead vegetation cover on the soil. According to that,this element is easily leaked out from the soil litter in a potassium availability study [63]. This cation availability depends more on the plants' demand for the nutrient than on the soil properties, as texture and mineralogy.

About the **H+Al**, the data analysis revealed sufficient concentrations, in the warm season, in 9 quadrants (75%) and, in the rainy one, in all 12 quadrants (100%). Just the A01Q01, A01Q04, and A02Q03 presented null values in both warm and rainy seasons. In the warm season, A02Q04, A03Q01, and A03Q04 showed high H+Al.

A previous study [64] indicates the H+Al (composed of H^{+} and Al^{3+}) in the tropical soils might reduce its productive potential. That data is supported by [65],who analyzed the toxic effects of aluminum on the plant growth and warned that the low pH (<5.0) leads to a high concentration of Al^{3+}, hence, to the potential acidity rising. In research carried out in Mato Grosso, it was found that it might injure the plant development [66].

However, the potential acidity reduction in these quadrants (A02Q04, A03Q01, and A03Q04) was reported under a high rainfall rate. Therefore, it contributes to avoiding the root growth inhibition and the absorption of the nutrient reduction [49], which could hinder vegetation development, especially thatof aluminum-sensitive ones.

As for **S.B.**, the concentrations were satisfactory in all 12 quadrants (100%) in warm and rainy seasons. It happened since the essential cations (Ca^{2+}, Mg^{2+}, and K^{+}) that are part of the sum of bases represent vital nutrients to the vegetation growth, as explained in contributions to the Agronomic Institute Campinas, S.P. [67]. This way, the proper values indicate the nutrients' availability in the soil as satisfactory.

Concerning the **CEC_{total}**, we verified that the exchangeable soil capacity is adequate. This attribute's cations stay withheld in the soil surface by the fraction of negatively charged clay. The manual about soil analysis describes that the nutrients are available to the plants in exchangeable conditions (exchangeable capacity) [4]. Thus, the results indicate the studied soils are good to plant nutrition.

Regarding the cation retention by the O.M. particles, it may be pointed out the relation between the CEC and the O.C because the O.C. favors the number of negatives charges in the soil. In research about carbon and the fertility attributes in Ponta Grossa,M.G.,the researchers observed that the CEC rise due to the rising of available O.C. in a tropical soil. The high temperature and humidity favor the O.M. decomposition [68].

About **V%**, the last one attribute analyzed in this research, andwe verified that ten quadrants (83,33%), in the warm season, and all 12 ones (100%), in the rainy season, have eutrophic soils. These soils are suitable for vegetation development since they are V > 50% and, consequently, are fertile, whilegrounds with V < 50% are dystrophic and have low fertility [47].

Amid the eutrophic soils, many cultivars present good productivity in those with V% between 50 and 80% [47]. It was found in 4 quadrants (33,33%) in the warm season, and six quadrants (50%), in the rainy one. The base saturation expresses the soil's overall fertility status, for it is calculated from the division between S.B. and CEC [47]. In other words, the V% illustrates which is percentual of bases in CEC.

The individual analysis of chemical attributes showed, therefore, that the alterations were mostly favorable. From the 132 values (11 characteristics in 12 quadrants) analyzed in each period, 113 (85,60%) were satisfactory in the warm season and 125 (95,69%) in the rainy season, as highlighted in bold in Table 10.

4. Conclusion

This research confirmed that it did happen chemical alteration at a low and a medium degree in the soils of the studied areas compared with the natural characteristics of city plinthosols. Nevertheless, it does not mean that the earth has lost its nutritional value because it was found to increase the soil quality of the areas in terms of nutrients availability.

Therefore, the alteration in the studied areas has not injured the chemical attributes concentration in the soil. They showed themselves as satisfactory, and they enable the reforestation of the sites. We suggest carrying out complementary physical and microbiological analysis, besides the phytosociological study in pristine forest areas, to ensure reforestation's effectiveness.

