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Eutrophication Process of Soil nearby a Sanitary Landfill and Its Influence on Brazilian Savanna Vegetation

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Abstract

This work aimed to demonstrate if exists a relation between eutrophic processes of soil (N, P, K, pH, and organic matter) with phytosociology mosaic of native tree species in Brazilian adjacent sanitary landfill areas of the savanna. One of the study area is located in Brasilia, Federal District, and the other one in Goiânia, State of Goiás, 210 km far each other. The methodology consisted in techniques, procedures and specific software applied to this kind of data. There were used plots and subplots for each area and for the vegetation and soil survey. Statistical significance showed that there exists a relationship between eutrophic processes of soil with phytosociology mosaic of native savanna tree species.

Keywords

Native Tree Species, Savanna, Network Neural Model, Nutrients

1. Introduction

Eutrophication can be defined simply as the production of organic matter in excess of what an ecosystem is normally adapted to processing [1], however, it is only part of a complex web of stressors that interact to shape and direct ecosystem level processes. Eutrophication is the process of enrichment of waters with excess plant nutrients, primarily phosphorus and nitrogen, which leads to enhanced growth of algae, periphyton, or macrophytes, so the eutrophication process is generated by human activities, and the most ubiquitous item is sewage, which is derived from a variety of sources: as a direct discharge, as a component of urban wastewater, or as sludge to be disposed of after treatment. In other words, it is the process in which a water body becomes overly enriched with nutrients, leading to plentiful growth of simple plant life. The excessive growth (or bloom) of algae and plankton in a water body are indicators of this process. In the last few decades, the eutrophication process shows a massive problem that is faced globally. The excessive presence of nitrogen and phosphorous in water leads to hypoxia and anoxia, reduced water quality, habitat degradation, loss of food web structure and the biodiversity [2]. In Brazil, around 260,000 tons of urban solid residues are collected daily. From this amount, about 35,000 tons are taken to sanitary landfills producing byproducts as biogas and leachates [2].

Savannas cover almost 20% of the earth's surface in a belt between 15˚ and 20˚ of latitude in both hemispheres. Brazilian savannas (*Cerrado*) covers more than 20% of the Brazilian territory (2 million·km^2), being the second in terms of national area covered [3] losing only to the Amazonian forest that occupied more than 3.5 million·km^2 [4]. The savanna flora is one of the richest among the world's savannas with more than 6000 species [5].

In the last decades, eutrophic process in soil and groundwater has developed by sanitary landfill presences in the Central Brazil [6]. This process results in the nutrients deposition, mainly: N, P and K ([7] [8] [9]). Modification in pH, organic matter ([8] [10]) and others chemical elements showed statistical significance ($p < 0.05$) and influence on the savanna vegetation ([9] [11] [12]). The nutrient deposition produces effects in vegetation dynamics, particularly in tree; it enhances the biomass of the species and modifies value importance of species ([1] [13]).

This study aimed to analyze the eutrophic process of soil in adjacent areas of sanitary landfill and the influences of this process in the Brazilian savanna vegetation. The answers to the question will be the main goal to demonstrate if the eutrophic process and nutrients deposition influence the savanna vegetation, around the sanitary landfill.

2. Materials

Two areas around sanitary landfill were studied: in the National Park of Brasilia, near Jockey Club landfill - 15˚45'56.56"S and 47˚59'55.25"W SAD 69 (in Brasilia city); and around the sanitary landfill of the Goiânia - 16˚39'09.77"S and 49˚23'37.08"W SAD 69 (in Goiânia city). These areas are located on savanna biome (Cerrado) in the Central Brazil.

Regional climate is Cwa (according Köppen climate classification), which is the typical savanna climate with wet summers (October to March) and dry winters (May to August).

Soils in the study area are mainly Latossoils and Neossoils (sandy soils), according to the Brazilian Classification System [14], or Oxisoils and Entisoils, respectively [15]. In each sanitary landfill were established three plots of 25 × 500 m (**Figure 1**), with 10 subplots each [6].

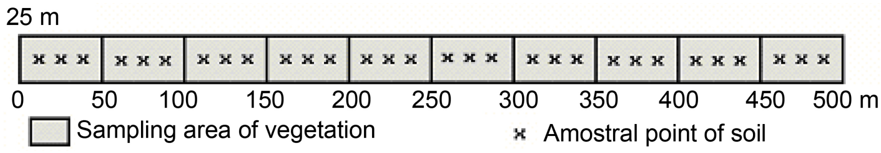

Figure 1. Plot and 10 subplot of sampling data of vegetation and 30 sampling soil points (x). The distance "0 m" means near area of the landfill.

3. Methods

Every individual tree (diameter at the breath height >5 cm) was sampled in each plot (**Figure 1**) and identified them to species level, using an identification key based on vegetative characters and comparative botanic matter in the herbarium UB of the University of Brasília and of the Brazilian Institute of Geology and Statistics (IBGE) both located in Brasilia city. Importance Value Index (IVI) was calculated according to [16].

