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Viability of using topsoil ferruginous yoke in the restoration of a waste dump

Viabilidad del uso de la tierra vegetal ferruginosa yugo en la restauración de un vertedero de resíduos

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SUMMARY

The aim of this study was to evaluate the effect of the application of topsoil from a ferruginous rock field on natural regeneration and ground cover in a waste dump. To accomplish this aim, 26 plots of 1 m² and one control were installed systematically. Soil cover was estimated according to the percentage of live coverage, litter and bare soil observed in each plot. A total of 675 individuals, with 201 recorded in the first sampling and 474 in the second, were recorded. In total, 24 species and 11 families were identified, and a group of six was indeterminate, where four species were found in the first sampling and two species in the second sampling. Families with superior wealth in relation to the total were Asteraceae (26.92 %) and Melastomataceae (15.38 %); however, the families that had a higher number of individuals in the sample were Poaceae and Verbenaceae, with 33.33 % and 28.85 %, respectively. Those in the second sampling were Poaceae, Portulacaceae and Verbenaceae, with 93.03 %, 68.16 % and 35.82 %, respectively. Among the habits found, herbaceous was highlighted, with 65.63 % of the sampled individuals, followed by 6.22 % for shrubs, 5.48 % for subshrubs and 1.18 % for trees. The sterile substrate stack does not have to establish favorable conditions for vegetation because the control portion (not topsoil) filled in the two samples with 100 % bare soil.

Key words: ferruginous rock field, mining, surface layer.

RESUMEN

El objetivo de este estudio fue evaluar el efecto de la aplicación de la capa superior del suelo del campo de roca ferruginosa sobre la regeneración natural y la cobertura del suelo en un vertedero de residuos. Para ambos se instalaron sistemáticamente 26 parcelas de 1 m² y una de control. Para la cobertura del suelo se estimó el porcentaje de cobertura viva, hojarasca y suelo desnudo observado en cada parcela. Se registraron 675 individuos, con 201 en la primera toma de muestras y 474 en la segunda. En total, se identificaron 24 especies y 11 familias, y un grupo de seis especies indeterminadas, donde se encontraron cuatro especies en la primera toma de muestras y las otras dos en la segunda. Las familias con mayor riqueza en relación con el total fueron Asteraceae (26,92 %) y Melastomataceae (15,38 %), sin embargo, las familias con mayor número de individuos fueron Poaceae y Verbenaceae en la primera muestra, con el 33,33 % y 28,85 %, respectivamente, y el segundo muestreo Poaceae, Portulacaceae y Verbenaceae con 93,03 %, 68,16 % y 35,82 %, respectivamente. Entre los hábitos que se encontraron, se destacó herbácea con 65,63 % de los individuos muestreados, seguida de 6,22 % de arbustos, 5,48 % de subarbustos y 1,18 % de árboles. El estrato de sustrato estéril no creó condiciones favorables para la vegetación, ya que la parte de control (no tierra vegetal) presentó en las dos muestras 100 % de suelo desnudo.

Palabras clave: campo, roca ferruginosa, mineras, capa superficial.

INTRODUCTION

Alpine pastures constitute vegetation physiognomy occurring in large areas of the Espinhaço, in Minas Gerais and Bahia, Goiás in some regions and large reserves of iron ore in the state of Pará (Viana and Lombardi 2007). These pastures are generally located at altitudes over 900 meters, which are considered centers of endemism characterized by high plant diversity (Giulietti *et al*. 1997).

The Alpine pastures may be associated with different types of lithology but occur mainly in quartzite and banded iron formations. The ferruginous rocky fields, known as vegetation yoke, are distributed in restricted areas associated with important deposits of iron ore and are among the most threatened and less studied ecosystems (Jacobi *et al.* 2007). For this reason, the vegetation on ferruginous yoke has high biological importance, being considered a priority area for biodiversity conservation in their region of occurrence. In terms of classification, vegetation yoke has been named as Rock Field on Canga (Viana and Lombardi 2007), Fields Ferruginous (Vincent *et al*. 2002) or on vegetation cover up (Secco and Mesquita 1983); the many nomenclatures can be a hindrance to the knowledge of physiognomy, especially in terms of comparison.

