PREFERENCE OF TREE SPECIES FOR TROPICAL FOREST ENVIRONMENTS

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Abstract. In order to characterize the environment where plant species have better adaptation, one way is to associate species abundance and distribution with environmental parameters. To do this, we worked in a tropical forest fragment, with point-quarter sampling. The sampling points were parameterized by topographic, hydrographic and soil components, using slope, aspect, distance and water body altitude differences, and fertility and grain size parameters. With canonical correlation analysis and principal component we could detect preferences of some species for water supply, which in turn correlates with some grain size and fertility parameters. The environmental variation related to species abundance and distribution allowed the indication, especially associated with water characteristics, of species for ecological restoration.
Keywords: *species ecology, phytosociology, environmental analysis, multivariate analysis, semideciduous forests*

Introduction

In order to become effective within the ecological precepts, ecological restoration and recovery of degraded areas are issues that require scientific and technological investment. Exploitation of natural resources, agricultural and industrial production and the urban population, with their environmental liabilities, cause impacts that require a task force for reconstruction of natural environments.

There is research about ecological restoration experiencing methodologies with successional processes, phytosociology, and seed rain, among others (Durigan and Dias, 1991; Barbosa et al., 1992; Tabarelli et al., 1993; Palmer et al., 1997; Barbosa and Lieberg, 1998; Kageyama and Gandara, 2001; Rodrigues and Gandolfi, 2001; Rodrigues and Leitão Filho, 2001; Coutinho et al., 2002; Almeida, 2004). However, the use of a restricted floristic diversity base, without considering ecophysiological information, is usual.

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Other factors that hinder ecological restoration activities are growing trends of warming and drought periods (Getirana, 2016), and competition with invasive grasses, contributing to the increased cost and methodological inefficiency.

A requirement to indicate species, improving the survival rate and seedling development in the field, is to know the relationship of the plant species with the natural environment, such as water regime, soil, fertility and topography (Aquino, 2006).

Among the information that aids in survival and development of plant species is adaptation to drained or poorly drained environments, soil acidity tolerance and fertility requirements, phytosociology of the species through horizontal and vertical parameters, sun or shade tolerance, and adaptation to the succession stage. For this information, the phytosociological inventory and environmental characterization are the first data sources (Oliveira Filho et al., 1994).

The soil component may be parameterized by fertility, particle size and soil water dynamics, among others, while the relief can be parameterized by altitude, slope, aspect, plans and curvature profiles. The components to characterize the preferred species environment will be gathered considering soil, geomorphology, geology, hydrology and climate.

However, the preferred environments for species characterization may be more accurate (Carvalho et al., 2005), since variations in the parameters create distinct and abrupt conditions that can only be perceived with increased scale. Thus, the objective was to analyze tree species in a tropical forest fragment, relating them to topographic, hydrographic and soil parameters, for the selection of species according to their ecological characteristics, aiming at restoration actions in similar environments.

The test was conducted at “Parque da Cascata”, which belongs to the Environmental Protection Area of “Serra Santa Helena”, in Sete Lagoas, Minas Gerais, Brazil, with high vegetative and hydrological importance (Mahé, 2009).

Materials and Methods

The natural vegetation in this region is savanna with grasslands and enclaves of Atlantic tropical forest (IBGE, 2004). It has been highly degraded or replaced, mainly by pasture.

Soils are grouped into three types: residual soils of metapelitic rocks, colluvial soils and residual soils of limestone, with color ranging from yellow to dark red (Associação de Desenvolvimento Ambiental, 2007).

Climate classification, according to Köppen, is Cwa, i.e., savanna climate with dry winter and rainy summer. The average annual temperature is 21.1 °C; the lowest average temperature is approximately 11.5 °C, recorded in June and July. The highest temperatures are between 28.5 °C and 30 °C, and occur in January to March and October to December. August and September are the driest months with relative air humidity (RH%) between 57.6 and 58.8%. January, February, March and December have the the highest RH (76.2 , 74.3, 74.8 and 76.7%). The dry season extends from May to September. The total average annual rainfall is 1.384 mm. The average daily evapotranspiration (ETp) is lower in June, 2.7 mm, and higher in October, whose daily average is 4.7 mm (Gomide et al., 2006).

The Municipal “Parque da Cascata”, created by Law 593 on September 27, 1977, has an area of 205 ha, with 92 ha of tropical forest area (ADESA, 2007). The inventoried area is shown in figure (*Fig. 1*).

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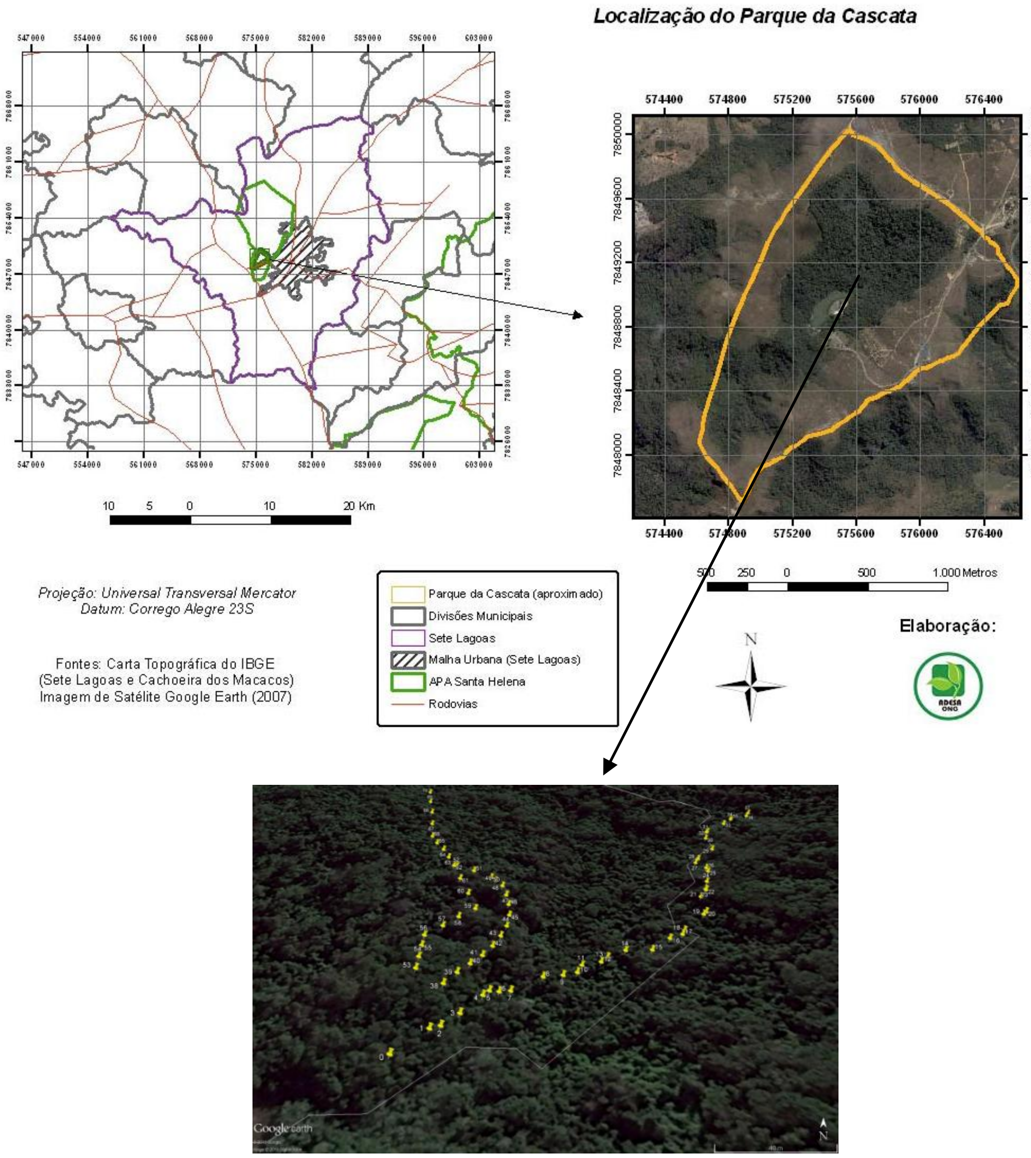

Figure 1. *Inventoried quadrant points and the stream in Municipal "Parque da Cascata" (Figure Credit: ADESA, 2007)*

A phytosociological inventory was performed through the Point-centred Quarter Method (Cottam and Curtis, 1956). Three transects were drawn (*Fig. 1*), the first near the watercourse, with 38 points, the second in an intermediate section, with 15 points, and the last transect is farthest from the stream bed, with 18 points.