Surface soil samples (0 - 15 cm) were collected from the adjacent area of landfill in savanna vegetation for chemical analysis, consisting in five subsamples which were combined. All soil samples were dried at 40˚C and sieved to <2 mm prior to analyses. The pH (H_2O), organic matter (OM: oxidable carbon) and total nitrogenous (Nt) were analyzed according to Kieldahl method [17]. Soil samples were digested with a mixture of concentrated HNO_3 and $HClO_4$. Al, Ca, K and Mg, were determined with flame atomic absorption spectrometry, P with inductively coupled plasma-atomic emission spectroscopy. All digestions were performed in duplicate.

The Stuttgart Neural Network Simulator (SNNS) software package was used to create the network and conduct training and testing. The back propagation algorithm was used for the training procedure, where the neural network got in to a form of a set of input layers, one for each independent variable, a set of hidden layers, and one output layer representing the estimate of the dependent variable ([8] [13] [18]). The form of the neural network used in this project is similar to the architecture used in [19]. These projects utilized the same neural network software package (SNNS) and software interface as did this study: a network of a hidden node for each input node, and the logistic sigmoid function.

The results (eigenvalues) were then altered using the logistic sigmoid function to reduce the range (+infinity, −infinity) usually to values between 0 and 1 ([19] [20]). The contamination level in this model was reached within relation of the data with the control data according to [15].

Soil features and the Importance Value Index of plant species were ordinated by direct analysis of gradient. Canonical Correspondence Analysis (CCA) were used to investigate relationships between environmental variables (pH, OM, N_t, P, K, Ca, Mg and Al) and IVI in sample plots (GYN + BSB). Significance of the overall CCA ordination was tested using a Monte Carlo permutation procedure [20].

Den-trended Correspondence Analysis (DCA) [17] was also carried out for the 40 highest IVI. All multivariate analyses used the CANOCO package ([20]).

Linear adjusts ($y = \beta_0 + \beta_1 \cdot x$); p-value and R^2 were calculated using an electronically analyses software.

4. Results

The 87 native tree species were identified (**Table 1**) and distributed in the 67 genders and 42 families. The families with the highest number of species were: Leguminosae with 11 species; Caesalpinaceae and Myrtaceae with five species each; and Rubiaceae, Melastomataceae, Apocynaceae and Annonaceae with four species each; this all representing 42% of sampling species.

The highest number of species distributed in many families corroborated with others phytosociological studies carried out in the savanna region (**Table 2**).

In Brasilia and Goiânia (210 km of distance between both cities) were registered 58% of the species in common: *Miconia albicans*, *Stryphnodendron adstringens*, *Alibertia macrophylla*, *Piptocarpha rotundifolia*, *Rudgea viburnoides.* Others species were registered in only one area: *Cayaponia tayuya* and *Anadenanthera colubrina*, only in Brasilia; and *Couepia grandiflora* and *Macrosiphonia longiflora* only in Goiânia.

The species with the highest IVI were: *Miconia albicans* with 25.80; *Stryphnodendron adstringens* with 16.28; *Alibertia macrophylla* with 16.27; *Piptocarpha rotundifolia* with 15.82; *Rudgea viburnoides* with 14.21; *Qualea grandiflora* with 13.93; *Enterolobium contortisiliquum* with 13.45; *Dalbergia miscolobium* with 11.13; and *Byrsonima crassa* with 11.12. The species that had the ten highest IVI value were registered in all subplots, with the exception of *Byrsonima crassa*, *Byrsonima intermedia* and *Piptocarpha rotundifolia* that were sampled in 80% of the subplots. *Rudgea viburnoides* was sampled in 55% of the subplots. The species that had IVI value <0.5 were sampled in 3% of subplots.

With the environmental variables (**Table 3**) were observed high average in relation of mesotrophic savanna data, this will be demonstrate if exist the eutrophic process in savanna soil around the sanitary landfills [21].

The average value of pH was high (±5.86) in relation of mesotrophic savanna data (Cerradão) which is ±4.7 ([12]). The same results occurred with others soil variables that showed in average an enhance of values in relation to the mesotrophic savanna data: OM of 7.60% [22] to 15.15% in this study; Nt of 0.45% [23] to 0.76%; K (mg/100g) of 1.69 ([12]) to 14.25; P (mg/100g) of 7.00 ([1]) to 8.65; Ca (mmolc/kg) of 3.00 [24] to 8.00; and Mg (mmolc/kg) of 2.00 [25] to 10.75; respectively. Only Al (mmolc/kg) had low value in relation to the savanna studies, of 12 [12] to 8.5.

The contamination levels were observed with the results of network neural model analysis (**Figure 2** and **Figure 3**) in relation with reference data [15], corroborating with results of **Table 3**. **Figure 2** and **Figure 3** show the central position of the studied plots.

