Floristic variations in a woody plant community along a trail in a Semideciduous Seasonal Forest, Viçosa, Minas Gerais State, Brazil[1]

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ABSTRACT - (Floristic variations in a woody plant community along a trail in a Semideciduous Seasonal Forest, Viçosa, Minas Gerais State, Brazil). The opening and use of a trail can modify abiotic factors along its route and in the closer surroundings. These changes can be verified by floristic changes of vegetation. This study evaluated a possible influence of a trail on the woody vegetation (DBH ≥ 2.5 cm, except lianas) in a Semideciduous Seasonal Forest in Viçosa, Minas Gerais State, Brazil (20º45'S and 42º51'W). Ten plots were sampled in an area near a trail and 10 other plots in the forest interior, totaling 718 individuals. Cluster (WPGMA) and ordination (DCA) analysis suggest that it may be a certain degree of influence of the trail on vegetation, although some results were intriguing. Further studies may be added to this in order to establish, in the future, environmental policies that take this source of interference with native ecosystems into account.
Key words: Brazilian vegetation, edge effect, Semideciduous Atlantic Forest

RESUMO - (Variações na composição florística em uma comunidade de plantas lenhosas adjacente a uma trilha de Floresta Estacional Semidecidual, Viçosa, Minas Gerais, Brasil). A abertura e utilização de trilhas podem modificar fatores abióticos em seu local de ocorrência e proximidades. Essas mudanças podem ser verificadas por meio das alterações florísticas da vegetação. Este estudo avalia possíveis influências de uma trilha sobre a vegetação lenhosa (DAP ≥ 2,5 cm, exceto lianas) em uma Floresta Estacional Semidecidual de Viçosa, Minas Gerais, Brasil (20º45'S e 42º51'W). Foram amostradas 10 parcelas em área próxima à trilha e outras 10 no interior do fragmento, totalizando 718 plantas. As análises de agrupamento (WPGMA) e ordenação (DCA) sugerem que pode haver influência da trilha sobre a vegetação, embora alguns resultados sejam intrigantes. Novos estudos poderão se somar a este no intuito de futuramente se estabelecer políticas ambientais que considerem essa fonte de perturbação sobre os ecossistemas nativos.
Palavras-chave: efeito de borda, Floresta Semidecidual Atlântica, vegetação brasileira

Introduction

The use of trails to recreation within forests became a rather frequent practice in modern life, which can be explained by factors such as increased urban population, reduction in the number of working hours, development of means of transport and greater investment in leisure (Lima 1972). Today, it is commonly agreed that natural trails bring man in closer contact with nature and allow the improvement of Environmental Education (Oliveira *et al.* 1999).

However, Andrade (2003) stated that trails crossing a forest often pass through rather fragile environments or in need of protection. Researches has shown that the "trail effect" (as we will call this effect) determines a strong physical impact on soil and

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vegetation (Cole 1978, Roovers *et al.* 2004), possibly causing alterations, for example, in the seed germination (Comita & Goldsmith 2008), in the floristic diversity (Roovers *et al.* 2004) and in the structure of woody plant communities (Eisenlohr *et al.* 2009). Information regarding the susceptibility of the vegetation to changes caused by the construction and use of natural trails must therefore become available to the planners responsible for the routing and installation of new trails. With this knowledge, rational systems could be created and planned that would lessen the impact on the most susceptible plant communities without exceeding the load capacity of a trail (Takahashi 1998). Further studies in this sense are needed.

The response of an ecosystem to recreation related impact is primarily determined by the ecological characteristics of the biophysical system (Graham & Hopkins 1993). As trampling in tropical rainforest occurs in the understory, the biophysical characteristics of this lower stratum strongly dictate resistance to impact. Kuss (1986) suggests that, in general, the moist, friable soils, year round vegetative activity and broad, thin plant leaves of the rainforest understory typify a fragile or low resistance environment. Therefore, in accordance with recreation ecology theory, trampling impacts in tropical rainforest should occur rapidly under low levels of use owing to the ecosystem's inherently low resistance to impact. Boucher *et al.* (1991), for instance, found recreation impacts in tropical rainforest.

Despite the importance of these investigations it is known that rainforest areas crossed by trails have not been extensively evaluated with respect to the possible impact these paths may have on the floristic composition. In view of the importance of this type of study as part of the efforts towards the maintenance of plant biodiversity and the recovery of native forest areas, the need of a vegetation analysis alongside trails of public use has become more evident. We think that the starting point of a correct planning and understanding of the vegetation dynamics and functioning in these areas is a diversified program of floristic and phytosociological studies.