Because the ferruginous fields do not have specific legislation for their conservation and utilization, they suffer from a paucity of programs for their rehabilitation, as soils of the iron formations are generally shallow and acidic and exhibit low fertility, low water holding capacity and a high concentration of oxidized iron (Souza and Carmo 2015).

In this regard, the use of topsoil can be viewed as a supplement or even a substitute for soil amendment practices because mined areas and piles of waste or barren land usually have severe chemical and physical limitations regarding plant establishment (Dias *et al.* 2007). And in this context, several questions arise at work: 1) Does the thin topsoil layer coming from ferruginous rocky fields provide good coverage of the substrate with a natural regeneration with high density and diversity of species? 2) Are there differences in density and diversity of species on the basis of samples taken in the dry and rainy seasons? 3) Will the sterile substrate stack establish the plants? Therefore, the aim of this study was to evaluate the natural regeneration and soil cover of a waste dump through the use of topsoil from a ferruginous rock field.

METHODS

Characterization of the area. The study area belongs to the mining company Anglo American Ferrous, which is situated in the municipality of Conceição do Mato Dentro (MG) located on the eastern edge of the southern Espinhaço. The climate is classified as humid subtropical in Köppen Cwa, with an average annual temperature of 20 °C and an average annual rainfall of 1,727.7 mm. Ferrasols, Cambisols, Lixisols and rock outcrops, occurring in relief, ranging from wavy to mountainous (SEBRAE 2000), predominate in the study area.

The experimental area under the central coordinates 18° 53’ 09.6” S and 43° 25’ 01.2” W has an average altitude of 701 meters, covers an area of 384 m² (0.0384 ha) and is located on a pile of barren ferruginous yoke, assembled by the company in August 2010. In December of the same year, individuals of *Vellozia squamata* Pohl. (canela-de-ema), originating from the redemption of the flora of adjacent areas for suppression, were planted on the cell.

The removed topsoil areas of ferruginous rocky fields where vegetation was also removed for the installation of the company was applied immediately to the experimental area in January 2011, forming a stack from storage of sterile material from the mining pit. This application was made to haul, being deposited into a layer whose thickness varied from approximately 0.5 to 1.0 cm.

In this study, 26 permanent plots of 1.0 m² were allocated systematically, three meters equidistant from each other, and a control plot of the same size in the adjacent area was included, where the application of topsoil was not performed.

Sampling and characterization of soil variables. To meet the physical and chemical characteristics of the waste dump substrates with and without application of topsoil (table 1), in the center of five instalments, single samples were collected at a depth of 0-10 cm and homogenized to form a composite sample that characterizes the area where the topsoil was applied, and five single samples in the area adjacent also compose a composite sample that featured the area where the topsoil was not applied. The samples were sent to the Laboratory of Soil Fertility, Federal University of the Jequitinhonha and Mucuri Valley, to perform the grain size analysis, using the protocol of EMBRAPA (2011) and chemistry according to Silva *et al.* (2008).

Table 1. Physical and chemical characterization of waste dump samples with and without topsoil in Conceição do Mato Dentro, MG.

Caracterización física y química de un vertedero de residuos con y sin depósito de tierra vegetal en Conceição do Mato Dentro, MG.

	Substrate	
Texture	Without topsoil	With topsoil
Sand (%)	47	49
Clay (%)	27	16
Silt (%)	26	35
Chemical attributes		
pH	5.2	5.5
P (mg dm^{-3})	1.95	1.91
K (mg dm^{-3})	5.06	5.82
Ca^{2+} ($cmol_C$ dm^{-3})	0.2	0.8
Mg^{2+} ($cmol_C$ dm^{-3})	0.1	0.4
Al^{3+} ($cmol_C$ dm^{-3})	0.10	0.64
H+Al ($cmol_C$ dm^{-3})	5.2	10.2
SB ($cmol_C$ dm^{-3})	0.31	1.35
t ($cmol_C$ dm^{-3})	0.41	1.99
T ($cmol_C$ dm^{-3})	5.51	11.55
V (%)	6.0	12.0
m (%)	24.0	32.0
MO (dag. kg^{-1})	1.1	3.7

pH (H_2O) ratio 1:2.5 (soil: water); P and K: Mehlich-1; Ca, Mg and Al,: KCl 1 mol L^{-1}; H + Al: calcium acetate 0.5 mol L^{-1} at pH 7.0; t: cation exchange capacity (CTC) effective; T: CTC pH 7.0; m: aluminum saturation; V: bases saturation.