Near areas of the landfills had contamination levels of 0.80 in Brasilia and 0.49 in Goiânia. These values corroborate with [3] data, which changed from 0.45 to

Table 1. Native tree species of savanna (Cerrado), average importance value index (IVI) registered in studied area of adjacent sanitary landfills: Jockey Club de Brasília landfill - BSB, and Goiânia landfill - GYN (SD = standard deviation, "x" represents the presence of specie in area).

Species	Families	Brasilia BSB	Goiânia GYN	IVI	SD
Acosmium dasycarpum (Vogel) Yakovlev	Caesalpiniaceae	x	x	3.14	0.16
Acosmium subelegans (Mohlenbr.) Yakovlev	Caesalpiniaceae	x	x	2.85	0.14
Aegiphila lhotzkyana Cham.	Verbenaceae	x	x	1.23	0.06
Alibertia macrophylla Schum.	Rubiaceae	x	x	16.27	7.81
Anacardium occidentale L.	Anacardiaceae	x	x	6.49	3.32
Anadenanthera colubrina (Vell.) Brenan	Leguminosae	x	-	0.33	0.02
Annona coriacea Mart.	Annonaceae	x	x	8.13	1.41
Annona dioica A.St. - Hil.	Annonaceae	x	-	0.86	0.04
Aspidosperma macrocarpon Mart.	Apocynaceae	x	x	5.34	3.27
Aspidosperma verbascifolium M. Arg.	Apocynaceae	x	x	1.45	0.07
Austroplenckia populnea (Reiss) Lund.	Celastraceae	x	x	2.94	2.15
Bauhinia holophylla Steud.	Caesalpiniaceae	x	-	0.71	0.04
Bauhinia mollis (Bong.) Walp.	Leguminosae	-	x	1.11	0.06
Bowdichia virgilioides H.B.K.	Leguminosae	x	-	0.54	0.03
Brosimum gaudichaudii Trécul	Moraceae	x	x	10.15	5.51
Byrsonima crassa Nied.	Malpichiaceae	x	x	11.12	3.56
Byrsonima intermedia A. Juss.	Malpichiaceae	x	x	10.91	6.55
Byrsonima verbascifolia (L.) DC.	Malpichiaceae	x	x	9.16	4.46
Cabralea canjerana (Vell.) Mart.	Meliaceae	x	x	0.55	0.03
Campomanesia xanthocarpa Berg	Myrtaceae	x	x	1.88	0.09
Caryocar brasiliense Camb.	Caryocaraceae	x	x	7.65	5.38
Casearia decandra Jacq.	Flacourtiaceae	-	x	2.13	0.11
Couepia grandiflora (Mart. Zucc.) Benth. ex Hook. f.	Chrysobalanaceae	-	x	0.26	0.01
Cayaponia tayuya (Vell.) Cogn.	Cucurbitaceae	x	-	0.33	0.02
Cissampelos ovalifolia DC.	Menispermaceae	x	-	0.45	0.02
Dalbergia miscolobium Benth.	Papilionoideae	x	x	11.13	9.56
Didymopanax macrocarpum Seem.	Araliaceae	x	x	7.4	2.37
Diospyros hispida A.DC.	Ebenaceae	x	x	3.19	2.16
Dimorphandra gardneriana Tul.	Leguminosae	x	x	1.01	0.05
Dipteryx alata Vog.	Leguminosae	x	x	2.77	2.14
Duguetia furfuracea (A. St. - Hil.) Saff.	Annonaceae	-	x	0.76	0.04
Eriotheca gracilipes (K. Schum.) A. Robyns	Bombacaceae	x	-	0.98	0.05
Eriotheca pubescens (Mart. Zucc.) Schott and Endl.	Bombacaceae	x	-	0.52	0.03
Erythroxylum suberosum St. Hil.	Erythroxylaceae	-	x	3.12	0.16