The purpose of this study was to characterize the floristic patterns in an area crossed by a trail in the forest fragment Mata da Biologia, in the Botanical Garden of the Universidade Federal de Viçosa (UFV), Viçosa, Minas Gerais State, Brazil.

We sought answers to the following question: once horizontal structural differences were observed between areas more and less exposed to the same trail (Eisenlohr *et al.* 2009), will we also find variations in the floristic patterns? If this is the case, the floristic blocks found in areas near and areas farther away from the trail should be distinct. If we find a gradient of species replacement, unable to specify a precise boundary between the edge and the inner flora, we will not have indications that the floristic patterns are harshly altered, at least in the range investigated.

The hypothesis tested is that there would be floristic differences between the different levels of vicinity of the trail.

Material and methods

Study area - The Mata da Biologia, which is part of the Botanical Garden of the Universidade Federal de Viçosa (UFV) (20º45'S and 42º51'W, mean altitude of 650 m, approximately 75 ha), belongs to the phytoecological region of the Semideciduous Seasonal Forest (Veloso *et al.* 1991). The climate type is Cwa (Köppen), with water stress from May through September and excess rainfall between December and March (Golfari 1975).

The county of Viçosa is set in a lowland area between the Alto Rio Grande Plateau, in the Serra da Mantiqueira Mountain Range, and extensions of the Serra do Caparaó Mountain Range. The relief is predominantly mountainous and gneissic Precambrian rocks prevail in the rock foundation (Viçosa 2007). The predominant soil type is Red-Yellow Dystrophic Latosol, but Red-Yellow Argisol and Cambisol are found as well (Ferreira Júnior *et al.* 2007).

Among the trails of public use crossing the fragment is the Sauá trail, where our survey was carried out. This trail is 1.216 m long, on average 102.35 cm wide (± 29.85 cm); in the segment of 278 m sampled in this study (the most homogeneous stretch of this trail, at vegetation point of view), the mean width is 99.6 cm (± 27.54 cm). We classified the impact of this trail as moderate, due to the width and type of use (only pedestrians and eventually cyclists). According to inhabitants of Viçosa town and former employees of the UFV, this trail is at least 50 years old (according to some statements, the trail exists ever since this area, formerly a coffee plantation, was no longer used and incorporated into the *campus* of the UFV in the 1920s).

Choice of sampling area - The sampling area was selected to avoid an aggressive edge effect (*sensu* Laurance *et al.* 1997) along the outer side of the fragment. Whereas more than 50% of edge effects reported occur until at least 50 m inside forest fragments (Laurance *et al.* 2002), the distance from the sampling region to the fragment edge was about 415 m (figure 1). Plots were marked out in the central part of the trail.

The study area was divided into three sectors: Edge, Middle Distance and Control; the first two near the trail and the other farther away (figure 1). The soil of these sectors was characterized based on the soil map drawn by Ferreira Júnior *et al.* (2007), which show that the vegetation of these three sectors grows on Epieutrofic Cambisol.

Size and allocation of sample units - We would like to allocate at least 10 plots in each of these sectors. However, as the environmental heterogeneity in the region of the trail was strong, especially in the types of soils (Ferreira Júnior *et al.* 2007) and topography (personal observations), we decided to reduce the number of sampling units for five plots in the Middle Distance and Edge sectors (figure 1), covering the area more homogeneous as possible along the trail. Then we decided to reduce the level of cutting diameter of the smallest individual sampled ("inclusion criterion") - DBH (diameter at breast height) - of 5 cm, as originally planned, to 2.5 cm (except lianas), to increase the sampling effort (number of individuals sampled). This new "inclusion criterion" would also allow a broad-based vegetation analysis of the chosen area.