In the first transect (points 0 to 37), flooded areas prevail near the stream that runs through a part of this transect. The second transect (points 38 to 52) has a forest with lianas, and the third transect (points 53 to 71) is the most remote area of the creek and with higher altitude terrain.

Points were marked at a distance of 10 m, and in each quadrant the nearest tree to the point was selected, measuring the diameter at breast height (DBH), total height using a digital hypsometer and the distance between the point and the tree. All trees with DBH ≥ 5 cm were considered by collecting botanical material for identification at the

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Herbarium PAMG of the Agricultural Research Company of Minas Gerais (Epamig) and support of the virtual herbarium Tropicos.org (2016), The Field Museum (2016) and The New York Botanical Garden (2007).

The fertile materials were herborized and included in the collection of the PAMG Herbarium /Epamig. The scientific names and phylogenetic relationships follow the APG III classification system (Souza and Lorenzi, 2012), and the confirmation of the scientific names and botanical synonymies were based on the Flora do Brasil 2020 (2016).

The phytosociological parameters of density, dominance, frequency and importance value (IV) were obtained for each species. Environment variables were analyzed with the most abundant species.

Soil samples were collected at points 1, 9, 19, 28, 39, 43, 47, 51, 56, 60, 65 and 68. We evaluated the following parameters: fertility (Lopes and Guilherme, 2004), particle density, particle size, macro and micro-porosity. With the aid of volumetric rings, thirty-six undisturbed samples were taken at three depths 0-10, 10-20, 20-30 cm and, separately, thirty-six deformed soil samples were collected.

The TanDEM-X derived DEM digital elevation model was used (Viana et al., 2015), with a spatial resolution of 12.5 x 12.5 m. Aspect and slope in degrees were calculated, and the distance of the water body and the difference in altitude between the point and the water body were generated with the help of a GIS (Geographic Information System). The information per point was extracted at the intersection of layers with these data and the quadrant points. The aspect was ranked in faces: North, Northeast, East, Southeast, South, Southwest, West and Northwest, by the framework of the original angles in classes defined by 22.5º angles. Thus angles that are in classes 0-22.5º and 337.5º-0 were classified as North face, or 0º. Angles 22.5º to 67.5º were classified as Northeast face, or 45º, and so on.

To explore the relationship among the physical medium parameters, we analyzed the correlation between the hydrography, topography, granulometry and soil fertility parameters considering the 12 points and the three soil depths sampling.

Finally, canonical correlation (CCA) multivariate analysis was applied to soil data, correlating with topographic and hydrographic attributes, and analysis of principal components (PCA) was applied to topographic, hydrographic and dendrometric attributes for more abundant species.

Results and Discussion

Structure of arboreal community

Two hundred thirty-five individuals belonging to 27 families, 47 genera and 65 species were inventoried. Nine species had only the genus defined and 8 species were not determined, remaining as morpho-species (*Tables 1 and 2*).

The largest families were Fabaceae with 6 species, Euphorbiaceae, Rubiaceae and Vochysiaceae with 5 species each, Lauraceae and Meliaceae, with 4 species each, and Annonaceae, Apocynaceae, Bignoniaceae and Cannabaceae with 2 species each. The other 14 families were of single-species. The most diverse families are among the 30 most diverse families of Minas Gerais, according to Oliveira Filho et al. (2008a). In general they are also quite representative families regarding number of species in the seasonal forests of Triângulo Mineiro (Araújo et al., 1997; Araújo and Haridasan, 1997), Zona da Mata (Silva et al., 2004), Southern Minas Gerais (Vilela

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et al., 2001; Machado et al., 2004) and in the Brazilian Cerrados (Costa and Araújo, 2001; Pereira-Silva et al., 2004).

Table 1. *Species identified with their popular names, conservation status (Cons.) and ecophysiological category (Ecol.). AB = Abundant; CO = Common; FR = Frequent; VR = Very rare; OC = Occasional; RA = Rare; ER = Extremely rare; C = Climax; P = Pioneer; IS = Initial Secondary; LS = Late Secondary (Oliveira Filho et al., 2008a; 2008b; 2008c; 2008d; 2008e)*

Family/Species	Common name(s)	Cons.	Ecol.
Anacardiaceae			
Astronium fraxinifolium Schott ex Spreng	Aroeira-vermelha, gonçalo-alves	AB	IS
Annonaceae			
Annona sylvatica A.St.-Hil.	Araticum-cagão-macho, araticum-do-mato, embira	FR	IS
Guatteria ferruginea A.St.-Hil.	Imbuí-amarela	ER	LS
Apocynaceae			
Aspidosperma subincanum Mart.	Guatambu-vermelho, pau-pereira-do-campo, perobinha	OC	LS
Bignoniaceae			
Jacaranda macrantha Cham.	Caroba, carobão	OC	IS
Cannabaceae			
Celtis pubescens Spreng.	Cipó-espinho, grão-de-galo	FR	P
Trema micrantha (L.) Blume	Crindiúva, pau-pólvora, periquiteira	OC	P
Caricaceae			
Jacaratia spinosa (Aubl.) A.DC.	Barrigudo, jacaratiá, mamãozinho, mamoeiro-de-espinho	FR	IS
Euphorbiaceae			
Alchornea glandulosa Poepp.	Amor-seco, maria-mole, tapiá	FR	P
Croton urucurana Baill.	Capixingui, urucurana, sangra-d'água	OC	P
Gymnanthes klotzschiana Müll.Arg.	Branquilho, branquinho, branquio	AB	IS
Fabaceae			
Copaifera langsdorffii Desf.	Copaíba, copaíba-vermelha, óleo-de-copaíba, pau-de-óleo	AB	P
Plathymenia reticulata Benth.	Vinhático, vinhático-branco	CO	P
Platycyamus regnelli Benth.	Angelim-rosa, folha-de-bolo, pereira, pereira-vermelha	RA	IS
Lauraceae			
Cryptocarya aschersoniana Mez	Canela-amarela, canela-fogo, canela-pimenta	FR	P
Nectandra megapotamica (Spreng.) Mez	Canela-cheirosa, canela-ferrugem, canela-loura, canela-preta	RA	IS
Ocotea corymbosa (Meisn.) Mez	Canela-corvo, canela-fedorenta	OC	P
Ocotea velutina (Nees) Rohwer	Canela-amarela, canelão-amarelo	RA	LS
Lecythidaceae			
Cariniana estrellensis (Raddi) Kuntze	Estopeira, jequitibá, pau-de-cachimbo	ER	C
Malvaceae			
Luehea grandiflora Mart.	Açoita-cavalo, açoita-cavalo-graúdo	AB	P
Melastomataceae			
Miconia chamissois Naudin	Maria-preta	VR	P
Meliaceae			
Cabralea canjerana (Vell.) Mart.	Canjerana, cedro-canjerana	VR	IS
Guarea guidonia (L.) Sleumer	Camboatã, canjerana-miúda, cedro-branco, jitó, marinheiro	RA	LS
Trichilia claussenii C.DC.	Catiguá-vermelho, quebra-machado	RA	IS
Trichilia pallida Sw.	Baga-de-morcego, catiguá	OC	P