References

[1] Nunes, R. R.; Rezende, M. O. O. "Recurso solo: propriedades e usos". São Carlos: Cubo, 2015.
[2] Silva, F. M.; Chaves, M. S.; Lima. Z. M. C. "Propriedades dos solos: Características químicas e mineralógicas". Natal: EDUFRAN,2009
[3] Rocha, J. H. T. *et al*. "Reflorestamento e Recuperação de Atributos Químicos e Físicos do Solo. Floresta e Ambiente",Rio de Janeiro, 22 (3), pp. 299 – 306. 2015.
[4] Teixeira, P. C. *et al*. "Manual de Métodos de Análise de Solo". 3 ed. Brasília: Embrapa, 2017.
[5] Silva, A. M.; Moraes, M. L. T.; Buzetti, S. "Propriedades químicas de solo sob reflorestamento ciliar após 20 anos de plantio em área de cerrado". Revista Árvore,35(1), pp. 97 – 106, 2011.
[6] Szymczak, D. A. *et al*."Qualidade química do solo com diferentes níveis de degradação em área de preservação permanente". Revista Monografias Ambientais, 10(10),, pp. 2158-2169, 2012.
[7] Khaledian, Y. *Et Al*. "Assessment and monitoring of soil degradation during land-use change using multivariate analysis." Land Degradation and Development [*online*], 28(1), pp. 128-141,2016.
[8] Pinto, N. G. M; Coronel, D. A. Degradação ambiental do Rio Grande do Sul: uma análise dos municípios e mesorregiões. Revista Brasileira de Agroecologia, 9(1), pp. 3-17, 2014.
[9] Brasil. "Instrução Normativa Ibama nº 04". Apr. 04, 2010. {Online] Available: http://www.ibama.gov.br/sophia/cnia/legislacao/IBAMA/IN0004-130411.PDF. [Accessed: Jan.11, 2019].
[10] Brasil. "Lei nº 9.985"Jul, 18, 2000. [Online]. Available: http://www.planalto.gov.br/ccivil_03/leis/L9985.htm. [Accessed: Jan.10, 2019].
[11] Brasil. "Lei n°12.651".May.25, 2012. [Online]. Available: http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651.htm. [Accessed: Mar. 02, 2019].
[12] Ansolin, R. D. *et al*. "Valoração ambiental em áreas de preservação permanente na bacia hidrográfica do Rio Passaúna, Estado do Paraná". Revista de Ciências Agroveterinárias,17(1), pp.118-127, 2018.
[13] Castro, M. N.; Castro, R. M.; Souza, P. C. "A importância da mata ciliar no contexto da conservação do solo". Revista Eletrônica de Educação da Faculdade Araguaia, 4(4), pp. 230-241, 2013.
[14] Valera, C. A. "Avaliação Do Novo Código Florestal: As Áreas de Preservação Permanente – APPs, e a conservação da qualidade do solo e da água superficial". Tese (Doutorado em Ciência do Solo) - Faculdade de Ciências Agrárias e Veterinárias – UNESP, 2017.
[15] Azevedo, R. E. S.; Oliveira. V. P. V. "Reflexos do novo Código Florestal nas Áreas de Preservação Permanente – APPs – urbanas". Revista Desenvolvimento e Meio Ambiente, 29,. 71-91, 2014.
[16] Novak, E. *et al*. "Chemical and microbiological attributes under different soil cover." Revista Cerne, 23(1), pp. 19-30, 2017.