Continued

Enterolobium contortisiliquum (Vell.) Morong	Leguminosae	x	x	13.45	8.67
Eugenia dysenterica DC.	Myrtaceae	x	x	8.29	5.41
Guapira noxia (Netto) Lundell	Nyctaginaceae	x	x	2.94	0.15
Hymenaea stigonocarpa Mart. ex Hayne	Leguminosae	x	x	4.22	0.21
Hyptidendron canum (Pohl. ex. Benth) RM. Harley	Labiatae	-	x	1.28	0.06
Inga cf. affinis DC.	Leguminosae	x	-	0.75	0.04
Kielmeyera coriacea (Spreng.) Mart.	Clusiaceae	x	x	3.71	0.19
Kielmeyera neriifolia Camb.	Guttiferae	x	x	4.65	2.23
Lafoensia pacari St. Hil.	Lythraceae	x	x	5.24	3.26
Licania humilis Cham and Schlect	Chrysobalanaceae	x	x	4.26	2.21
Machaerium acutifolium Vog.	Leguminosae	x	-	2.79	0.14
Machaerium opacum Vogel	Papilionoideae	x	-	1.05	0.05
Macrosiphonia longiflora (Desf.) M. Arg.	Apocynaceae	-	x	0.15	0.01
Miconia albicans (Sw.) Triana	Melastomataceae	x	x	25.8	10.29
Miconia ferruginata DC.	Melastomataceae	x	x	7.66	2.38
Miconia langsdorffii Cogn.	Melastomataceae	x	-	3.57	1.18
Miconia sellowiana Naudin	Melastomataceae	-	x	4.62	2.23
Mimosa laticifera Rizz. and Mattos Filho	Leguminosae	x	x	1.09	0.05
Myrcia cf. lingua (O. Berg) Mattos and Legrand	Myrtaceae	x	x	9.15	3.46
Myrcia rostrata DC.	Myrtaceae	x	x	3.27	2.16
Neea theifera Oerst.	Nyctaginaceae	x	x	8.84	6.44
Ocotea pulchella Mart.	Lauraceae	-	x	0.34	0.02
Ouratea hexasperma (St. Hil.) Benth.	Ochinaceae	x	x	5.02	0.25
Ouratea spectabilis (Mart. ex Engl.) Engl.	Ochinaceae	x	-	3.52	0.18
Palicourea rigida Kunth Bate-caixa	Rubiaceae	x	x	1.99	0.10
Piptocarpha rotundifolia (Less.) Baker	Asteraceae	x	x	15.82	6.79
Pisonia ambigua Heimerl.	Nyctaginaceae	-	x	0.66	0.03
Psidium pohlianus Camb.	Myrtaceae	-	x	0.43	0.02
Pouteria ramiflora (Mart.) Radlk	Sapotaceae	x	x	4.35	1.22
Pouteria torta (Mart.) Radlk.	Sapotaceae	x	-	4.12	0.21
Qualea grandiflora Mart.	Vochysiaceae	x	x	13.93	10.7
Qualea multiflora Mart.	Vochysiaceae	x	-	2.78	0.14
Rapanea coriacea R. Br. ex Roem. and Scult.	Myrsinaceae	x	-	2.98	0.15
Rapanea ferruginea (Ruíz and Pav.) Mez	Myrsinaceae	x	x	2.49	1.12
Rhodocalyx rotundifolius M. Arg.	Apocynaceae	-	x	0.98	0.05
Rudgea viburnoides (Cham.) Benth.	Rubiaceae	x	x	14.21	4.71
Sclerolobium paniculatum Vogel	Caesalpiniaceae	x	x	2.55	0.13

Continued

Senna rugosa (G. Don) Irwin and Barneby	Caesalpiniaceae	x	x	10.03	6.50
Siparuna guianensis Aubl.	Monimiaceae	x	x	4.57	1.23
Solanum lycocarpum St. Hil.	Solanaceae	x	x	4.15	0.21
Sthrychnos pseudo-quina St. Hil.	Loganiaceae	x	x	1.58	0.08
Styrax ferrugineus Nees and Mart.	Styracaceae	x	x	4.16	1.21
Strychnos pseudoquina St. Hil.	Loganiaceae	-	x	1.64	0.08
Stryphnodendron adstringens (Mart.) Coville	Leguminosae	x	x	16.28	9.81
Symplocos cf. pubescens Klotzsch ex Benth.	Symplocaceae	x	-	4.47	3.22
Tabebuia aurea (Mart.)	Bignoniaceae	x	-	3.05	2.15
Tabebuia roseo-alba (Ridley) Sandwith	Bignoniaceae	-	x	0.88	0.04
Tocoyena formosa (C. and S.) K. Sch.	Rubiaceae	-	x	0.46	0.02
Vernonia ferruginea Less.	Compositae	x	-	0.78	0.04
Virola sebifera Aubl.	Myristicaceae	x	x	6.07	5.30
Vochysia thyrsoidea Pohl	Vochysiaceae	x	x	5.13	1.26
Xylopia aromatica (Lam.) Mart.	Annonaceae	x	x	5.85	2.29

Table 2. Floristic richness in phytosociological registers realized in the savanna areas.

Phytosociological registers		Species	Families
Bouxin (2006)		79	49
Balduíno *et al.* (2005)		73	38
Fiedler *et al.* (2004)		46	23
Saporetti Jr. *et al.* (2003)		85	44
Felfili *et al.* (2002)		80	34
Batalha *et al.* (2001)		81	40
Balatova-Tulackova and Surli (1982)		66	38
In this study	BSB	72	37
	GYN	67	36

0.99. [21] described that the distinct values between Brasilia and Goiânia were caused by differences age of landfill implementation (today more than 40 years).

In **Table 4** were observed the eigenvalues and representative order of the soil variables. OM, Nt, P and Ca were the variables with the highest representation of the model. These variables represent 74.96% and 81.83% of all variance %, to Brasilia and Goiânia, respectively.

Figure 4 shows the linear adjusts between numbers of species with the environmental variables. All linear adjusts were significant (**Table 5**) showing directly proportional enhance of the soil features concentration with enhance of the numbers of species.

Table 3. Average and standard deviation (±) of physical and chemical soil propriety registered in studied plots: adjacent area of Jockey Club landfill in Brasilia/DF, plus current references data.