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Monimiaceae			
Mollinedia widgrenii A.DC.	Corticeira, pau-de-espeto, pimenteira	OC	IS
Moraceae			
Sorocea bonplandii (Baill.) W.C. Burger et al.	Folha-de-serra, laranjeira-do-mato	OC	IS
Myrtaceae			
Eugenia florida DC.	Guamirim, pitanga	OC	P
Nyctaginaceae			
Guapira opposita Vell.	Flor-de-pérola, joão-mole, maria-mole	OC	IS
Ochnaceae			
Ouratea tenuifolia Engl.	Guaratinga, guatinga	ER	IS
Polygonaceae			
Coccoloba mollis Casar	Falso-novateiro, folha-de-bolo	OC	P
Primulaceae			
Myrsine umbellata Mart.	Capororoca, capororoca-branca	FR	P
Rubiaceae			
Amaioua guianensis Aubl.	Canela-de-veado, marmelada-brava, pimentão-bravo	FR	IS
Faramea hyacinthina Mart.	Limãozinho-bravo, marmelada-de-cachorro	OC	IS
Ixora brevifolia Benth.	Ixóra-arbórea	FR	IS
Psychotria carthagenensis Jacq.	Carne-de-vaca, erva-de-rato-branca, rainha	FR	IS
Rutaceae			
Galipea jasminiflora (A. St.-Hil.) Engl.	Jasmim-do-mato, mamoninha, quina-de-três-folhas	FR	IS
Metrodorea stipularis Mart.	Laranjeira-do-mato, limoeiro-do-mato	OC	IS
Salicaceae			
Casearia decandra Jacq.	Café-do-mato, chá-de-bugre, guaçatonga, pau-de-espeto, pau-vidro	OC	P
Solanaceae			
Solanum rugosum Dunal	Jurubeba-do-mato	ER	IS
Urticaceae			
Cecropia pachystachya Trécul	Árvore-da-preguiça, embaúba	CO	P
Vochysiaceae			
Qualea dichotoma (Mart.) Warm.	Pau-terra e pau-terra-da-areia	CO	IS
Qualea multiflora var. *pubescens* Mart.	Pau-de-tucano, pau-terra-do-campo	FR	P
Qualea parviflora Mart.	Pau-terra-de-flor-miúda, pau-terra-mirim	OC	P
Vochysia tucanorum Mart.	Amarelinho, pau-de-tucano, pau-doce	CO	P

Using the classification of successional categories, by Oliveira Filho et al. (2008a; 2008b; 2008c; 2008d; 2008e), of Minas Gerais forest inventory we found that of the 46 species identified (*Table 1*), 21 (45.6%) are initial secondary, 20 (43.5%) are pioneers, 4 (8.7%) are late secondary and one (2.2%) is climax.

As for the conservation status (*Table 1*), 4 (8.7%) species are abundant, 5 (10.9%) are common, 11 (23.9%) are frequent, 15 (32.6%) are occasional, 5 (10.9%) are rare, 2 (4.3%) are very rare and 4 (8.7%) are extremely rare (Oliveira Filho et al., 2008a; 2008b; 2008c; 2008d; 2008e). The Parque da Cascata houses species of extremely rare occurrence (*Guatteria ferruginea*, *Cariniana estrellensis*, *Ouratea tenuifolia* and *Solanum rugosum*), very rare occurrence (*Miconia chamissois* and *Cabralea canjerana*)

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and rare occurrence (*Platycyanus regnelli*, *Nectandra megapotamica*, *Ocotea velutina*, *Guarea guidonia* and *Trichilia claussenii*), and this indicates special attention to the development of conservation and management strategies.

Of the 46 species identified, 14 (30.4%) are endemic to Brazil: *Annona sylvatica* (Lobão, 2015), *Casearia decandra* (Marquete, 2016), *Celtis pubescens* (Santos, 2014), *Eugenia florida* (Sobral, 2014), *Galipea jasminiflora* (Pirani, 2011a), *Guatteria ferruginea* (Lobão, 2016), *Jacaranda macrantha* (Lohmann, 2015), *Metrodorea stipularis* (Pirani, 2011b), *Mollinedia widgrenii* (Peixoto, 2014), *Ocotea velutina* (Quinet, 2014), *Platycyamus regnelli* (Moura, 2016), *Psychotria carthagenensis* (Zappi, 2014), *Qualea dichotoma* (Souza, 2014) and *Trichilia claussenii* (Stefano, 2012), and occur mainly in phytogeographical areas of the Atlantic Forest and Cerrado.

Table 2 shows the horizontal phytosociological parameters for the inventoried species. Among the 46 species identified, 35 are suitable for reforestation, restoration and consolidation of degraded areas, because they present rapid growth, are pioneering or produce fruits eaten by animals (Lorenzi, 2008; 2009a; 2009b).

Table 2. *Abundance values (Ni), Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDom) and Importance Value (IV) for the inventoried species*

Code	Scientific Name	Ni	RD (%)	RF (%)	RDom (%)	IV
21	*Ixora brevifolia* Benth.	45	19.15	8	20.52	47.67
39	*Gymnanthes klotzschiana* Müll.Arg.	26	11.06	9.6	4.06	24.73
17	*Galipea jasminiflora* (A.St.-Hil) Engl.	32	13.62	4.8	3.86	22.28
25	*Metrodorea stipularis* Mart.	18	7.66	4	8.48	20.14
1	*Alchornea glandulosa* Poepp.	14	5.96	6.4	4.45	16.81
12	*Copaifera langsdorffii* Desf.	5	2.13	3.2	11.31	16.64
32	*Plathymenia reticulata* Benth.	4	1.70	3.2	6.88	11.78
2	*Amaioua guianensis* Aubl.	8	3.40	2.4	1.38	7.18
14	*Cryptyocharya aschersoniana* Mez	3	1.28	2.4	2.40	6.07
7	*Cariniana estrellensis* (Raddi) Kuntze	3	1.28	0.8	3.73	5.80
19	*Guarea guidonia* (L.) Sleumer	4	1.70	3.2	0.53	5.43
28	*Nectandra megapotamica* (Spreng) Mez.	3	1.28	2.4	1.03	4.70
36	*Qualea multiflora* var. *pubescens* Mart.	2	0.85	1.6	2.20	4.65
30	*Ocotea velutina* (Nees) Rohwer	2	0.85	1.6	2.05	4.50
20	*Guatteria ferruginea* A.St.-Hil.	2	0.85	1.6	1.92	4.37
22	*Jacaranda macrantha* Cham.	3	1.28	2.4	0.43	4.11
15	*Eugenia florida* DC.	4	1.70	0.8	1.49	3.99
33	*Platycyamus regnelli* Benth.	1	0.43	0.8	2.47	3.69
23	*Jacaratia spinosa* (Aubl.) A.DC.	1	0.43	0.8	2.46	3.68
9	*Cecropia pachystachya* Trécul.	3	1.28	1.6	0.63	3.51
29	*Ocotea corymbosa* (Meisn.) Mez.	1	0.43	0.8	2.27	3.49
3	*Annona sylvatica* A.St.-Hil.	2	0.85	1.6	0.92	3.37
6	*Cabralea canjerana* (Vell.) Mart.	2	0.85	0.8	1.48	3.13
47	*Vochysia* sp.	1	0.43	0.8	1.77	3.00
41	*Solanum rugosum* Dunal	2	0.85	1.6	0.25	2.70