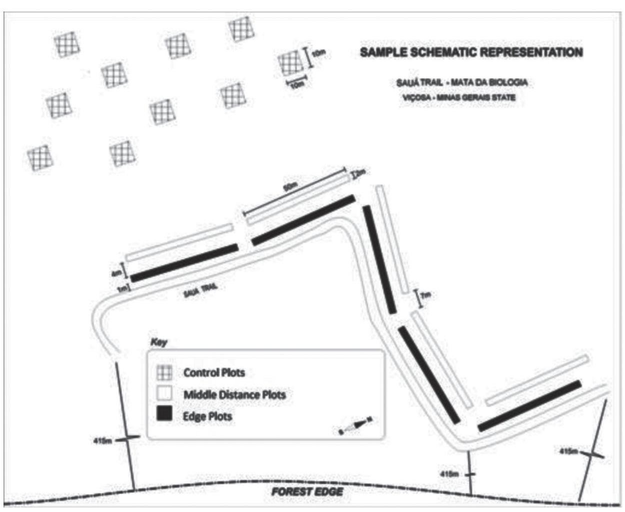

Figure 1. Sample schematic representation of a survey in the central region of the Sauá trail, in the Mata da Biologia, Viçosa, Minas Gerais State, Brazil.

Within the fragment, at approximately 50 m of the trail, the heterogeneity in soil and topography was less pronounced, so we decided to work with 10 plots (randomly distributed), then composing the Control sector (figure 1). Increased sampling in the Control sector would be an advantage in the sense of a more detailed analysis of the forest vegetation structure without direct trail influence.

Edge and Middle Distance sector were marked lengthwise (2×50 m, figure 1), to faithfully reproduce the woody vegetation structure along the trail. This seems to be the most adequate method for gradient studies (Causton 1988 *apud* Borém & Oliveira Filho 2002), since rectangular plots with the longer axis perpendicular to the analyzed gradient ensure greater internal homogeneity and tends to optimize the gradient effect (Felfili & Rezende 2003). These plots were marked at a distance of 7 m from each other. The plot size in Control sector was 10×10 m to ensure both homogeneity and sampling impartiality within a plot, focusing only on the environmental conditions of the forest. This difference between edge and inner plots was also exploited by Oliveira Filho *et al.* (2007).

Data measurement - The sampled individuals (DBH $\geq$ 2.5 cm, except lianas) were collected as described by Fidalgo & Bononi (1984) and identified at the family level according to APG II (2003), and at the species level based on analysis of specialists and comparison with material of known identity of Herbarium of Viçosa (VIC). This Herbarium stores the voucher specimens. Software Plantminer (Carvalho *et al.* 2010) was consulted for the detection of synonyms in the list of species and standardization of synonyms for the accepted taxonomic name. We standardized the spellings of the species according to MOBOT (2007).

Statistical analysis - An abundance matrix (number of individuals of each species in the plots, relativized by the total number of individuals in each plot) was constructed. An outlier analysis was performed with PC-ORD 4.0 (McCune & Mefford 1999) to identify very peculiar samples that go beyond the scope of the general survey pattern (Gauch 1982, McCune & Mefford 1999). The cutting point was determined at 2.0 and the Euclidian distance was used. One sample (from Control sector, named Contr10) detected as outlier were eliminated from the matrices used in the multivariate analyses (below).

To evaluate the floristic similarity in the plots of the four sampled sectors, we performed a dendrogram by the WPGMA method, indicated for comparison between groups with different number of samples, calculated as weighted averages (McCune & Grace 2002), using software FITOPAC 2.1 (Shepherd 2009). The Steinhaus index, highly recommended in the ecological literature (Legendre & Legendre 1998), was chosen. To give more reliability to the results, we applied the WPGMA using also the coefficient of Morisita (mod. Horn). The cophenetic correlation coefficient (Valentin 2000) was calculated to verify the degree of distortion between the original matrices (containing the Steinhaus/Morisita similarity between each pair of samples) and the calculated ones (containing the similarity shown in WPGMA dendrogram).

Although the cluster analyses are essential to evaluate floristic affinities, they will not let you see clearly possible gradients. To achieve this goal, ordination analysis is recommended (Kent & Coker 1992). Thus, an ordination analysis of DCA – *Detrended Correspondence Analysis* (Hill & Gauch 1980) was performed to rank the plots along representative axes of species composition, based on the abundance matrix, using software PC-ORD version 4.0 (McCune & Mefford 1999). DCA is a widely used technique in ecology and a powerful tool for vegetation analyses, mainly to gradient analysis (Gauch 1982, Kent & Coker 1992, McGarigal *et al.* 2000). The options of rescaling axes and downweighting rare species of the PC-ORD 4.0 were used. To check what level the replacement of species occurred along the gradient, we get the length of gradient (in units of standard deviations, SD) provided by the principal axes of the DCA. A complete replacement of species occurs when this value is 4 SD (Hill & Gauch 1980). We also verified the results of a preliminary matrix which eliminated species occurring in only one plot in order to remove noise and improve the explanation rate of the main axes for the total data variance. However, due to the substantial differences between the two datasets (complete matrix and matrix without rare species), we preferred to maintain the complete matrix in the final analysis.