Biome	Studies site	Soil variables							
		pH	MO (%)	Nt (%)	P (mg/100g)	K (mg/100g)	Ca (mmolc/kg)	Mg (mmolc/kg)	Al (mmolc/kg)
In this study	Brasilia - BSB	5.82 ± 0.12	41.85 ± 0.48	0.60 ± 0.08	6.80 ± 3.44	11.22 ± 4.51	6.53 ± 1.45	11.65 ± 4.26	8.24 ± 4.26
	Goiânia - GYN	5.99 ± 0.09	52.64 ± 3.37	0.84 ± 0.12	9.73 ± 1.18	15.86 ± 2.97	9.55 ± 2.25	10.45 ± 2.56	9.63 ± 1.58
savanna *strictu sensu*	Ruggiero *et al.* (2002)	4.00 ± 0.80	35.30 ± 8.45	-	4.90 ± 1.66	7.60 ± 4.30	1.20 ± 0.63	1.70 ± 0.67	11.30 ± 2.71
	Lilienfein *et al.* (2001)	-	-	0.11	2.7	2.27	5.05	4.97	29.9
	Haridasan *et al.* (2000)	4.9	-	0.23	-	1.69	1.5	1.33	12
forest	Carvalho *et al.* (2005)	5.60 ± 0.3	29.00 ± 11.00	-	12.40 ± 11.90	11.90 ± 4.60	-	2.00 ± 0.60	4.00 ± 0.42
cerradão (savanna forest)	Haridasan *et al.* (2000)	4.7	-	0.15	-	8.7	3	5	6.1

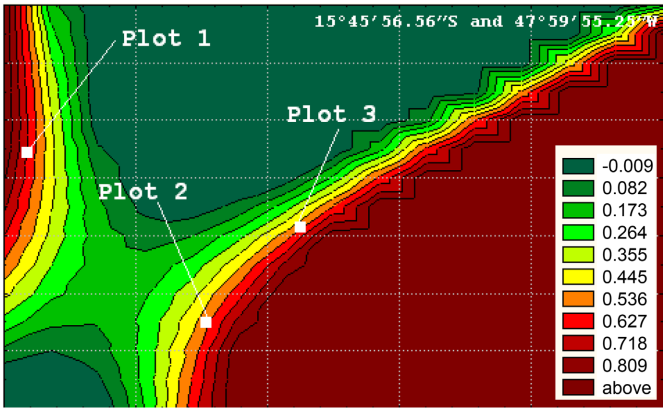

Figure 2. Study plots in Brasilia and contamination levels determined by network neural model.

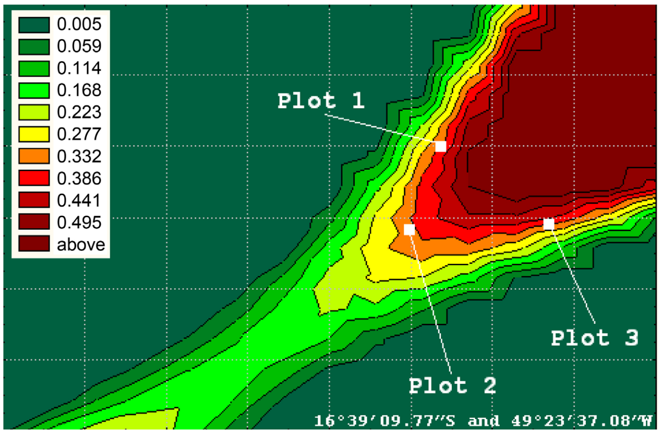

Figure 3. Study plots in Goiânia and contamination levels determined by network neural model.