Soil moisture and penetration resistance were measured in the center of each plot using a soil moisture meter (model HH2, Marconi brand) that provides values expressed in percentage (%) and a semi-automatic mechanical penetrometer (model Penetrographer SC-60, SoilControl) that provides values expressed in kilograms per square centimeter (kg cm^{-2}). The penetration resistance (RP) is a variable that indicates the degree of compression of an area along the soil profile, expressed in MPa (Oliveira *et al.* 2007). Regarding the maximum strength and the maximum resistance to 5 cm and 10 cm depth, to understand the degree of difficulty that the species would have to develop, three resistance values were established. The equipment was calibrated and corrected with the moisture data before use.

Analyses of the soil cover. To assess the soil cover, an estimate of the percentage of the total vegetation coverage provided by each of the 26 plots and portion control was established according to the method of Braun-Blanquet (1979). This coverage was classified into three categories: live coverage (portion of living vegetation), litter (portion of dead vegetation) and bare soil (portion devoid of living or dead vegetation). Two samples were taken during the year, one in July (early dry season) and another in November (beginning of the rainy season).

Floristics and phytosociology of regenerating community. To meet the temporal variation of species colonizing the waste dump ferruginous yoke, floristic and phytosociological surveys were conducted in two periods of the year (beginning of the dry and rainy seasons). For this, in all 26 plots, the counting of all living individuals present within the plots and species identified directly in the field was performed when possible, and when this was not possible to perform *in situ*, the same was performed with the aid of literature. In the plots that noted the presence of *Vellozia squamata*, which had been planted before mounting the experiment, there was the counting of the ballots to separately meet their influence on the development of others.

The species and families were classified according to the Angiosperm Phylogeny Group III (APG III 2009). The verification of the spelling and nomenclatural synonymies was performed from the information contained in the databases of sites Missouri Botanic Garden - Mobot and The International Plant Names Index (IPNI 2012). In addition, for a better description of the floristic changes observed in the area, the species were classified according to their origin, habit and dispersion syndrome.

To evaluate the composition of herbaceous vegetation structure, bushes and trees of the study area, all living individuals observed within the sampled plots were recorded. With these data, one can determine the frequency and density, absolute and relative, as well as the Shannon diversity index (H') (Mueller-Dombois and Ellenberg 1974, Magurran 2004) of the sample units.

To evaluate the changes in the floristic relationships between the sampling periods, rectified correspondence analysis (DCA) with a principal matrix of the presence and absence of the species was performed.

Relationships of the vegetation with the substrate. Aiming at analyzing the possible correlation between the assessed environmental variables and species sampled in the study area, a canonical correspondence analysis (CCA) was performed. For this, two arrays, one principal, the presence and the absence of the species, and a secondary, with environmental variables (land cover data, penetration resistance and number of individuals of *Vellozia squamata*), were prepared.

The data regarding the presence and absence of species in the plots and the two analyses (CCA and DCA) were logarithmic. All multivariate analyses were processed by the PC-ORD version 6.0 program (McCune and Mefford 2011).

RESULTS

Groundcover. According to the data coverage of the substrates collected in the two sampling periods (dry and rainy seasons), changes were observed in the mean values of living mulch, litter and bare soil (figure 1). For live coverage, up to 58 % of the litter and exposed soil exhibited a decrease of 12 %. These results are quite relevant, especially compared to the control plot in which there was no change during the study period for the remaining soil with exposure of 100 %.

Floristic composition and phytosociology. The results obtained in the floristic survey recorded a total of 675, with 201 individuals in the first sampling (dry season) and 474 in the second sampling (rainy season). A total of 24 species belonging to 11 families were identified, of which 23 were identified in the first sampling (dry season) and the second sampling (rainy season); in addition, a group of six indeterminate species was formed, with four species found in the first sampling and two species in the second. The families with the highest number of species were Asteraceae and Melastomataceae, with 26.92 % with 15.38 % of the sample, respectively.