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43	*Trema micrantha* (L.) Blume	3	1.28	0.8	0.57	2.65
16	*Faramea hyacinthina* Mart.	2	0.85	1.6	0.12	2.58
47	*Aspidosperma* sp.	2	0.85	0.8	0.74	2.39
47	Undertermined 5	1	0.43	0.8	1.00	2.22
47	Undertermined 2	1	0.43	0.8	0.98	2.20
35	*Qualea dichotoma* (Mart.) Warm.	1	0.43	0.8	0.70	1.92
11	*Coccoloba mollis* Casar.	1	0.43	0.8	0.60	1.82
47	*Alchornea* sp.	1	0.43	0.8	0.57	1.80
27	*Mollinedia widgrenii* A.DC.	1	0.43	0.8	0.53	1.76
47	Undertermined 6	1	0.43	0.8	0.51	1.73
47	*Ouratea* sp.	1	0.43	0.8	0.45	1.68
47	Undertermined 7	1	0.43	0.8	0.41	1.63
47	*Swartzia* sp.	1	0.43	0.8	0.32	1.55
47	Undertermined 4	1	0.43	0.8	0.28	1.50
24	*Luehea grandiflora* Mart.	1	0.43	0.8	0.27	1.49
26	*Miconia* cf. *chamissois* Naudin	1	0.43	0.8	0.26	1.49
40	*Senna multijuga* (Rich.) H.S. Irwin & Barneby	1	0.43	0.8	0.25	1.47
47	*Croton* sp.	1	0.43	0.8	0.23	1.45
47	Undertermined 3	1	0.43	0.8	0.22	1.44
47	Undertermined 8	1	0.43	0.8	0.21	1.43
47	*Bauhinia* sp.	1	0.43	0.8	0.20	1.42
47	*Jacaranda* sp.	1	0.43	0.8	0.19	1.42
10	*Celtis pubescens* Spreng.	1	0.43	0.8	0.19	1.41
46	*Vochysia tucanorum* Mart.	1	0.43	0.8	0.15	1.38
44	*Trichilia claussenii* C.DC.	1	0.43	0.8	0.12	1.35
47	Undertermined 1	1	0.43	0.8	0.12	1.34
18	*Guapira opposita* Vell.	1	0.43	0.8	0.09	1.32
47	*Myrcia* sp.	1	0.43	0.8	0.08	1.31
5	*Astronium fraxinifolium* Schott ex Spreng.	1	0.43	0.8	0.08	1.30
47	*Chomelia* sp.	1	0.43	0.8	0.08	1.30
38	*Myrsine umbellata* (Mart.) Mez	1	0.43	0.8	0.07	1.30
37	*Qualea* cf. *parviflora* Mart.	1	0.43	0.8	0.08	1.30
4	*Aspisdosperma subincanum* Mart.	1	0.43	0.8	0.06	1.29
31	*Ouratea* cf. *tenuifolia* Engl.	1	0.43	0.8	0.06	1.29
34	*Psychotria* cf. *carthagenensis* Jacq.	1	0.43	0.8	0.06	1.29
42	*Sorocea bonplandii* (Baill.) W.C. Burger et al.	1	0.43	0.8	0.04	1.27
45	*Trichilia pallida* Swartz.	1	0.43	0.8	0.05	1.27
8	*Casearia decandra* Jacq.	1	0.43	0.8	0.03	1.26
13	*Croton urucurana* Baill.	1	0.43	0.8	0.04	1.26
47	*Daphnopsis* sp.	1	0.43	0.8	0.04	1.26

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Species with higher IV

The species with the highest importance values (IV) (*Table 2*) were *Ixora brevifolia* (47.67), *Gymnanthes klotzschiana* (= *Sebastiania commersoniana* (Baill) L.B. Sm. & Downs (Oliveira, 2014)) (24.73), *Galipea jasminiflora* (22.28), *Metrodorea stipularis* (20.14), *Alchornea glandulosa* (16.81) and *Copaifera langsdorffii* Desf. (16.64). The abundance of these species, totaling 160 individuals, represent 68% of the sampled individuals.

Relating these species with other surveys in the same typology, Machado et al. (2004) inventoried a fragment of seasonal forest near a pond in Lavras, Minas Gerais, Brazil, in an area of Atlantic Forest, with Köppen Cwa climate, on nitosoils and argisoils, and found only one individual of *S. commersoniana*, and many *G. jasminiflora*. Rocha et al. (2005) inventoried a swamp forest on cambisoils and argisoils in Coqueiral, Minas Gerais, Brazil, less than 50 km from Lavras, in the transition of the Cerrado to the Atlantic Forest area, and found that *G. jasminiflora*, *S. commersoniana* and *M. stipularis* had the highest IV, and occupied mainly the hillside areas.

Meira-Neto and Martins (2002), inventorying a fragment from natural regeneration, about 60 years old in the municipality of Viçosa, Zona da Mata, Minas Gerais, in an Atlantic Forest area, with Aw climate, did not obtain registration of any of the species with the highest abundance in this present survey.

In surveys of shrubby tree flora, even in similar environments, there are low floristic similarities, indicating that there are other large-scale conditionings interfering with the distribution of the species.

Regarding some features of the most expressive species, *I. brevifolia* is considered late secondary, and exclusive to semi-deciduous forest of altitude, occurring mainly in well-drained and medium fertility terrain (Prado Júnior et al., 2012).

S. commersoniana is classified as a pioneer species, deciduous with autochoric dispersion (Cappelatti and Schmitt, 2009) and occurs almost exclusively in humid areas, in riparian forests and flooded forests (Barddal et al., 2004; Kanieski, 2013). It is usually found in groups, reaching pure populations, developing in fields and on the border of clumps; it is rare within dense primary forest (Lorenzi, 2008). In the alluvial plain of the Paraiba River in São José dos Campos, São Paulo, Brazil, *S. commersoniana* presented the second highest IV, occurring in the dominant stratum in both the canopy and the understory (D'Orazio and Catharino, 2013). The *Sebastiania* genus includes species considered exclusively of marsh, such as: *S. brasiliensis* Spreng, *S. edwalliana* Pax & K. Hoffm., *S. klotzschiana* (Müll. Arg.) Müll. Arg. (Torres et al. 1992) and *S. serrata* (Baill. ex Müll. Arg.) Müll. Arg. (Ivanauskas et al., 1997).

Regarding soil conditions, *S. commersoniana* occurred mostly in neosoils (Botrel et al., 2002), indicating a preference for soils with higher sand content (Kolb et al., 1998). According to Callegaro (2012), the presence of this species may be related to the secondary stage of forest succession, being an indicator species of this stage in a mixed broadleaf forest stretch, classifying it as a pioneer species (Longhi-Santos, 2013).

G. jasminiflora is an early secondary species (Oliveira Filho et al., 2008d), endemic to Brazil, which occurs in phytogeographical areas of Cerrado and Atlantic Forest, in the vegetation of semideciduous forest (Pirani, 2011a). This

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species showed preference for dry soil, occurring at low densities in swamp forest (Teixeira and Assis, 2003).

Both *M. stipularis* and *G. jasminiflora* are early secondary species (Oliveira Filho et al., 2008d), occur mainly within the dense forest and are less frequent in open and secondary formations, with very low population density (Lorenzi, 2008). *M. stipularis* can be found in the phytogeographic areas of Cerrado and Atlantic Forest in the vegetation of semideciduous forest (Pirani, 2011b).

A. glandulosa is a pioneer species (Oliveira Filho et al., 2008d), which may appear in swamps, but occurs mainly in areas with temporary waterlogging, such as ciliary or riparian and gallery forests, and even drier forests, where waterlogged soil never occurs. It can be found in Cerrado (*lato sensu*) vegetation, riparian or gallery forest, rain forest and restinga (sandbank vegetation) (Paula-Souza, 2014).

C. langsdorffii is a pioneer species (Oliveira Filho et al., 2008e), characteristic of Cerrado transition to broadleaf semideciduous forest formations, occurring in secondary formations and in dense primary forests (Lorenzi, 2008). According to Oliveira Filho and Ratter (2001), *C. langsdorffii* is a habitat generalist, and, in general, is dominant in the face of most of the remaining forests in the Central South of the state of Minas Gerais.

Relationship of species and the environment

The correlations between the physical medium parameters, hydrography, topography ("Appendix *Table 1*"), granulometry and soil fertility parameters ("Appendix *Tables* 2 and 3") are in "Appendix *Tables 4, 5 and 6*" considering the 12 points and the three soil sampling depths. Via quantification of sand, silt and clay levels, the soil textural classes ranged from franco silty-clayey to silty-clayey. The relief is predominantly wavy, especially the aspect to the southwest.

Twenty-nine significant correlations greater than or equal to 0.70 in the 0-10 cm layer, 62 correlations in the 10 to 20 cm layer, and 46 at 20 in the 30 cm layer were found. The smaller amount of correlations in the topsoil may be due to the contribution of nutrient cycling by litter deposition, which is the layer least dependent on the source material.

In the canonical correlation between fertility and particle size parameters (*Fig. 2*), we found positive associations among fine sand, micro-pores, particle density and silt levels with Mg, Ca, SB, V, Zn, Fe, Mn, Cu, and P. In the opposite direction, there are positive associations among coarse sand, clay and macro-pores with H + Al, K, Al, and Aluminum Saturation. The pH, CEC and organic matter did not show associations with other parameters, both in magnitude and in direction.