[17] IBGE. Instituto Brasileiro de Geografia e Estatística. "Cidades". 2019. Available: https://cidades.ibge.gov.br/brasil/pa/paragominas/panorama. [Accessed: Nov.12, 2019].
[18] Bastos, T. X. *et al*. "Informações agroclimáticas do município de Paragominas para o planejamento agrícola". In Congress on Meteorology 14., 2006, Florianópolis. Anais...Florianópolis: SBMET, 2006.
[19] Alves, L. W. R.; Carvalho, E. J. M.; Silva, L. G. T. "Diagnóstico Agrícola do Município de Paragominas, PA". Embrapa Amazônia Oriental, Belém:, 2014.
[20] Tavares, A. A. A. *et al*. "Estatísticas Municipais Paraenses: Paragominas". FAPESPA, Belém, 2016.
[21] Rodrigues, T. E. *et al*. "Caracterização e Classificação dos Solos do Município de Paragominas, Estado do Pará". Belém, Embrapa Amazônia Oriental, 2003.
[22] IBGE. Instituto Brasileiro de Geografia e Estatística. "Manual de Pedologia", IBGE, Rio de Janeiro 2015.
[23] Prodanov, C. C.; Freitas, E. C. "Metodologia do Trabalho Científico: Métodos e Técnicas da Pesquisa e do Trabalho Acadêmico". Feevale, Novo Hamburgo:, 2013.
[24] Freitas, E. P. *et al*."Indicadores ambientais para áreas de preservação permanente". Revista Brasileira de Engenharia Agrícola de Ambiental, 17(4), pp. 443-449, 2013.
[25] Strahler, A. N. "Hypsometric (area-altitude) analysis of erosional topography." Bulletin of the Geological Society of America, 63, pp. 1117-1142, 1952.
[26] IBGE. Instituto Brasileiro De Geografia E Estatística. "Mapeamento de Recursos Naturais do Brasil. Escala 1:250000"., 2017. Rio de Janeiro: IBGE Available: https://downloads.ibge.gov.br/downloads_geociencias.htm. [Accessed: Jul, 20, 2019].
[27] Fernandes, A. R. *et al*. "Quality reference values and background concentrations of potentially toxic elements of soils from Eastern Amazon, Brazil." Journal of Geochemical Exploration, 190, pp. 453-463, 2018.
[28] Giuliatti, N. M. *et al*. "Variabilidade da precipitação mensal e anual no município de Paragominas-PA". Enciclopédia Biosfera, 16(29), pp. 1716-1730, 2019.
[29] Lemos, J. J. S. "Níveis de degradação no nordeste brasileiro". Revista Econômica do Nordeste, 32(3), pp. 406-429, 2001.
[30] Silva, R. G.; Ribeiro, C. G. "Análise da Degradação Ambiental na Amazônia Ocidental: um Estudo de Caso dos Municípios do Acre". Revista Estudos Regionais, 42(1), pp. 91-110, 2004.
[31] Ayres, M. *et al*. "BioEstat 5.0: aplicações estatísticas nas áreas das ciências biológicas e médicas". Belém: MCT; IDSM; CNPq, 2007.
[32] Microsoft Corporation."Microsoft Office Excel, versão 201"6, Estados Unidos. Programa. Gerenciador de planilhas eletrônicas: Microsoft Corporation, 2016.
[33] IBM. "Statistics for Windows, Version 22.0". Armonk, NY: IBM Corp, 2013. Available: https://ibm-spss-statistics-base.br.uptodown.com/windows. [Accessed: Jul. 03, 2019].