The families with the largest number of individuals, *i.e.*, higher density, were Poaceae and Verbenaceae in the dry season, with 33.33 % and 28.85 %, respectively, and in the rainy season, Poaceae, Verbenaceae and Portulacaceae, with 93.03 %, 68.16 % and 35.82 %, respectively.

Some species occurred only during one sampling period, such as *Conoclinium macrocephalum* (Less.) DC., and *Sida rhombifolia* L., which were recorded only from the first sampling, while *Cyperus* sp., *Sida* sp. and morphospecies accounted for just 4:05 in the second (table 2).

This change in species richness between samples demonstrates that the variation in floristic composition in cave communities can be observed both over the years and in the same year (Munhoz and Felfili 2008). These changes are probably due to the specific characteristics of the species, which may be influenced, among other factors, by climatic conditions.

When comparing the six species with the highest density in each sample, it was noticed that there was a reduction in the number of individuals of the species *Merremia cissoides*, and along with an increase, *Portulaca oleracea* had the highest increase in its density, which is three times that observed in the first sampling (three and 137 individuals in the dry and rainy seasons, respectively), which is a fairly representative jump (figure 2). This change was considered favorable to the conservation status of the area because the species has reduced the number of individuals that are exotic and increased those that are native (*Portulaca oleracea*).

The Shannon index was 2.43 (dry season) and 1.91 (rainy season), where the low value for the rainy season refers to the considerable increase in the number of individuals of *Melinis minutiflora* and *Portulaca oleracea*, which pos-

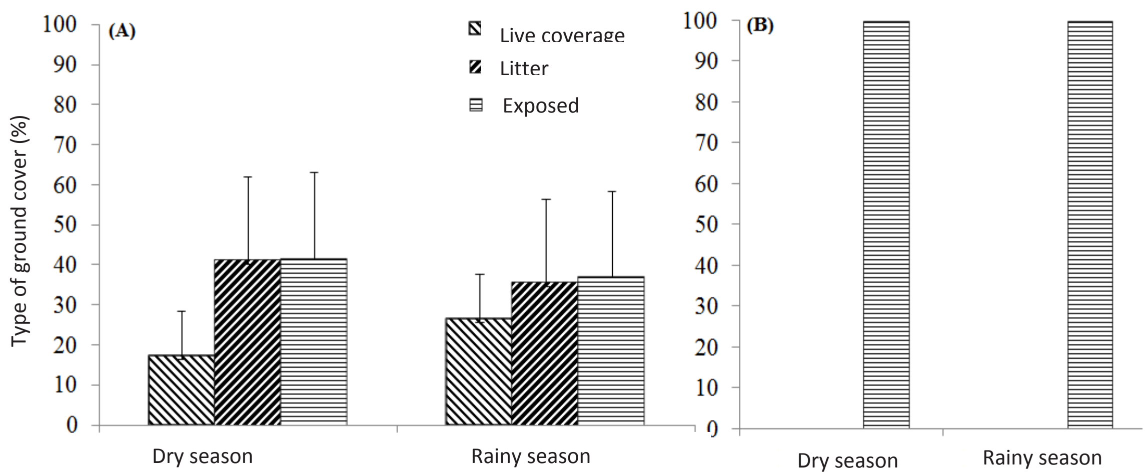

Figure 1. Average percentage of soil cover at the sterile yoke ferruginous experimental cell at the beginning of the dry season (July 2012) and the rainy season (November 2012) in the municipality of Conceição do Mato Dentro, MG, where A = area with topsoil and B = area without topsoil.

Porcentaje promedio de cobertura del suelo en la célula experimental ferruginosa yugo estéril al comienzo de la estación seca (julio de 2012) y la estación lluviosa (noviembre de 2012) en el municipio de Conceição do Mato Dentro, MG, donde A = área con tierra vegetal y B = área sin tierra vegetal.