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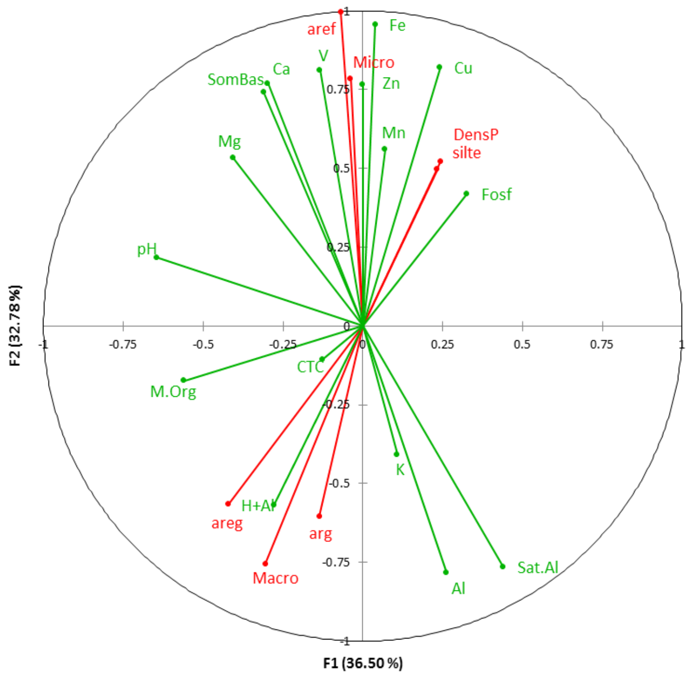

Figure 2. *Canonical correlation among particle size and fertility parameters for the soil depth up to 30 cm (average levels)*

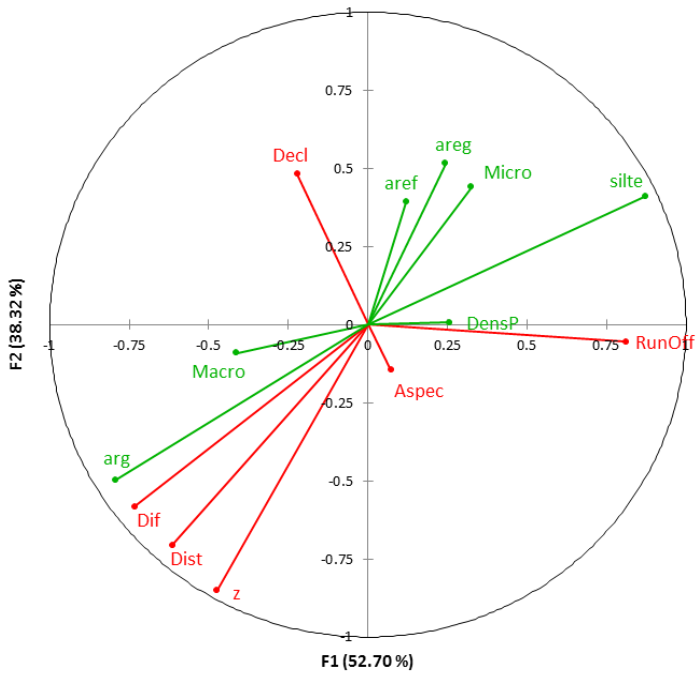

Figure 3. *Canonical correlation among parameters particle size, topography, altitude difference and distance from the water body, for the soil depth up to 30 cm (average levels)*

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In the canonical correlation among particle size, relief and hydrographic parameters in *Fig. 3*, it is observed that the difference in altitude and the distance from the water body are positively correlated, and validate the negative correlation with runoff. It was found that, with increasing distance from the stream, the clay content and the amount of macro-pores increase, hence silt, sand and micro-pore content reduce.

Thus, a negative correlation between micro-pores and clay occurred. We expected the opposite effect, increasing the amount of micro-pores and reducing macro-pores with stream clearance and increase in clay content, since the function of the macro-pores is to facilitate aeration and water infiltration into the soil, and the function of micro-pores is retaining water. The aspect and slope were not associated with the soil particle size.

In the relationship of species of higher IV to physical parameters by principal components (*Fig. 4*), related to altitude difference and distance from the water body, runoff, aspect, slope and dendrometric parameters (height and sectional area), we found two species. They showed greater preference for river proximity: *Alchornea glandulosa* (1) and *Gymnanthes klotzschiana* (39), with few individuals of species 39 away from the stream, showing tolerance to well-drained sites. In addition to these species, some *Ixora brevifolia* (21) and *Galipea jasminiflora* individuals (17) occurred in areas with increased runoff and nearby water, which shows tolerance of these species to poorly drained environments.

An uncontrolling source interfering in the distribution of species is seed dispersal, which may be adding a contribution to the aggregation of individuals, inherent in a larger-scale approach, it not being possible to isolate this effect. *Alchornea glandulosa* and *Ixora brevifolia* have zoochory mainly by avifauna (Pascotto, 2006; Prado Júnior et al., 2012), with less chance of this effect, but *Gymnanthes klotzschiana*, *Galipea jasminiflora* and *Metrodorea stipularis* have autochoric dispersion (Cosmo et al., 2010; Piedade, 1991), with a greater chance of aggregation in the plant community.

The size of the trees did not show a strong negative correlation with increasing steepness, and no significant negative correlation with the faces turned mainly to the north, but the direction of the vectors showed this trend. The tallest species and with more sectional area were *Ixora brevifolia* and *Metrodorea stipularis*.

A feature of the analyzed environment is its face, mainly on the southwest. The species with greater abundance also occurred on the southeast and south faces, but with greater overlap on the southwest face, indicating that they prefer less exposure to sunlight throughout the year.

The difference in altitude and distance from the water body indicated the species *Alchornea glandulosa* and *Sebastiania commersoniana* as having lower dispersion, being closer to the water body and at different altitudes. The species with greater occurrence and farther from the water body was *Metrodorea stipularis*.

Interestingly, *Alchornea glandulosa* had the lowest amount of runoff, indicating it does tolerat places with greater drainage and/or tendency to waterlog, contrary to information found in the literature. An assumption for this may be in the 12.5 x 12.5 m resolution of the digital elevation model, and the distance of trees to the quadrant point, selecting cells (pixels) with lower runoff adjacent to the cells containing the tree position in the ground.

In preference in relation to the slope, the species that occupied sites with greater steepness was *Achornea glandulosa*, and among the other species, there were no large variations as to slope preference.

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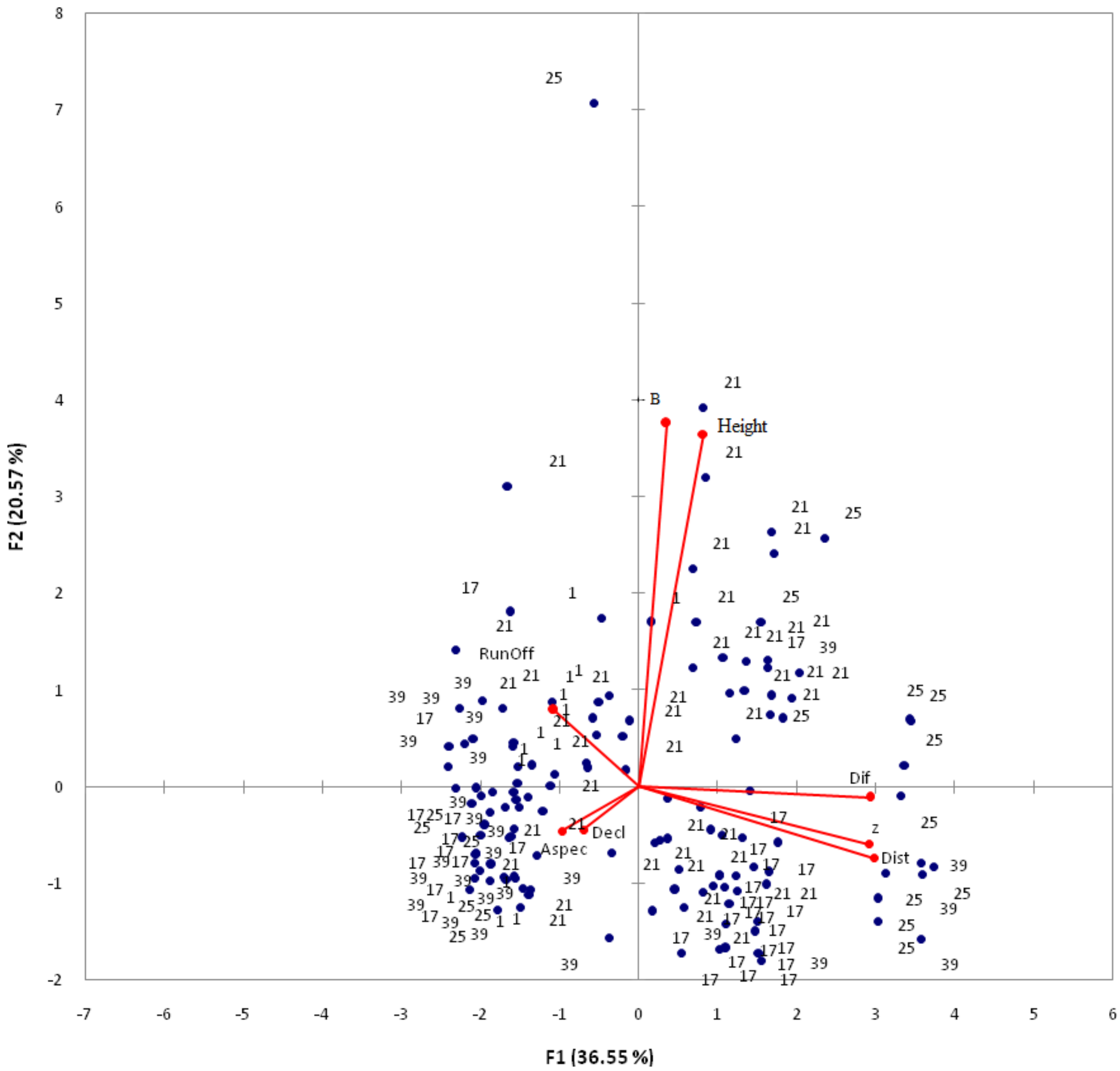