[34] Barroco Neta, E. F.; Nishiwaki, E. "Variações sazonais na ciclagem de nutrientes em uma floresta da Amazônia Central". Brazilian Applied Science Review, Curitiba, v. 2, n. 5, p. 1747-1759, out. /dez. 2018.

[35] Campos, S. A. C. *et al*."Intensidade e evolução da atividade agropecuária como indicador da degradação ambiental na região da Caatinga". In: Sociedade Brasileira de Economia, Administração e Tecnologia rural, 48., 2010, Viçosa. Anais eletrônicos... Viçosa: UFV, 2010, p. 1-19.

[36] Pinto, N. G. M; Lopes, M. M.; Coronel, D. A."Análise da Degradação Ambiental nos Municípios e Mesorregiões do Estado do Paraná". Revista Paranaense de Desenvolvimento, 35(126), pp. 191-206, 2014.

[37] Hair Junior, J. F. *et al*. "Multivariate Data Analysis." 7 ed. Harlow: Pearson Education Limited, 2014.

[38] Lattin, J. M.; Carrrol, J. D.; Green, P. E. "Análise dados multivariados". Tradução: Haure Avristscher.: Cengage Learning, São Paulo, 2011.

[39] Oliveira, E. C.; Carvalho Filho, A. A.; Firetti, R. "Identificação e Elaboração de Variáveis Estatísticas Através de Técnicas Multivariadas no Estudo da Produção de Grãos e Fibras, nas Região Administrativa de Presidente Prudente-SP". Semina Ciências Exatas e Tecnológicas, 35(2), pp. 159-180,2014.

[40] Silva, M. C.; Silva, J. D. G.; Borges, E. F. "Análise de componentes principais para elaborar índices de desempenho no setor público". Revista Brasileira de Biometria, 33(3), pp. 291-309, 2015.

[41] Lemos, J. J. S. Níveis de degradação no nordeste brasileiro. Revista Econômica do Nordeste, Fortaleza,32(3), pp. 406-429, 2001.

[42] Cunha, N. R. S. *et al*. A "Intensidade da Exploração Agropecuária como Indicador da Degradação Ambiental na Região dos Cerrados, Brasil". Revista Estudos Regionais, Piracicaba, 46(2), pp. 291-323,2008.

[43] Costa, F. M. "Estatística". UEPA, Belém, 2011.

[44] Ribeiro, A. C.; Guimarães, P. T. G.; ALVAREZ, V. H. "Recomendações para o uso de corretivos e fertilizantes em Minas Gerais": 5ª aproximação,CFSEMG,Viçosa 1999

[45] Prezotti, L. C.; Guarçoni, A. "Guia de interpretação de análise de solo e foliar". Incaper, Vitória, 2013.

[46] Sobral, L. F. *et al*. "Guia Prático para Interpretação de Resultados de Análises de Solo" Embrapa Tabuleiros Costeiros, Aracaju, 2015.

[47] Pestana, M.; Varennes, A.; Correia, P. J. "Clorose férrica induzida pelo calcário". 61(7), 2015.

[48] Cadorin, D. A.; Mello, N. A.; Montemezzo, E. "Aspectos químicos e morfológicos dos solos urbanos utilizados pelas espécies *Lagerstroemia indica L., Schinus molle L. e Bauhinia variegata L.*, em três bairros da cidade de Pato Branco/PR". Revista Brasileira de Arborização Urbana, 8(3), pp. 39-51, 2013

[49] Ronquin, C. C. "Conceitos de fertilidade do solo e manejo adequado para as regiões tropicais".: Embrapa Monitoramento por Satélite, Campinas, 2010.

[50] Feitosa, K. K. A. *et al*. "Relações solo–vegetação em "ilhas" florestais e savanas adjacentes, no Nordeste de Roraima". Ciência Florestal, 26(1), pp. 135-146, 2016.

[51] International Plant Nutrition Institute. "Manual Internacional de Fertilidade do Solo". Tradução: Alfredo Scheidt Lopes. POTAFOS. Piracicaba, 1998.

[52] Pinho, R. C.; Miller, R. P.; Alfaia, S. S. "Agroforestry and the Improvement of Soil Fertility: A View from Amazonia." Applied and Environmental Soil Science, v. pp. 1-11, 2012.

[53] Marenco, R. A. *et al*."Fisiologia de espécies florestais da Amazônia: fotossíntese, respiração e relações hídricas". Revista Ceres, 61(7), pp. 786-799, 2014.

[54] Villa, E. B. *et al*."Aporte de serapilheira e nutrientes em área de restauração florestal com diferentes espaçamentos de plantio". Floresta e Ambiente, 23(1), pp. 90-99, 2016.

[55] Villar, M. L. P. "Manual de interpretação de análise de plantas e solos e recomendação de adubação". EMPAER, Cuiabá, 2007.

[56] Quevedo, C. M. G.; Paganini, W. S. "Impactos das atividades humanas sobre a dinâmica do fósforo no meio ambiente e seus reflexos na saúde pública". Revista de Ciência e Saúde Coletiva, 16(8), pp. 3529-3539, 2011.