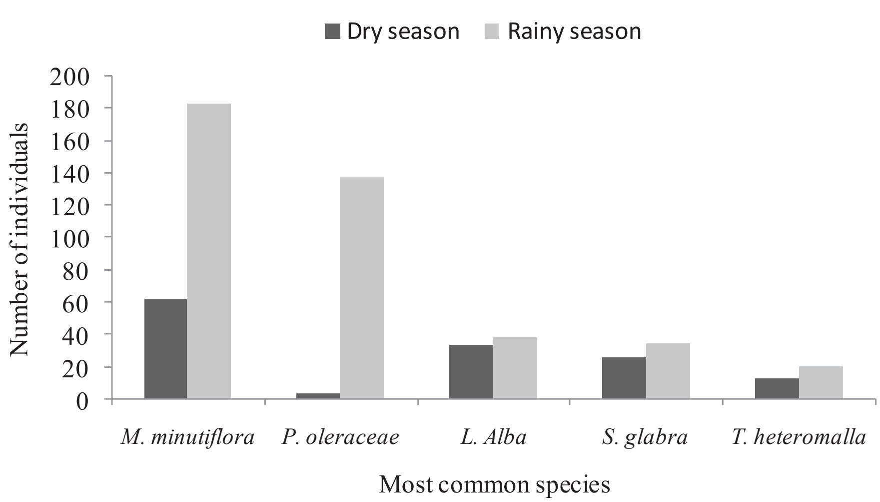

Figure 2. Comparison between the numbers of individuals of six species of highest frequency in the 26 established cell sterile ferruginous yoke plots in the municipality of Conceição do Mato Dentro, Minas Gerais.

Comparación entre el número de individuos de seis especies de mayor frecuencia en las parcelas 26 celulares establecidas yugo ferruginosas estériles en el municipio de Conceição do Mato Dentro, Minas Gerais.

Table 2. List of species in alphabetical order of the plant families sampled in both periods in the 26 plots installed in a waste dump in Conceição do Mato Dentro, Minas Gerais.

Lista de especies en orden alfabético de las familias de plantas muestreadas, en ambos períodos, en las 26 parcelas instaladas en un vertedero de residuos en Conceição do Mato Dentro, Minas Gerais.

Families	Species	Origin	Habit	Dispersion syndrome	Occurrence	
					Dry season	Wet season
Asteraceae	*Acantospermum australe* (Loefl.) Kuntze	N	H	Zoo	X	X
	Ageratum conyzoides L.	N	H	Ane	X	X
	Baccharis dracunculifolia DC.	N	S	Ane	X	X
	Conoclinium macrocephalum (Less.) DC.	N	SAr	Ane	X	-
	Eremanthus erythropappus (DC.) MacLeish	N	A	Ane	X	X
	Vernonia scorpioides (Lam.) Pers.	N	S	Ane	X	X
	Vernonia polysphaera Baker	N	S	Ane	X	X
Cecropiaceae	*Cecropia hololeuca* Miq.	N	A	Zoo	X	X
Ciperaceae	*Bulbostylis capillaris* (L.) C.B. Clarke	N	H	Aut	X	X
	Cyperus sp.	N	H	Aut	-	X
Convolvulaceae	*Ipomoea purpúrea* (L.) Roth	E	H	Aut	X	X
	Merremia cissoides (Lam.) Halier f.	E	H	Aut	X	X
Euphorbiaceae	*Croton urucuana* Baill.	N	A	Aut	X	X
Fabaceae	*Macroptilium lathyroides* (L.) Urb.	N	H	Aut	X	X
	Senna reniformis (G. Don) H.S.	N	S	Aut	X	X
Malvaceae	*Sida rhombifolia* L.	E	SAr	Aut	X	-
	Sida sp.	E	SAr	Aut	-	X
Melastomataceae	*Miconia* sp1	N	S	Zoo	X	X
	Miconia sp2	N	S	Zoo	X	X
	Tibouchina candolleana (DC.) Cogn.	N	A	Ane	X	X
	Tibouchina heteromalla (D.Don) Cogn.	N	S	Ane	X	X
Poaceae	*Chloris radiata* L.	E	H	Aut	X	X
	Melinis minutiflora P. Beauv.	E	H	Aut	X	X
Portulacaceae	*Portulaca oleraceae* L.	N	H	Aut	X	X
Verbenaceae	*Lippia alba* (Mill.) N.E. Br.	N	H	Zoo	X	X
	Stachytarpheta glabra Cham.	N	SAr	Aut	X	X
Indeterminada	Morphospecie 1	_	_	_	X	X
	Morphospecie 2	_	_	_	X	X
	Morphospecie 3	_	_	_	X	X
	Morphospecie 4	_	_	_	-	X
	Morphospecie 5	_	_	_	-	X
	Morphospecie 6	_	_	_	X	X

N = native, E = exotic, H = herbaceous, S = shrub, Sar = Sub-shrub, Zoo = zoochorous, Ane = anemocoric, Aut = autochoric.

sibly generated ecological dominance in the area and consequently lower floristic diversity (table 3).