Figure 4. *Analysis of major components of physical parameters (distance and altitude difference of the water body, slope, aspect) and tree size (basal area and height) for the species with the highest importance value*

Continuing with we discuss relationships between particle size parameters associated to topography and water features and also identify relationships between fertility parameters and particle size parameters.

For *Alchornea glandulosa* and *Gymnanthes klotzschiana* species, which prefer the shortest distance from the stream and less difference in altitude, we can expect small differences in clay, silt and sand content, reducing the percentage of clay and increasing silt and sand. In these environments, particle densities and micro-porosity will be greater, following the trends in figure 3. Continuing the correlations, for fertility, Al contents are lower, and Ca, Mg, P, SB, V, Cu, Zn, Fe and Mn contents are higher, although all Fe and Mn levels in the samples are above the need of the plants.

In all samples, the micro and macro-porosity are high, but not enough to retain water by surface tension forces, and particle density indicates higher organic matter content.

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Acidity is low, the Ca content is high, the Mg content is moderate and the P content is low. Zn and Cu have high values and base saturation is high.

After the analysis, it follows that for degraded environments with similar topographical, hydrological and soil conditions, colonization would start by including these major species, all of them initial secondary, except *Alchornea*, which is pioneer. That is, all have requirements to start the ecological succession, theoretically heliophytic species in their early development. *Achornea* and *Gymnanthes* could be planted closer to the stream, *Galipea* and *Ixora* could mainly occupy the middle range, and *Metrodorea* would be planted farther from the stream, based on the analyses presented.

Conclusion

Ecological restoration processes and recovery of degraded areas go through issues such as indication of native species, which require well-founded forest inventories, within the floristic, phytosociology, ecophysiology, and even faunal relationships.

The results in this study demonstrate a relationship between biotic and abiotic factors of the area, and confirm the influence of the stream that flows through the fragment on the vegetation, determining species occurrence and distribution. To validate the indication of species to compose ecological restoration proposed in this work, an assay with long-term monitoring is necessary.

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ANNEXES

Table 1. *Physical parameters: altitude (z), distance from the stream (Dist), difference of altitude between the point and the stream (Dif), slope in degrees (Decl), sun exposure in azimuth (Aspec), runoff (runoff), for the soil sampling points, coordinates UTM Zone 23/WGS 84*

POINT	x (m)	y (m)	z (m)	dist (m)	dif (m)	decl (m)	aspec	*runoff*
1	575656	7849054	939	17	1	17	180	9
9	575725	7849113	950	43	9	17	135	1
19	575810	7849151	942	12	-2	6	135	2
28	575835	7849231	948	0	0	8	180	3266
39	575673	7849101	952	39	15	19	180	1
43	575696	7849135	962	74	24	8	180	1
47	575703	7849177	959	102	18	3	270	1
51	575690	7849205	964	120	19	11	180	1
56	575657	7849129	957	71	20	7	0	1
60	575683	7849168	958	112	15	8	135	436
65	575654	7849234	974	160	23	9	135	1
68	575639	7849275	978	185	20	12	180	1

Table 2. *Mean grain size among the three depths (0-10, 10-20, 20-30 cm): fine sand (sand), coarse sand (csand), clay, silt, particle density (DensP), macro-porosity, micro-porosity and total porosity (poreden)*

POINT	sand	csand	clay	silt	DensP	macrop	microp	poreden
	--------------------%----------------------				g/cm^3	----------%----------		
1	3	4	38	55	2,24	19,2	40,3	59,5
9	8	1	33	57	2,33	9,9	46,5	56,4
19	4	2	36	58	2,25	12,4	41,5	53,9
28	4	3	30	63	2,29	14,2	37,7	51,9
39	3	2	45	50	2,21	19,2	34,3	53,5
43	3	3	44	51	2,30	16,4	38,3	54,7
47	3	3	46	48	2,25	16,4	37,3	53,7
51	3	2	49	45	2,23	20,0	33,6	53,6
56	3	3	45	49	2,13	15,5	35,5	51,0
60	3	3	46	48	2,29	15,3	37,8	53,1
65	3	2	48	48	2,26	16,5	34,9	51,4
68	2	2	49	47	2,26	16,6	37,8	54,4

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Table 3. *Mean fertility values among the three layers (0-10, 10-20, 20-30 cm): phosphorus (P), potassium (K), aluminum (Al), calcium (Ca), magnesium (Mg), Cation Exchange Capacity (CEC), Hydrogen + Aluminium (H + Al) Sum of Bases (SB), Saturation by Aluminum (m), Bases Saturation (v), Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn), pH and organic matter (om)*

POINT	P	K	Al	Ca	Mg	CEC	H+Al	SB	m	v	Cu	Fe	Mn	Zn	pH_{H2O}	om
	-----mg/dm³-----		-------------------------cmolc/dm³--------------------------						------%------		----------------mg/dm³------------------					Dag/kg
1	2.78	58	1.95	2.20	0.44	9.98	12.3	2.78	31.45	18	0.84	89.70	20.72	0.84	6.7	4.01
9	3.81	50	0.30	5.89	0.77	10.71	3.9	6.79	5.60	62	3.42	870.50	74.64	2.45	5.7	3.86
19	7.48	63	3.17	1.29	0.25	10.22	8.5	1.70	65.27	17	3.21	386.00	21.47	1.69	5.0	2.74
28	2.92	51	3.29	1.27	0.41	8.36	6.5	1.81	65.44	21	1.63	124.37	59.06	0.65	4.7	3.05
39	2.02	60	5.67	0.85	0.22	10.67	9.4	1.23	81.89	12	1.32	95.79	27.60	0.73	4.6	3.73
43	1.74	97	3.30	1.85	0.49	8.73	6.1	2.59	62.20	28	1.23	80.90	51.52	0.63	5.4	3.50
47	1.74	104	3.92	3.46	0.63	12.03	7.7	4.35	48.62	36	1.19	88.39	61.29	1.23	5.2	4.23
51	2.07	73	5.48	2.70	0.51	13.96	10.6	3.40	64.87	22	1.27	177.53	46.17	1.50	4.8	5.23
56	2.06	80	3.74	1.55	0.50	9.81	7.6	2.26	65.91	23	1.05	82.44	32.00	0.21	5.6	3.80
60	2.50	97	5.06	1.12	0.25	14.91	13.3	1.62	76.65	10	1.15	108.86	49.37	0.55	5.4	4.19
65	2.26	97	4.77	1.79	0.29	10.98	8.7	2.33	67.22	22	0.70	126.63	25.14	0.59	5.5	3.62
68	2.68	85	4.03	2.54	0.52	12.21	8.9	3.29	55.13	27	1.40	154.96	38.09	1.20	5.4	3.86