To assist in the interpretation of the DCA axes, we performed Analysis of Variance (ANOVA) one-way (Zar 1999), in which the scores of the plots were the response variable and the distance of the trail, the categorical predictor variable. We tested the assumptions of normality of residuals and homoscedasticity by D'Agostino and Levene tests (Zar 1999), respectively. When the F test of ANOVA was significant at 5% significance, we performed a *post hoc* Tukey test (Zar 1999) to detect between which sectors would be the difference.

Results and Discussion

The survey of the three sampled sectors resulted in a floristic list composed of 108 species, including the category "Undetermined" (table 1), resulting in a sampling effort of 718 individuals.

The similarity dendrogram for the plots of the three sectors (figure 2) evidenced the formation of two large floristic groups. Five plots of the forest interior (Control sector) have formed a group (see the right side of figure 2). The other group, formed by the remaining plots, appears divided into groups that show mixing between plots of different sectors. On the one hand, the similarity analysis indicated that the trail may not be related to the floristic patterns of the study region, since no cohesive blocks were formed in the dendrogram. However, the isolation of five plots in the Control sector provides clues about a hypothetic separation of the two floras (the inner forest and the trail ones) that must be more investigate in further analysis (see DCA analysis, below). The similarity was generally low, which is confirmed by the fact that no group with over 40% similarity contained more than two plots. The cophenetic correlation coefficient was 0.78, indicating a good trustworthiness (i.e., 78% of floristic similarity was reproduced in the dendrogram). Using the Morisita (mod. Horn) coefficient in the WPGMA, the isolation of some plots of the Control sector remained and showed even more clearly evident (figure 3). Here, the cophenetic coefficient was higher than the former WPGMA (0.90).

The DCA ordination (figure 4) on axis 1 (eigenvalue = 0.4806, explaining 14.11% of the total variance) apparently represented (with exception of some plots of the Middle Distance sector) a polarization trail-forest interior; the plots of the inner (Control sectors) were predominantly on the left-hand of the diagram. Actually the ANOVA indicated a difference between the scores of these sectors ($F = 12.30$, d.f. = 2, $p = 0.001$), and Tukey's *post hoc* test showed that this difference was found between the Control and the other two sectors ($p_{\text{Control} \times \text{Edge}} = 0.002$, $p_{\text{Control} \times \text{Middle Distance}} = 0.003$). The length of gradient was 3.103, evidencing a significant substitution in the species that compose the different plots under study.

Table 1. Floristic list of the survey in the Mata da Biologia, Viçosa, Minas Gerais State, Brazil. E = Edge sector; M = Middle Distance sector; C = Control sector. Sample code given by P.V. Eisenlohr (PVE) or W.G. Ferreira Júnior (WGFJ). no col.: not collected.