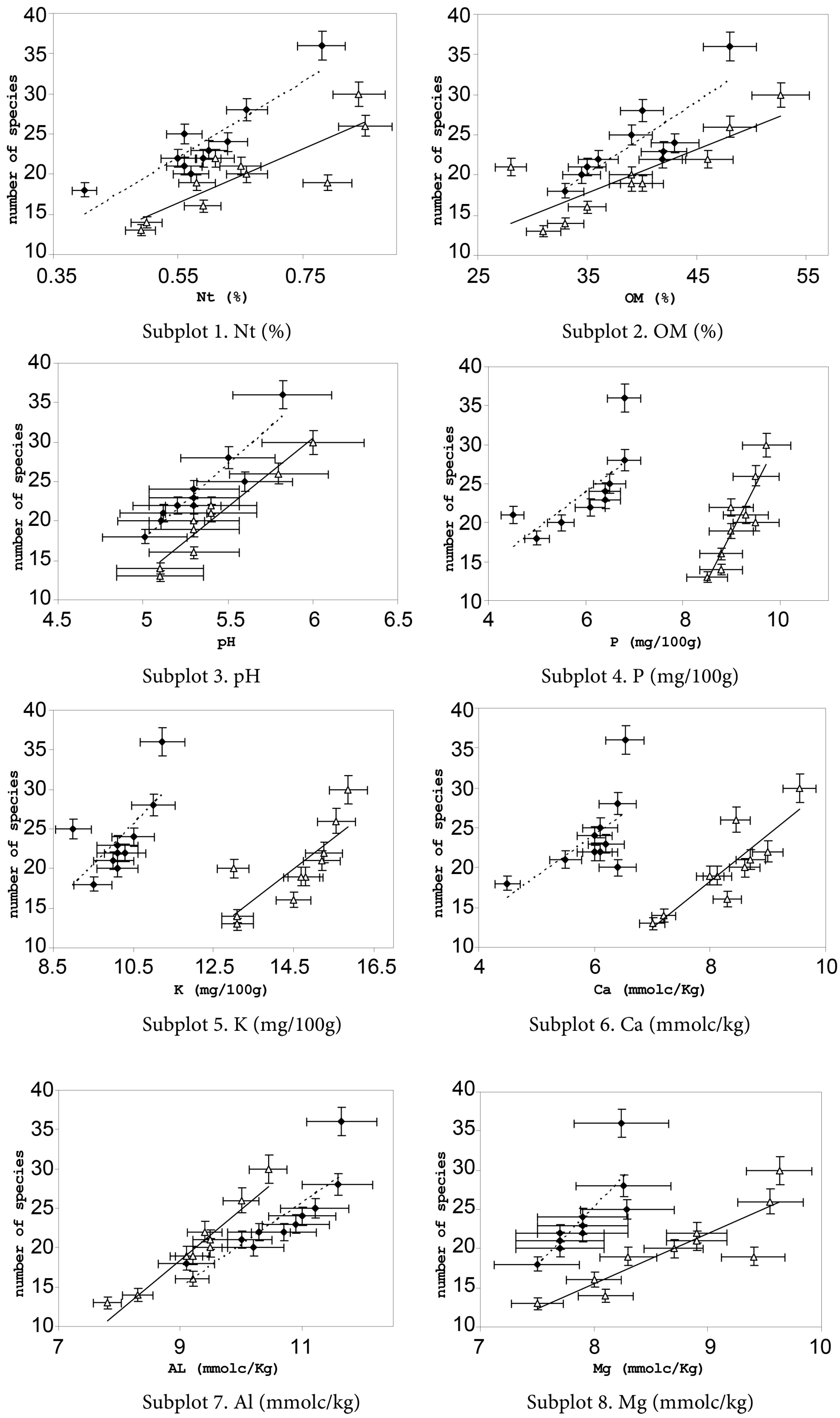

Figure 4. Number of species (±standard deviation) registered in the 20 subplots (♦Brasilia and △Goiânia) and its relation with chemical soil variables (Nt, OM, pH, P, K, Ca, Al and Mg). Linear adjust were plotted to Brasilia (- - - - BSB) and Goiânia (------ GYN).

Table 4. Eigenvalues of soil data in Brasilia and Goiânia.

	Brasilia			Goiânia		
Component*	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
OM	7.321	29.99	29.99	6.221	34.68	34.68
Nt (%)	4.524	22.22	52.21	3.816	27.56	62.24
Ca (mmolc/kg)	2.931	15.43	67.64	2.111	12.24	74.48
P (mg/100g)	1.598	7.32	74.96	1.658	7.35	81.83
K (mg/100g)	1.595	6.44	81.4	1.495	6.44	88.27
pH (%)	1.444	7.04	88.44	1.288	5.45	93.72
Mg (mmolc/kg)	1.004	6.25	94.69	1.054	4.15	97.87
Al (mmolc/kg)	0.522	5.31	100	0.522	2.13	100

*p-value to all variables <0.001.

Table 5. Statistical parameters of linear adjust between number of species in subplots (n˚ sp) (y) and soil variables (Nt = total nitrogenous, OM = organic matter, pH, P, K, Ca, Al and Mg) (x).

Relation	Site	Equations	R^2	EP	p-value
n˚ spxNt	Brasilia	$y = -0.001x + 0.872$	0.86	0.070	0.015
	Goiânia	$y = -0.023x + 1.306$	0.83	0.263	0.019
n˚ spx OM	Brasilia	$y = -0.093x + 19.945$	0.88	0.010	0.026
	Goiânia	$y = -0.704x + 26.048$	0.93	0.015	0.002
n˚ spx pH	Brasilia	$y = -0.016x + 5.870$	0.92	0.026	0.021
	Goiânia	$y = -0.042x + 6.436$	0.91	0.125	<0.001
n˚ spx P	Brasilia	$y = -0.031x + 8.554$	0.90	0.023	0.033
	Goiânia	$y = -0.226x + 14.595$	0.94	0.490	<0.001
n˚ spx K	Brasilia	$y = -0.266x + 23.241$	0.89	0.048	0.032
	Goiânia	$y = -0.595x + 2.863$	0.89	0.101	<0.001
n˚ spx Ca	Brasilia	$y = -0.375x + 13.140$	0.90	0.057	0.001
	Goiânia	$y = -0.451x + 5.891$	0.83	0.090	<0.001
n˚ spx Al	Brasilia	$y = -0.324x + 6.221$	0.96	0.012	<0.001
	Goiânia	$y = -0.781x + 9.801$	0.97	0.010	0.002
n˚ spx Mg	Brasilia	$y = -0.324x + 1.121$	0.91	0.111	0.022
	Goiânia	$y = -0.961x + 6.427$	0.98	0.075	<0.001

R^2 = determination coefficient; EP = standard error; p = significance level.