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Table 4. *Pearson Correlation among the hydrographic parameter (distance from the stream, dist), topographic parameters (z, slope, aspect, runoff), soil parameters (sand, coarse sand (csand), clay, silt, pore density (poreden), macro and micro-pores, aluminum (Al), Ca, Mg, P, K, Cation Exchange Capacity (CEC), H + Al, sum of bases (SB), aluminum saturation (m), base saturation (V), micro-nutrients (Cu, Fe, Mn, Zn, pH), organic matter (om), in the first 10 cm of soil (n=12)*

Variables	dist	slope	aspec	runoff	sand	csand	clay	silt	poreden	macrop	microp	Al	Ca	Mg	P	K	CEC	H+Al	SB	m	V	Cu	Fe	Mn	Zn	pH	om
z	**0.95**	-0.21	0.04	-0.24	-0.34	-0.30	**0.74**	**-0.71**	0.46	0.10	-0.56	0.36	-0.02	-0.10	-0.55	0.41	-0.01	0.00	-0.02	0.10	0.04	-0.34	-0.30	0.05	-0.09	0.03	0.29
dist		-0.19	0.07	-0.39	-0.33	-0.20	**0.81**	**-0.81**	0.31	0.04	-0.45	0.41	0.03	-0.09	-0.44	0.52	0.19	0.17	0.03	0.10	-0.01	-0.35	-0.28	0.01	0.02	0.18	0.43
slope			0.03	-0.15	0.37	0.29	-0.23	0.11	-0.06	-0.37	**0.58**	-0.13	0.29	0.18	0.08	-0.52	0.33	0.12	0.27	-0.21	0.09	0.13	0.28	-0.06	0.45	0.22	0.27
aspec				0.10	-0.15	0.21	0.03	-0.01	0.11	0.15	0.11	0.02	0.19	0.09	-0.18	0.02	0.28	0.13	0.18	-0.10	0.02	-0.13	-0.13	0.43	0.34	-0.24	0.24
runoff					-0.10	0.04	-0.54	**0.66**	0.44	0.01	-0.06	-0.07	-0.25	-0.16	-0.06	-0.32	-0.08	0.12	-0.25	0.09	-0.23	0.01	-0.11	0.34	-0.26	-0.24	-0.45
sand						-0.42	**-0.60**	0.44	0.13	-0.48	0.55	**-0.70**	0.55	0.33	0.16	-0.50	0.00	-0.40	0.52	-0.55	0.52	**0.70**	**0.91**	0.35	0.56	0.29	-0.17
csand							0.03	-0.04	-0.48	0.30	0.31	0.00	0.18	0.41	-0.11	0.19	0.46	0.28	0.21	-0.20	0.04	-0.53	-0.55	-0.03	-0.05	0.27	0.49
clay								**-0.98**	-0.20	0.31	**-0.66**	**0.67**	-0.15	-0.15	-0.41	**0.67**	0.20	0.30	-0.13	0.32	-0.17	-0.57	**-0.58**	-0.20	-0.23	-0.14	**0.59**
silt									0.25	-0.25	0.54	-0.56	-0.03	0.01	0.44	**-0.64**	-0.29	-0.26	-0.04	-0.16	0.03	0.51	0.46	0.12	0.10	0.03	**-0.70**
poreden										-0.21	-0.02	-0.12	-0.08	-0.22	-0.13	-0.19	-0.25	-0.17	-0.11	-0.01	0.01	0.16	0.21	0.19	0.02	0.15	-0.40
macrop											-0.46	0.22	-0.15	0.08	-0.55	0.40	-0.30	-0.21	-0.11	0.07	0.11	**-0.80**	**-0.71**	-0.07	**-0.72**	-0.14	0.15
microp												**-0.63**	0.41	0.34	0.49	-0.42	0.20	-0.10	0.39	-0.46	0.25	0.46	0.57	0.02	**0.62**	**0.59**	-0.09
Al													**-0.71**	**-0.72**	-0.02	0.34	0.13	**0.68**	**-0.71**	**0.86**	**-0.80**	-0.49	**-0.60**	-0.42	-0.46	-0.46	0.18
Ca														**0.92**	-0.40	-0.10	0.38	-0.39	**1.00**	**-0.95**	**0.88**	0.13	0.36	**0.59**	**0.62**	0.46	0.50
Mg															-0.45	-0.01	0.25	-0.48	**0.94**	**-0.95**	**0.90**	-0.05	0.11	0.49	0.38	0.44	0.47
P																-0.27	-0.12	0.20	-0.41	0.37	-0.49	**0.61**	0.45	-0.51	0.24	0.04	-0.52
K																	0.27	0.31	-0.06	0.11	-0.05	-0.48	-0.54	0.05	-0.37	0.09	0.49
CEC																		**0.70**	0.38	-0.19	-0.04	-0.12	-0.06	0.42	0.42	0.18	**0.76**

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H+Al																			-0.40	0.55	**-0.73**	-0.20	-0.31	-0.04	-0.04	-0.18	0.35
SB																				**-0.95**	**0.89**	0.10	0.32	**0.59**	**0.59**	0.46	0.52
m																					**-0.94**	-0.15	-0.34	**-0.58**	-0.49	-0.52	-0.31
V																						0.08	0.29	0.49	0.32	0.42	0.27
Cu																							**0.90**	0.14	**0.62**	-0.03	-0.49
Fe																								0.20	**0.68**	0.21	-0.36
Mn																									0.34	-0.08	0.29
Zn																										0.26	0.18
pH																											0.15

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Table 5. *Pearson Correlation among the hydrographic parameter (distance from the stream, dist), topographic parameters (z, slope, aspect, runoff), soil parameters (sand, coarse sand (csand), clay, silt, pore density (poreden), macro and micro-pores, aluminum (Al), Ca, Mg, P, K, Cation Exchange Capacity (CEC), H + Al, sum of bases (SB), aluminum saturation (m), base saturation (V), micro-nutrients (Cu, Fe, Mn, Zn, pH), organic matter (om), in the first 20 cm of soil*