Among the habitats found, herbaceous is highlighted, with 65.63 % of the sampled individuals, followed by 6.22 % shrubs, 5.48 % subshrubs and 1.18 % trees.

Although the number of native herbaceous species decreased in the second sample, the occupation of the native herbaceous species has not been lost because the number of alien species remained the same in the two samples (table 4).

Table 3. Parameters for the phytosociological species found, in alphabetical order, of the 26 plots installed in a waste dump in Conceição do Mato Dentro, Minas Gerais.

Parámetros para la especie fitosociológicas encuentran, en orden alfabético, de las 26 parcelas instaladas en un vertedero de residuos en Conceição do Mato Dentro, Minas Gerais.

Species	AF (%)		RF (%)		AD (%)		RD (%)	
	DS	RS	DS	RS	DS	RS	DS	RS
Acantospermum australe	3.85	3.85	0.93	0.69	0.003	0.003	0.50	0.21
Ageratum conyzoides	3.85	3.85	0.93	0.69	0.003	0.005	0.50	0.42
Baccharis dracunculifolia	3.85	3.85	0.93	0.69	0.005	0.003	0.99	0.21
Conoclinium macrocephalum	3.85	0.00	0.93	0.00	0.003	0.000	0.50	0.00
Eremanthus erythropappus	3.85	3.8 5	0.93	0.69	0.003	0.003	0.50	0.21
Vernonia scorpioide	7.69	7.69	1.85	1.38	0.005	0.005	0.99	0.42
Vernonia polysphaera	15.38	15.38	3.70	2.76	0.013	0.013	2.48	1.05
Bulbostylis capillaris	11.54	23.08	2.78	4.14	0.008	0.016	1.49	1.27
Cyperus sp.	0.00	3.85	0.00	0.69	0.000	0.003	0.00	0.21
Ipomoea purpúrea	7.69	3.85	1.85	0.69	0.008	0.003	1.49	0.21
Merremia cissoides	15.38	11.54	3.70	2.07	0.039	0.008	7.43	0.63
Croton urucuana	7.69	7.69	1.85	1.38	0.005	0.008	0.99	0.63
Macroptilium lathyroides	7.69	7.69	1.85	1.38	0.016	0.016	2.97	1.27
Senna reniformis	19.23	23.08	4.63	4.14	0.016	0.018	2.97	1.48
Sida sp.	0.00	3.85	0.00	0.69	0.000	0.003	0.00	0.21
Sida rhombifolia	3.85	0.00	0.93	0.00	0.003	0.000	0.50	0.00
Miconia sp1	7.69	7.69	1.85	1.38	0.005	0.005	0.99	0.42
Miconia sp2	3.85	11.54	0.93	2.07	0.003	0.010	0.50	0.84
Tibouchina candolleana	3.85	7.69	0.93	1.38	0.005	0.008	0.99	0.63
Tibouchina heteromalla	42.31	50.00	10.19	8.97	0.031	0.052	5.94	4.22
Chloris radiata	19.23	19.23	4.63	3.45	0.016	0.013	2.97	1.05
Melinis minutiflora	65.38	100.00	15.74	17.93	0.159	0.474	30.20	38.40
Portulaca oleraceae	11.54	80.77	2.78	14.48	0.008	0.357	1.49	28.90
Cecropia hololeuca	3.85	3.85	0.93	0.69	0.003	0.003	0.50	0.21
Lippia alba	65.38	65.38	15.74	11.72	0.086	0.099	16.34	8.02
Stachytarpheta glabra	57.69	65.38	13.89	11.72	0.065	0.089	12.38	7.17
Morphospecie 1	3.85	7.69	0.93	1.38	0.003	0.005	0.50	0.42
Morphospecie 2	3.85	3.85	0.93	0.69	0.005	0.005	0.99	0.42
Morphospecie 3	3.85	3.85	0.93	0.69	0.005	0.005	0.99	0.42
Morphospecie 4	0.00	3.85	0.00	0.69	0.000	0.003	0.00	0.21
Morphospecie 5	0.00	3.85	0.00	0.69	0.000	0.003	0.00	0.21
Morphospecie 6	3.85	0.00	0.93	0.00	0.003	0.000	0.50	0.00
Shannon index		Dry season=	2.43	Rainy season=		1.91		