Soil properties values against IVI species in Canonical Correspondence Analysis (CCA) revealed significant correlation in all soil variables ($F > 3.18$ and $p < 0.001$) in the axes, represented in the ordination diagram (Figure 4 and Figure 5).

The canonical coefficients, the intra set correlation coefficients, and the correlation between environmental variables and ordination axes are presented in

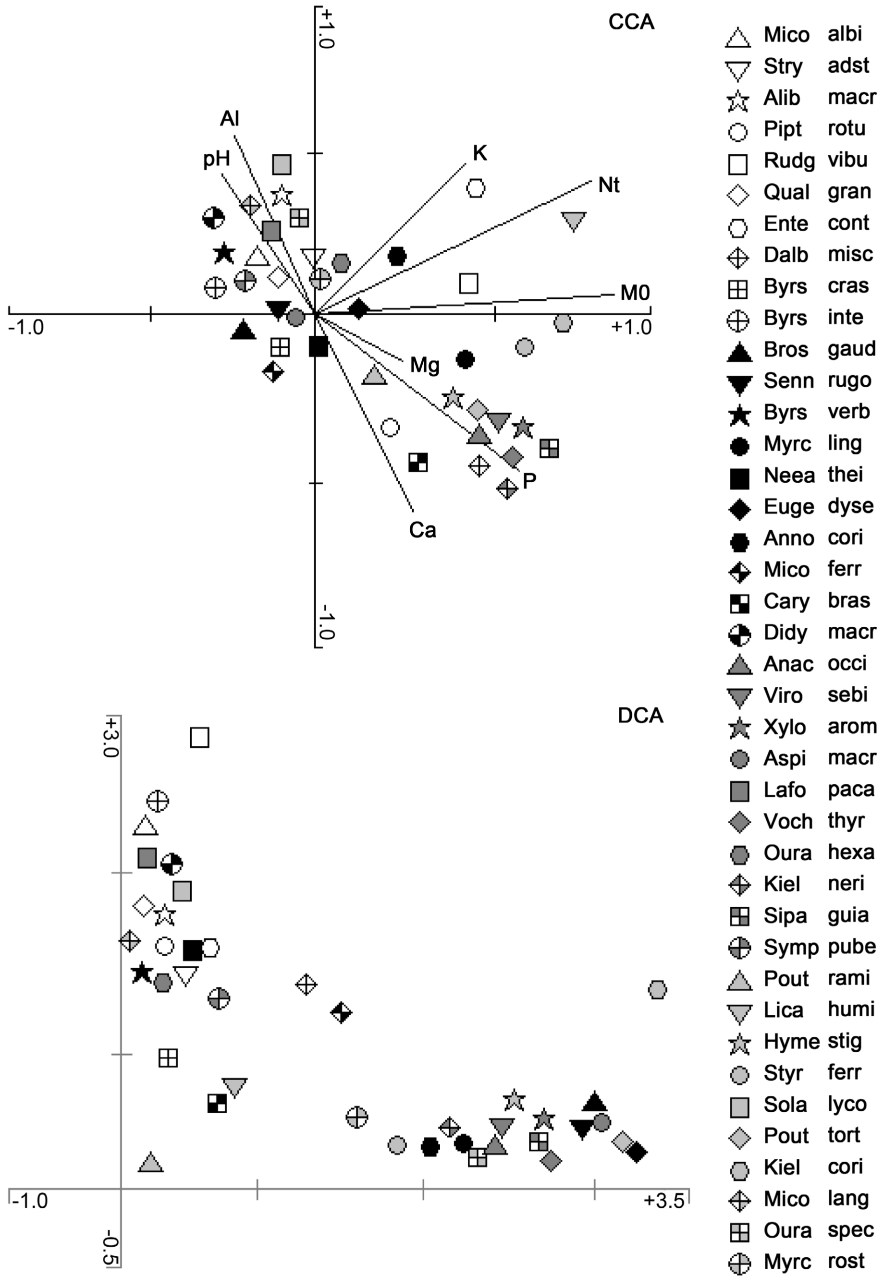

Figure 5. Canonical Correspondence Analysis (CCA) between the 40 species with high value of IVI and the eight soil variables (pH, OM = organic matter, Nt = total nitrogenous, P, K, Ca, Mg and Al). Ordination diagram of de-trended correspondence analysis (DCA) using the 40 highest IVI of the study areas.