Family/Species	E	M	C	Code
ANNONACEAE				
Annona cacans Warm.		X	X	PVE 182
Guatteria cf. *ferruginea*	X			PVE 375
Guatteria sellowiana Schltdl.	X			PVE 193
Guatteria sp.	X	X		PVE 446
Guatteria villosissima A. St.-Hil.	X			PVE 260
Rollinia laurifolia Schltdl.			X	WGFJ 665
Rollinia sericea (R.E. Fr.) R.E. Fr.			X	WGFJ 779
Rollinia sylvatica (A. St.-Hil.) Mart.			X	WGFJ 931
ARECACEAE				
Arecaceae sp.	X	X		PVE 57
Syagrus romanzoffiana (Cham.) Glassman		X	X	WGFJ 1.082
BURSERACEAE				
Protium warmingiana March.	X	X	X	PVE 302
CARDIOPTERIDACEAE				
Citronella megaphylla (Miers) R.A. Howard	X	X	X	PVE 316
Citronella paniculata (Mart.) R.A. Howard	X			PVE 226
CLUSIACEAE				
Rheedia gardneriana Planch. & Triana		X		PVE 176
EUPHORBIACEAE				
Alchornea glandulosa Poepp.	X	X		PVE 279
Sapium glandulosum (L.) Morong			X	WGFJ 937
FABACEAE				
Anadenanthera peregrina (L.) Speg.	X	X	X	PVE 331
Bauhinia forficata Link			X	WGFJ 1.007
Copaifera sp.	X	X		PVE 381
Dalbergia cf. *foliolosa*			X	WGFJ 1.029
Dalbergia nigra (Vell.) Allemão *ex* Benth.	X	X		PVE 415
Fabaceae 1	X			PVE 291
Fabaceae 2	X			PVE 461
Inga pilosula (Rich.) J.F. Macbr.			X	WGFJ 284
Machaerium stipitatum (DC.) Vogel		X		PVE 87
Peltophorum dubium (Spreng.) Taub.	X	X	X	PVE 64
Piptadenia gonoacantha (Mart.) J.F. Macbr.	X	X	X	PVE 332
Pithecellobium langsdorffii Benth.			X	WGFJ 74
Platypodium elegans Vogel	X		X	PVE 445
cf. *Pseudopiptadenia contorta* (DC.) G.P. Lewis & M.P. Lima	X			no col.
Senna macranthera (DC. *ex* Collad.) H.S. Irwin & Barneby			X	WGFJ 706
Senna multijuga (Rich.) H.S. Irwin & Barneby	X			PVE 231
LACISTEMATACEAE				
Lacistema pubescens Mart.		X		PVE 178
LAURACEAE				
Endlicheria paniculata (Spreng.) J.F. Macbr.	X	X	X	PVE 296
Nectandra lanceolata Nees	X	X	X	PVE 309
Nectandra reticulata (Ruiz & Pav.) Mez		X		PVE 07
Nectandra sp.1	X			PVE 194
Nectandra sp.2	X			PVE 204
Ocotea cf. *pubescens*		X		PVE 128
Ocotea cf. *pulchella*	X			PVE 289
Ocotea corymbosa (Meisn.) Mez		X		PVE 89
Ocotea dispersa (Nees) Mez	X	X	X	PVE 133
Ocotea divaricata (Nees) Mez	X			PVE 448
Ocotea sp.1	X			no col.
Ocotea sp.2			X	WGFJ 1.173
Ocotea teleiandra (Meisn.) Mez		X	X	PVE 481

continue

Table 1 (continuation)

Family/Species	E	M	C	Code
LECYTHIDACEAE				
Cariniana estrellensis (Raddi) Kuntze		X	X	WGFJ 775
MALVACEAE				
Ceiba speciosa (A. St.-Hil.) Ravenna			X	WGFJ 938
Luehea grandiflora Mart.	X	X	X	PVE 235
cf. *Pachira stenopetala* Casar.		X		PVE 109
Pseudobombax grandiflorum (Cav.) A. Robyns	X	X	X	PVE 82
MELASTOMATACEAE				
Miconia chamissois Naudin			X	WGFJ 1.025
MELIACEAE				
Cabralea canjerana (Vell.) Mart.	X	X	X	PVE 252
Cedrela fissilis Vell.	X		X	PVE 397
Guarea kunthiana A. Juss.			X	WGFJ 583
Guarea macrophylla Vahl			X	WGFJ 624
Trichilia elegans A. Juss.		X		PVE 489
Trichilia lepidota Mart.	X	X	X	PVE 135
Trichilia pallida Sw.	X	X	X	PVE 98
MONIMIACEAE				
Mollinedia schottiana (Spreng.) Perkins			X	WGFJ 793
MORACEAE				
Acanthinophyllum ilicifolia (Spreng.) W.C. Burger			X	WGFJ 809
Maclura splendens (Sw.) DC.			X	WGFJ 174
Sorocea bonplandii (Baill.) W.C. Burger, Lanj. & Wess. Bôer	X	X		PVE 326
MYRTACEAE				
Eugenia cf. *leptoclada* O. Berg	X	X		PVE 232
Eugenia cf. *stictosepala* Kiaersk.	X	X		PVE 388
Marlierea teuscheriana (O. Berg) D. Legrand			X	WGFJ 1.027
Myrcia fallax (Rich.) DC.	X		X	WGFJ 694
Myrciaria glomerata O. Berg		X	X	WGFJ 764
NYCTAGINACEAE				
Guapira opposita (Vell.) Reitz			X	WGFJ 765
PIPERACEAE				
Piper aduncum L.			X	WGFJ 714
PHYTOLACCACEAE				
Piper sp.1		X		PVE 158
Piper sp.2	X			PVE 259
ROSACEAE				
Prunus sellowii Koehne	X	X	X	PVE 187
RUBIACEAE				
Amaioua guianensis Aubl.		X	X	WGFJ 1.103
Amaioua sp.	X			PVE 456
Bathysa nicholsonii K. Schum.	X	X		PVE 334
Coffea arabica L.	X	X	X	PVE 389
Coutarea hexandra (Jacq.) K. Schum.	X	X	X	PVE 394
Guettarda viburnoides Cham. & Schltdl.	X	X	X	PVE 95
Psychotria carthagenensis Jacq.		X		PVE 86
Psychotria conjugens Müll. Arg.		X	X	PVE 137
Psychotria myriantha Müll. Arg.	X	X	X	PVE 141
Psychotria sp.			X	WGFJ 598
Randia sp.		X		PVE 88
Rubiaceae sp.		X		PVE 119
Rudgea sessilis (Vell.) Müll. Arg.			X	WGFJ 794
RUTACEAE				
Citrus sp.	X	X		no col.
Zanthoxylum rhoifolium Lam.	X	X		PVE 338