AF = absolute frequency, RF = frequency relative, AD = absolute density, RD = relative density, D S= dry season, RS =rainy season.

Correlations between species and environmental variables. In the canonical correspondence analysis (CCA), the correlations between the species and environmental variables were significant by the permutation Monte Carlo ($P >$ 0.001) test. However, the eigenvalues for the first two axes and the proportion of the explained variance were low. Furthermore, note that only the maximum strength and the number of individuals of the performed correlated analysis were found for the first ordination axis (figure 3A).

Thus, no significant correlations were found for the other environmental variables and the second axis. These data demonstrate that it was not possible to observe the formation of very different groups of parcels along the sample, *i.e.*, the ordering could not clearly separate groups of species correlated with environmental variables, showing that there was no strong influence of the environmental variables observed for the sample units studied with a distinction between the dry and rainy season.

The same pattern was observed for the rectified correspondence analysis (DCA) in which the eigenvalues were low in the two axes of ordination and a clear separation of floristic groups correlated with sampling times (figure 3B) is not possible. Here, as observed in the CCA, it is possible to infer that time was not considered capable of capturing the floristic variables composition.

Table 4. Number of species identified in each sample according to its origin and habitat in a waste dump in the municipality of Conceição do Mato Dentro, Minas Gerais. Nat = Native; Exo = Exotic; Arb = Arboreal; Ar = Shrub; SAr = Sub-shrub; Herb = Herbaceous.

Número de especies identificadas en cada muestra de acuerdo con su origen y su hábitat en un vertedero de residuos en el municipio de Conceição do Mato Dentro, Minas Gerais. Nat = nativo; Exo = exótica; Arb = arbóreo; Ar = arbusto; RAE = Sub-arbusto; H= Hierba.

Season	Origin		Habit			
	Nat	Exo	Arboreal	Ar	SAr	Herb
Dry season	19	5	4	7	4	9
Rainy season	19	5	4	7	3	10

DISCUSSION AND CONCLUSIONS

The data coverage of the substrates shows that topsoil played a key role in the protection and coverage of the substrate. This increase in the amount of live coverage provides great stability to the substrates and the countryside, an improved structure, increases soil organic matter and allows for the acceleration of the successional process (Corrêa 2004).

Regarding the decrease in the percentage of litter, it is possible that this is related to the renewal of the aerial parts of the species, which is favored by the wet season; such a relationship is widely observed in phenological studies. This relationship occurs because during this season's highest water supply, new leaves performing photosynthesis actively produce and accumulate food reserves to meet