Table 6, where the most significant variables of the first two axes according to *t* values for soil variables can also be distinguished. Considering the canonical coefficients and intra set correlation coefficient, the most significant soil variable were OM, Nt, Ca and Al. Al was the different one in relation to network neural model, this chemical element showed significance in correlation with vegetation data.

Species with highest IVI: *Miconia albicans*, *Stryphnodrendon adstringens*,

Table 6. Canonical correlation coefficients of the environmental variables: pH, OM = organic matter, Nt = total nitrogenous, P, K, Ca, Mg and Al. Coefficients >0.4 in bold.

Environmental	Correlation				pH	OM	Nt	P	K	Ca	Mg	Al
variables	ax 1	ax 2	ax 1	ax 2								
pH	−0.48	0.56	−0.13	0.45	-							
OM	0.95	−0.42	0.7	0.09	0.19	-						
Nt	0.88	−0.55	−0.11	0.41	0.21	0.12	-					
P	−0.08	−0.48	0.16	−0.31	−0.1	−0.14	−0.21	-				
K	0.49	0.51	0.43	0.29	0.11	−0.07	0.46	0.31	-			
Ca	−0.66	0.54	0.21	−0.33	−0.41	0.33	0.61	0.19	0.41	-		
Mg	−0.02	0.13	0.05	−0.02	0.45	0.01	0.08	0.06	−0.59	0.21	-	
Al	0.61	0.44	0.25	0.31	−0.11	−0.16	0.15	0.24	−0.41	−0.1	−0.08	-

Alibertia macrophylla and *Qualea grandiflora* joined in CCA near pH and Al axes. These axes received a set of 19 species. [12] also observed this same pattern when some species developed best in Al soil presence. Other important ax was P with 10 relationated species.

Others species joined with others axes, for example: *Enterolobium contortisiliquum*, *Rudgea virbunoides* and *Piptocarpha rotundifolia*; with K, OM and Ca, respectively, which are species that had high value of biomass. *Miconia ferruginata*, *Brosimum gaudichaudii* and *Byrsonima crassa* had low correlation with the axes of the soil variables.

In soil study in physiognomies, [25] observed these patterns; species as *Hymenaea aurea* were associated to Mg ax and *Sweetia fruticosa* to Ca ax.

In the de-trended correspondence analysis (DCA) for the highest IVI species, the first and second axes contributed with 34% and 57% of the variation, respectively. The ordination diagram of this analysis showed two different groups. The first was mainly formed by the highest IVI species (as *Miconia albicans* and *Stryphnodrendon adstringens*) and second by the lowest IVI species (as *Ouratea spectabilis* and *Miconia langsdorffii*).

5. Discussion

[26] [27] and [28] showed in their studies the IVI heterogeneity of tree species. These authors described that the dynamic alteration of the tree species in distinct areas were caused by different abiotical and environmental factors in the communities.

High value of standard deviation (SD) showed the preference of species by any place. This pattern resulted in large amplitude of IVI value. The SD varied from 0 to 50% of IVI value. The frequency, abundance and dominance parameters were transcribed in the IVI value [29].

[30] and [31] examined the relationship between soil and distance around landfills, and observed the high significant statistical of landfill presence in the

soil features, the same was observed in [21] and [32]) studies.

Eutrophic process was also confirmed with the highest significant variation mainly N, P, K, Ca and organic matter deposition in the soil around the sanitary landfills. This pattern was observed in others studies around landfills ([30] [31] [32] [33]).

[6] with diversity vegetation data around landfill (in the same area) observed enhance of diversity with enhance value of the soil features concentration, but did not observe statistical significance of floristic diversity between the subplots gradient (near or far of the landfills limit).

[14] and [25] described that soil gradient had a great impact in structure, dynamic and diversity of tree. [7] confirmed the effects of soil nutrients in the savanna vegetation mainly N, P, Ca, Al, Mg and K. [12] and [22] observed that OM and pH were also determinant factors in soil mesotrophic of vegetation feature and distribution.

[34] showed strong correlation between vegetation patterns and surface soils properties, in savanna region. He also observed that there is an intimate relationship between the properties of the surface soil horizons and the nature and also abundance of plant species which affects nutrient, as well as water absorption and retention in the biomass and upper rhizosphere.

Such a considerable correspondence between plant variation and soil features could be explained by the fact that vegetation itself influences soil characteristics at the upper layers, for instance by transferring organic matter through nutrient cycling [17].

Several authors examined the influence of fertility, such as the availability of nutrients in plant density and other vegetation characteristics ([13] [26] [28] [33] [35]).

The multivariate relation between plant-soil in the nature was evidenced in this study, corroborating with [36]. [20] described that environment and species developed associated sets such as observed in DCA analysis. [37] showed that dynamic vegetation reflects the adaptation within the local soil nutrition.

6. Conclusion

The studied sanitary landfills were in the eutrophic process of soil with enhanced values of pH, OM, Nt, P, K, Ca and Mg in relation to the control and reference data of mesotrophic soils; and there is a relation between eutrophic process with the savanna vegetation and the species distribution around sanitary landfills.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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