continue

Table 1 (continuation)

Family/Species	E	M	C	Code
SALICACEAE				
Casearia cf. *gossypiosperma*		X		no col.
Casearia decandra Jacq.	X		X	PVE 414
Casearia sylvestris Sw.		X		PVE 181
Xylosma prockia (Turcz.) Turcz.	X	X	X	PVE 120
SAPINDACEAE				
Allophylus edulis (A. St.-Hil., Cambess. & A. Juss.) Radlk.	X	X	X	PVE 311
Allophylus sericeus Radlk.			X	WGFJ 1.080
Cupania sp.			X	no col.
Cupania vernalis Cambess.			X	WGFJ 940
SAPOTACEAE				
Chrysophyllum flexuosum Mart.	X	X	X	PVE 313
Chrysophyllum sp.		X		no col.
SIMAROUBACEAE				
Picramnia regnelli Engl.			X	WGFJ 1.018
SIPARUNACEAE				
Siparuna cf. *brasiliensis*	X			PVE 257
Siparuna guianensis Aubl.	X	X	X	PVE 418
SOLANACEAE				
Brunfelsia uniflora (Pohl) D. Don			X	WGFJ 1.092
SYMPLOCACEAE				
Symplocos pubescens Klotzsch *ex* Benth.			X	WGFJ 508
ULMACEAE				
Celtis iguanaea (Jacq.) Sarg.			X	WGFJ 587
URTICACEAE				
Laportea aestuans (L.) Chew	X			PVE 253
UNDETERMINED				
Undetermined 1	X			PVE 307
Undetermined 2	X			no col.
Undetermined 3	X			no col.
Undetermined 4	X			no col.

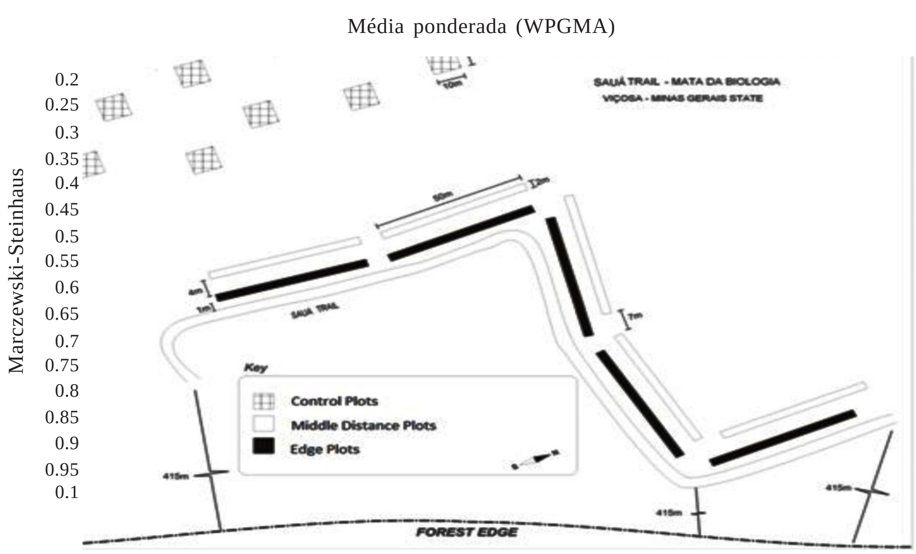

Figure 2. Dendrogram of floristic similarity (WPGMA), using the Steinhaus coefficient, based on the sampling of 20 plots in the Mata da Biologia, Viçosa, Minas Gerais State, Brazil. Edge: plots of the Edge sector; MDist: plots of the Middle Distance sector; Contr: plots of the Control sector.