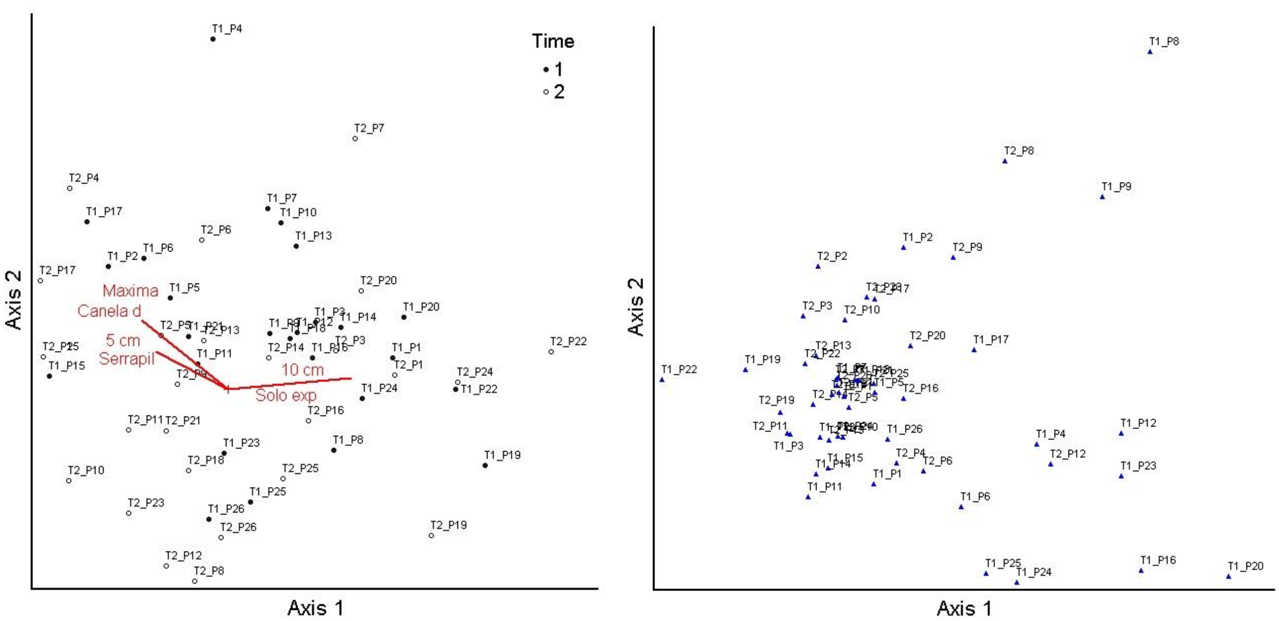

Figure 3. Diagram of ordering in the first two axes of the canonical correspondence analysis (CCA) with the floristic and environmental (A) data and detrended correspondence analysis (DCA) (B). T1 and T2 are data for the dry season and the rainy season, respectively.

Diagrama de ordenación en los dos primeros ejes del análisis de correspondencia canónica (CCA) con los datos ambientales (A) y florística y análisis de correspondencia sin tendencia (DCA) (B). T1 y T2 son los datos de la estación seca y la estación lluviosa, respectivamente.

the stress in the dry season (Souto 2006). At this time, the litter, which in the dry season protects the substrate from high temperatures, now with the rains provides nutrients to plants through decomposition.

Other floristic areas of the ferruginous rock field survey also highlighted the richness of the Asteraceae family; this abundance is related to the wide variation of habitat, going from herbaceous to woody, and sometimes to bindweed. In this study, species with an herbaceous habitat, *Ageratum conyzoides*, shrub as *Baccharis dracunculifolia* and tree *Eremanthus erythropappus* were registered (Ataíde *et al.* 2011).

The families reported here as the most important (Poaceae, Verbenaceae, Portulacaceae) were also found in other studies in rocky fields in Brazil but with a different order (Viana and Lombardi 2007).

The large number of individuals of the Poaceae family may be related to the high presence of the specie *Melinis minutiflora* in the area, which is considered to be an invasive species of initial colonization (Matos *et al.* 2009). The presence of this species may be related to its use in the revegetation of slopes in the adjacent cell in the study areas. *Melinis minutiflora* has small and light seeds that facilitate their dispersion and may be dormant for a long period, and even then, they exhibit a high potential for germination (Martins *et al*. 2011). In addition, the high aggressiveness of *Melinis minutiflora* makes the establishment of native grasses difficult (Martins *et al*. 2001), which probably required the adoption of control measures to achieve the success of the recovery in the waste dump in the study.

This pattern of initial colonization by herbaceous, ruderal and invasive sub-shrubs can be attributed to the wide geographical distribution of this group of plants, resulting in a broad ecological tolerance of these species to limited environmental factors, such as those found in areas in the degradation process. However, this colonization is important for the recovery of areas because these plants start to contribute to nutrient cycling, providing ecological conditions that are most favorable to the establishment of other shrubs and trees through a successional model of facilitation (Bruno 2000).

Based on the results indicating the absence of significant correlations, we can infer that the evaluation time considered here was too short for such environmental variables to be able to influence the floristic composition of the area; as a result, a wider range of assessment correlations between species and environmental factors can be observed most clearly and could thus separate groups of species according to the environmental conditions.

The substrate of the waste dump does not provide favorable conditions for the establishment of vegetation.

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