[57] Farage, J. A. P. *et al*. "Determinação do índice de estado trófico para fósforo em pontos do Rio Pomba". Engenharia na Agricultura, 18(4), pp. 322-329, 2010.

[58] Chaves, L. H. G.; Souza, R. S. "Avaliação da fertilidade dos solos da região produtora de abacaxi do estado da Paraíba". Enciclopédia Biosfera, 13(24), pp. 129, 2016.

[59] Soares, I. D. *et al*. "Propriedades físico-químicas de resíduos agroflorestais amazônicos para uso como substrato". Nativa, 2(3), pp.155-161, 2014.

[60] Salvador, J. T.; Carvalho, T. C.; Lucchesi, L. A. C. "Relações cálcio e magnésio presentes no solo e teores foliares de macronutrientes". Revista Acadêmica Ciência Animal, 9(1), pp. 27-32, 2011.

[61] Favarin, J. L. *et al*. "Correção do magnésio no solo é essencial ao cafeeiro". Revista Visão Agricola, Piracicaba, 12, pp. 76-78, 2013.

[62] Viana, R. M. *et al*. "Soil quality indicators for different restoration stages on Amazon rainforest." Soil and Tillage Research, 140, pp. 1-7, 2014.

[63] Kaminski, J. *Et Al*. "Potassium availability in a Hapludalf soil under long term fertilization". Revista Brasileira de Ciência do Solo, 34(3), pp.783-791, 2010.

[64] Almeida Júnior, A. A. B.; Nascimento, C. W. A.; Barros, F. M. R. "Acidez potencial estimada pelo método do pH SMP em solos do estado da Paraíba". Revista Brasileira de Ciência do Solo, 39(3), pp. 767-773, 2015.

[65] Miguel, P. S. B. *Et al*. "Efeitos tóxicos do alumínio no crescimento das plantas: mecanismos de tolerância, sintomas, efeitos fisiológicos, bioquímicos e controles genéticos". CES, 24(1), pp. 13-29, 2010.

[66] Prado, M. R. V. "Estimativa da acidez potencial dos solos do estado de mato grosso com base em métodos tampões". Tese (Doutorado em Agricultura tropical) – Faculdade de Agronomia e Zootecnia, Universidade Federal do Mato Grosso, Cuiabá, 2018.

[67] Raij, B. V. "Fertilidade do solo no Brasil - Contribuições do Instituto Agronômico de Campinas". Informações Agronômicas, Piracicaba,. 132, pp. 1-13, 2010.

[68] Briedis, C. *et al*. “Carbono do solo e atributos de fertilidade em resposta à calagem superficial em plantio direto. Pesquisa Agropecuária Brasileira [*online*]

Author Profile

Ana Beatriz Matos Rodrigues, Undergraduate degree in Environmental Engineering, MBA student in Urban, agrarian, and environmental law.Former monitor of the environmental quality laboratory, Campus VI, Paragominas. And former volunteer of a Scientific Initiation Program. Castanhal, Pará, Brazil. Phone: +55 (91) 99914-5665

Nathália Melo Giuliatti, Undergraduate degree in Environmental Engineering, MBA student in Quality and Environmental Management. Former member of a Junior Enterprise and former volunteer of a Scientific Initiation Program. Paragominas, Pará, Brazil. Phone: +55 (91) 98236-5511.

Rodolfo Pereira Brito, Full Graduate Environmental Engineering, Specialist in Environmental Law and Publica Policy, Specialist in Renewable Energy, Specialist in Environmental Management, Specialist in Planning and Management of Regional Development, master’s in environmental management, Doctor in Environmental Engineering. Pará State University, Brazil. Phone 55 (91) 983393999

Antônio Pereira Júnior, Full Graduate in Biological Sciences, Specialist in Water Planning and Management, Specialist in Water and Environmental Management, master’s in environmental sciences. Coordinator of the Environmental Quality Laboratory, Campus VI, Paragominas, Para, Brazil. Phone: 55 (91)98282-1079.