According to Hill & Gauch (1980), a length of gradient upper than 1.0 indicates that more than 50% of species are changed along the gradient and a value of 4.0 indicates total changing.

The second DCA axis, which explained 8.79% of the total variance in the data (eigenvalue = 0.2993), indicates a mixture of the plots of the Control sector from the others (figure 4). Actually no significant variation among the scores of three groups was detected by ANOVA ($F = 0.239$, d.f. = 2, $p = 0.79$). The length of the gradient (2.658) reveals a high turnover of species, but as can be seen from the graph in figure 4 and the outcome of the ANOVA, it was not related to any trend gradient related to the distance of the trail.

If on the one hand the DCA data should be viewed with caution, given that the explanation of these two axes was low, on the other hand it supports part of the

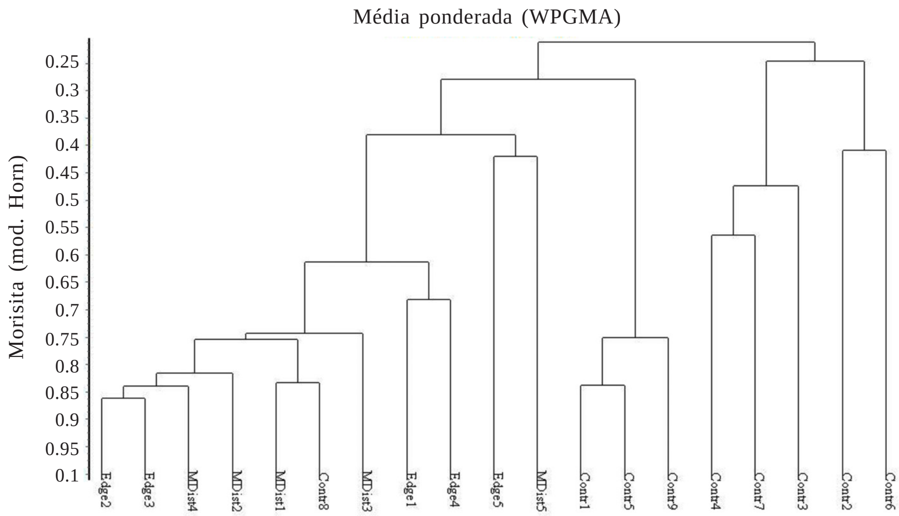

Figure 3. Dendrogram of floristic similarity (WPGMA) using Morisita (mod. Horn) coefficient, based on the sampling of 20 plots in the Mata da Biologia, Viçosa, Minas Gerais State, Brazil. Edge: plots of the Edge sector; MDist: plots of the Middle Distance sector; Contr: plots of the Control sector.

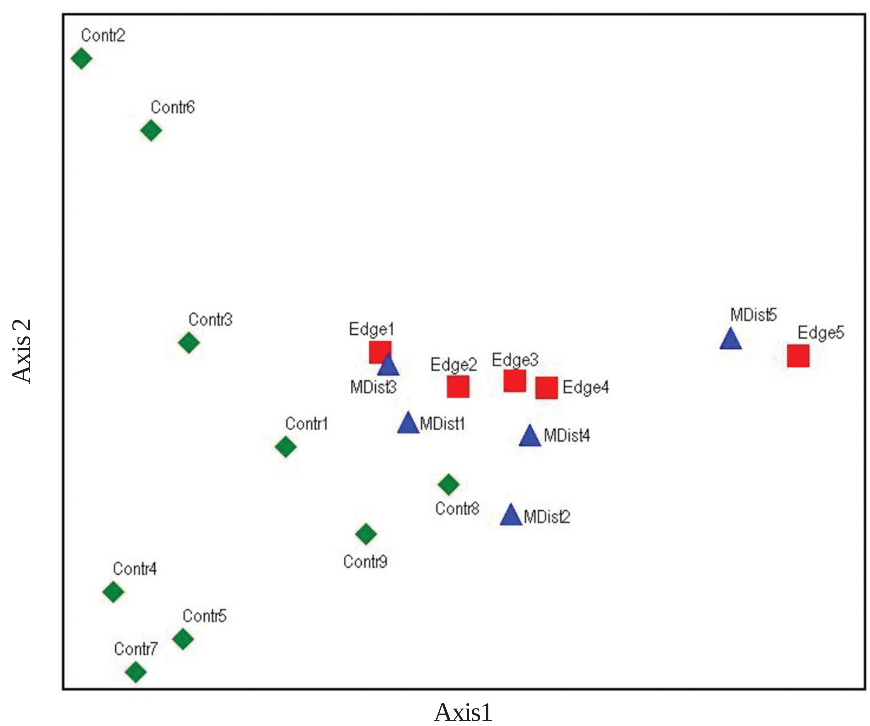

Figure 4. DCA ordination diagram of the 20 plots sampled in the Mata da Biologia, Viçosa, Minas Gerais State, Brazil.