Variables	**dist**	**slope**	**aspec**	**runoff**	**sand**	**csand**	**clay**	**silt**	**poreden**	**macrop**	**microp**	**Al**	**Ca**	**Mg**	**P**	**K**	**CEC**	**H+Al**	**SB**	**m**	**V**	**Cu**	**Fe**	**Mn**	**Zn**	**pH**	**om**
z	**.95**	0.21	.04	0.24	0.29	0.33	**.75**	**0.76**	0.42	.34	0.23	.41	0.08	.05	0.43	**.61**	.03	.06	0.05	.17	0.07	0.45	0.26	0.07	0.26	0.08	.06
dist		0.19	.07	0.39	0.31	0.33	**.81**	**0.84**	0.30	.41	0.26	.43	0.04	.02	0.41	**.59**	.27	.25	0.02	.14	0.08	0.46	0.24	0.16	0.22	.02	.20
slope			.03	0.15	.38	0.28	0.17	.13	.10	.11	0.14	0.16	.23	.01	0.21	**0.59**	.16	.02	.19	0.19	.14	.04	.33	0.05	.20	0.02	.11
aspec				.10	0.11	.11	.03	0.01	.38	.24	0.13	.10	.11	0.02	0.15	.23	0.28	0.32	.10	0.03	.18	0.06	0.13	.16	.14	0.31	.15
runoff					.04	.52	0.57	**.60**	.06	0.32	0.02	0.04	0.19	0.09	0.01	0.37	0.44	0.26	0.19	.15	0.09	0.01	0.12	.30	0.15	0.36	0.35
sand						0.51	**0.60**	.49	.40	**0.74**	**.79**	**0.77**	**.85**	**.71**	.34	0.36	.05	0.49	**.83**	**0.86**	**.82**	**.75**	**.96**	**.73**	**.84**	.11	.24
csand							0.22	.26	.01	.09	0.37	.17	0.53	0.38	0.28	0.10	0.02	.32	0.52	.47	0.51	0.52	**0.65**	0.19	**0.65**	.22	0.34
clay								**0.99**	0.35	**.67**	0.55	**.69**	0.35	0.28	0.51	**.58**	.21	.40	0.33	.46	0.39	**0.58**	0.50	0.41	0.44	0.04	.31
silt									.29	**0.59**	.47	**0.62**	.24	.18	.55	**0.58**	0.27	0.38	.22	0.36	.30	.55	.41	.30	.37	0.03	0.40
poreden										0.29	.36	0.28	.26	.02	.26	0.16	0.09	0.22	.23	0.24	.25	.42	.41	.47	.43	0.03	.30
macrop											**0.84**	**.83**	**0.61**	**0.63**	0.37	.06	.16	.53	**0.61**	**.68**	**0.66**	**0.64**	**0.62**	**0.74**	0.46	0.33	.15
microp												**0.88**	**.77**	**.77**	**.60**	.04	0.14	**0.63**	**.78**	**0.85**	**.83**	**.82**	**.78**	**.70**	**.71**	.27	0.04
Al													**0.78**	**0.76**	0.46	.17	.06	.55	**0.78**	**.87**	**0.81**	**0.70**	**0.69**	**0.58**	0.57	0.42	.20
Ca														**.91**	.24	0.06	.19	0.47	**.00**	**0.98**	**.97**	**.64**	**.83**	**.66**	**.82**	.23	.33
Mg															.14	.05	.08	0.52	**.93**	**0.92**	**.92**	.51	**.65**	**.70**	**.62**	.27	.21
P																0.15	0.20	0.33	.23	0.36	.30	**.80**	.50	.03	.56	0.13	0.28
K																	0.11	0.09	0.02	.10	.01	0.23	0.32	.01	0.23	.26	0.07
CEC																		**.77**	.18	0.14	0.04	0.27	.10	0.28	.04	.54	.43
H+Al																			0.48	.51	**0.66**	**0.64**	0.43	**0.68**	0.48	.32	.18

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SB																			**0.98**	**.97**	**.62**	**.81**	**.67**	**.80**	.24	.32
m																				**0.97**	**0.70**	**0.84**	**0.65**	**0.81**	0.27	0.20
V																					**.70**	**.79**	**.73**	**.80**	.13	.21
Cu																						**.82**	.50	**.84**	0.16	.06
Fe																							**.60**	**.93**	.03	.30
Mn																								.55	.01	.29
Zn																									0.15	.40
pH																										0.14

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Table 6. *Pearson Correlation among the hydrographic parameter (distance from the stream, dist), topographic parameters (z, slope, aspect, runoff), soil parameters (sand, coarse sand (csand), clay, silt, pore density (poreden), macro and micro-pores, aluminum (Al), Ca, Mg, P, K, Cation Exchange Capacity (CEC), H + Al, sum of bases (SB), aluminum saturation (m), base saturation (V), micro-nutrients (Cu, Fe, Mn, Zn, pH), organic matter (om), in the first 30 cm of soil*

Variables	dist	slope	aspec	runoff	sand	csand	clay	silt	poreden	macrop	microp	Al	Ca	Mg	P	K	CEC	H+Al	SB	m	V	Cu	Fe	Mn	Zn	pH	om
z	**0.95**	-0.21	0.04	-0.24	-0.45	-0.43	**0.78**	**-0.76**	0.15	0.10	-0.21	0.30	0.16	0.34	-0.40	**0.81**	0.53	-0.09	0.39	0.05	-0.02	-0.44	-0.22	0.22	-0.15	-0.33	0.49
dist		-0.19	0.07	-0.39	-0.48	-0.44	**0.84**	**-0.83**	0.09	0.16	-0.20	0.31	0.26	0.40	-0.36	**0.83**	0.53	0.11	0.42	-0.02	0.02	-0.46	-0.20	0.14	-0.12	-0.15	**0.59**
slope			0.03	-0.15	0.38	-0.33	-0.11	0.08	0.20	0.51	-0.31	-0.02	0.27	0.05	-0.16	-0.55	-0.36	0.08	0.01	-0.32	0.37	0.15	0.38	-0.13	-0.02	0.33	0.14
aspec				0.10	-0.08	-0.26	0.08	-0.04	0.41	0.24	-0.11	0.21	0.25	0.47	-0.12	0.10	0.16	0.28	0.20	-0.10	0.08	-0.06	-0.13	0.19	0.24	-0.05	0.10
runoff					0.18	0.37	**-0.58**	**0.60**	0.01	-0.12	0.06	-0.14	-0.24	0.07	0.10	-0.28	-0.18	-0.30	-0.16	0.12	-0.08	0.04	-0.13	0.27	-0.20	-0.32	-0.19
sand						-0.43	**-0.63**	0.56	0.32	-0.37	**0.62**	**-0.77**	0.53	0.24	0.38	-0.57	-0.31	**-0.63**	0.46	**-0.75**	**0.77**	**0.76**	**0.87**	**0.62**	0.57	0.03	-0.22
csand							-0.32	0.36	-0.56	0.04	-0.30	0.20	**-0.69**	-0.41	0.14	-0.24	-0.36	0.29	**-0.73**	**0.63**	**-0.66**	-0.23	-0.56	**-0.64**	-0.46	0.20	-0.24
clay								**-0.99**	-0.21	0.46	-0.46	**0.66**	-0.09	0.08	**-0.60**	**0.78**	0.53	0.37	0.06	0.34	-0.32	**-0.67**	-0.45	-0.10	-0.30	-0.10	**0.65**
silt									0.23	-0.46	0.44	**-0.62**	0.05	-0.11	**0.60**	**-0.76**	-0.51	-0.32	-0.10	-0.29	0.26	**0.64**	0.39	0.05	0.28	0.09	**-0.68**
poreden										-0.36	0.37	-0.43	0.54	0.20	0.09	0.02	-0.09	-0.29	0.47	-0.55	0.55	0.32	0.44	0.37	0.37	0.02	-0.37
macrop											**-0.86**	**0.72**	-0.28	0.06	-0.56	-0.03	-0.05	**0.58**	-0.38	0.43	-0.38	-0.57	-0.45	-0.38	-0.47	0.20	**0.68**
microp												**-0.77**	0.43	0.12	0.52	-0.12	0.11	-0.48	0.48	-0.59	0.53	**0.70**	**0.64**	**0.61**	**0.62**	-0.12	-0.52
Al													**-0.61**	-0.31	**-0.60**	0.40	**0.64**	**0.79**	-0.57	**0.80**	**-0.78**	**-0.77**	**-0.82**	-0.56	**-0.62**	-0.44	0.34
Ca														**0.73**	0.41	-0.01	-0.04	-0.39	**1.00**	**-0.95**	**0.93**	0.55	**0.77**	0.53	**0.73**	0.43	0.16
Mg															0.12	0.15	0.07	-0.21	**0.78**	**-0.61**	**0.61**	0.17	0.32	0.58	0.40	0.26	0.50
P																-0.46	0.04	-0.24	0.38	-0.50	0.39	**0.84**	**0.58**	-0.02	**0.74**	-0.12	-0.43
K																	0.48	0.05	0.21	0.23	-0.21	**-0.61**	-0.44	0.17	-0.25	-0.22	0.39
CEC																		0.15	0.33	0.27	-0.37	-0.03	-0.12	0.18	0.26	**-0.73**	0.15

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H+Al																			-0.50	0.58	**-0.66**	-0.46	-0.57	**-0.66**	-0.35	0.35	0.18
SB																				**-0.93**	**0.91**	0.51	**0.70**	**0.64**	**0.73**	-0.24	0.18
m																					**-0.99**	**-0.72**	**-0.91**	**-0.61**	**-0.77**	-0.45	0.01
V																						**0.65**	**0.89**	**0.67**	**0.68**	0.44	0.04
Cu																							**0.87**	0.30	**0.86**	-0.12	-0.48
Fe																								0.48	**0.78**	0.04	-0.20
Mn																									0.39	-0.34	0.10
Zn																										-0.22	-0.22
pH																											0.08

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