WPGMA cluster analysis, since the first axes detected some floristic similarities possibly related to the interference level of the trail.

An essential aspect regarding to the study area is that the effect of variables such as relief and altitude (which were practically homogeneous in all plots) could be minimized and the variable soil reasonably controlled (since their class is the same). So although it is difficult to establish a causal relationship between the trail and the floristic changes, it is possible to suggest that the different trends described here reflect, at least to a considerable extent, the level of contact with the trail. In fact, the "trail effect" is a factor that could modify dynamics of plant and animal communities to a certain degree (Cole 1978), which naturally results in alterations in the species composition. But, why do we find sometimes a mixture of plots of different sectors? It is possible that some species would respond to the conditioning factors of the "trail effect" (luminosity, temperature, wind intensity, relative air humidity) in a certain way, while others would respond absolutely differently to the same factors. These different ways of biological response could help us to answer that question.

Moreover, one could assume that with the opening of this trail, at least 50 years ago, a few seedlings had been brought to the site, giving rise to a process of natural succession. We assume "a few seedlings" because, as mentioned before, the effect of opening a trail on the appearance of new species (part of "trail effect") was probably not as strong as that caused by a fragment border (the "edge effect"; see Murcia 1995) or large gaps (see, *e.g.*, Connell 1978). Over the course of time, the disturbances (falling trees forming gaps, and particularly, trampling on the trail influencing soil compaction *etc.*) could have been frequent and the succession may not have advanced satisfactorily, or, as suggested above, the species favored by the opening of the trail could have moved to nearby forest gaps, where there was no problem of compaction as typically found in trails. However, the situation in the case of a trail is a little different, since the people and animals that use it can transport seedlings to that region and, as a consequence, this area could have conditions to carry on with the natural succession. Nevertheless, it seems therefore that in the trail vicinity and in the forest interior the arrival of seedlings is similar (Eisenlohr *et al.* 2009). Some researches carried out in trails and its surroundings have indicated higher rates of germination in soils with higher contents of organic matter and nutrients (*e.g.*, Cole & Spildie 2007). Then, a more detailed evaluation of soil (fertility and granulometry) could provide a greater understanding of species distribution and environmental gradients. Moreover, a future research focused on the seeds and seedlings bank and soil compaction could provide a better view of the impacts generated by the trail in the vegetation community. In this context, obtaining data on light incidence in the sample areas would be important since the light is one of the most important physical factors in the seedlings development of tropical tree species. The revaluation over a larger temporal scale could also add more information to perform numerical analyses.

It is therefore suggested that the variables conditioned by the "trail effects" (luminosity, temperature, relative air humidity, for example), physical and chemical soil properties and a possible spatial structure should be considered in future studies in order to investigate a possible concurrence among these variables in the floristic patterns of areas crossed by trails.

As we could not distinguish differences between edge and middle sectors, but only among them and Control sector, we also suggest that a higher number of sectors should be sampled at different levels of trail contact, to raise the chances of clearly detecting the limits of the effects caused by the trail in the nearer and farther forest areas. Naturally, care must be taken that the successive sampling of sectors would not imply in the inclusion of variables that could hamper the understanding of the "trail effect". Moreover, we could ask: had there been other types of disturbance on this trail in the past? Had large forest gaps been formed? This type of questioning points to the need for a temporary monitoring of the trails and the contrasting of the resulting data with past and present floristic and diversity patterns, to establish, for one thing, some degree of predictability for the future.

Besides, the next step would be the measurement and inclusion of abiotic variables, as well as to investigate how the trails of other fragments, particularly those that attract most visitors, have modified the adjacent forest vegetation. In the future, a revision of studies conducted with this same objective could indicate environmental policies and adequate actions of management and recovery, considering natural trails as one of the elements that affect the structure and composition of our forests.

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