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SPECIES TURNOVER DRIVES GRASSHOPPER'S COMMUNITY
ACROSS DIFFERENT LANDSCAPES CONFIGURATION

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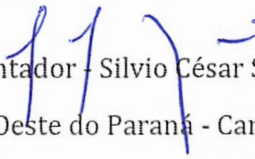
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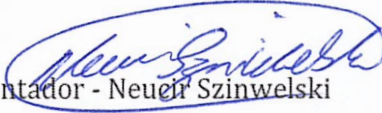
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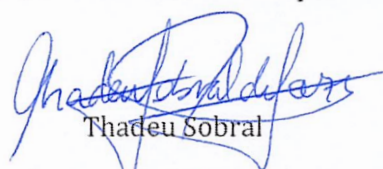
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SPECIES TURNOVER DRIVES GRASSHOPPER'S COMMUNITY ACROSS DIFFERENT
LANDSCAPES CONFIGURATION

Species turnover drives grasshopper's community across different landscapes configuration

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ABSTRACT

Landscape modification and subsequent habitat loss is cited as a main driver of biodiversity loss in terrestrial ecosystems and drives of changes in species composition in Atlantic forest, mainly for species turnover. Here, we aimed to test the effect of landscape modification on grasshoppers' species composition in Atlantic Forest, hypothesizing that changes on grasshopper species composition would be resulted of species turnover rather than species nestedness. To test the hypothesis, we sampled grasshopper communities in sites with different landscape configuration along the Iguaçu National Park and then restrict spatial and environmental factors in the community analysis to assess only the effect of landscape modification on grasshoppers' species composition. Our findings suggest that landscape modification affects grasshopper's communities by species turnover. Here, we identified that the gradient of anthropic-forest-urbanized landscapes was the main anthropic factor acting on species turnover, beyond the naturally expected spatial and environmental turnover. Also, our results show that anthropic and urbanized sites benefit different species. This may indicate that natural grasshopper's communities, and probably others groups, are in only 11% remaining of Atlantic forest, while others new and contrasting synanthropic communities are formed in with association with anthropic and urbanized areas. In the point-of-view of ecosystems functioning the alteration of grasshopper's communities may lead loss of process and species associated with this group, such as plants and vertebrates. Therefore, for conservation and management actions it is necessary to maintain natural communities to the maximum in order to avoid possible changes in the entire regional ecosystem.

KEY WORDS: β -diversity; Orthoptera; Land-use; Atlantic Forest; partial-dbrDA;

A SUBSTITUIÇÃO DE ESPÉCIES DIRECIONA AS COMUNIDADES DE GAFANHOTOS ATRÁVES DE DIFERENTES CONFIGURAÇÕES DA PAISAGEM

RESUMO

A modificação da paisagem e a subsequente perda de habitat é citada como o principal direcionador da perda de biodiversidade nos ecossistemas terrestres e de mudanças na composição das espécies na Mata Atlântica, principalmente pela substituição de espécies. Aqui, objetivamos testar o efeito da modificação da paisagem na composição de espécies de gafanhotos na Mata Atlântica, hipotetizando que as mudanças na composição das espécies de gafanhotos seriam resultado da substituição de espécies e não do aninhamento de espécies. Para testar a hipótese, amostramos comunidades de gafanhotos em locais com diferentes configurações de paisagem ao longo do Parque Nacional do Iguaçu e depois restringimos fatores espaciais e ambientais na análise da comunidade para avaliar apenas o efeito da modificação da paisagem sobre composição das espécies de gafanhotos. Nossos resultados sugerem que a modificação da paisagem afeta as comunidades de gafanhotos por meio da substituição de espécies. Aqui, identificamos que o gradiente das paisagens antrópico-florestais-urbanizadas foi o principal fator antrópico atuando na substituição de espécies, além da substituição espacial e ambiental naturalmente esperada. Além disso, nossos resultados mostram que os locais antropizados e urbanizados beneficiam diferentes espécies. Isto pode indicar que as comunidades de gafanhotos naturais, e provavelmente outros grupos, estão em apenas 11% restantes da Mata Atlântica, enquanto outras comunidades sinantrópicas novas e contrastantes são formadas em associação com áreas antrópicas e urbanizadas. No ponto de vista do funcionamento dos ecossistemas, a alteração das comunidades de gafanhotos pode levar à perda de processos e espécies associadas a este grupo, tais como plantas e vertebrados. Portanto, para ações de conservação e manejo é necessário manter ao máximo as comunidades naturais a fim de evitar possíveis mudanças em todo o ecossistema regional.

KEY WORDS: β -diversity; Orthoptera; Uso do solo; Mata Atlântica; dbRDA-parcial

INTRODUCTION

Over the past 500 years, humans' pressure has triggered an alarming biodiversity loss by extinctions, threats, and local population declines that is comparable with the five previous mass extinctions on Earth's history (Barnosky *et al.* 2011). Landscape modification and subsequent habitat loss is cited as a main driver of biodiversity loss in terrestrial ecosystems (Hansky 2005). In the tropics, the biodiversity threatening is most alarming, where only 12% of the world's dense tropical forest is significantly distant of anthropized area to ensure low biodiversity loss (Potapov *et al.* 2008). Neotropical forests, as Amazon and Atlantic Forest, are being deforested and main converted in agriculture and pasture areas (Moran *et al.* 1998, Ribeiro *et al.* 2009). Comparing to the pre-colonial period, the Atlantic Forest embrace only 11% of original vegetation, disposed in small and disconnected fragments (most less than 50ha), covering 150 million hectares (Ribeiro *et al.* 2009). Due to its biodiversity of endemic species and large anthropic impacts and treats, Atlantic Forest is listed as a world conservation 'hotspot' (Myers *et al.* 2000).

The effects of landscape modification on Atlantic Forest biodiversity has been well studied in the last two decades (Tonhasca *et al.* 2002, Olifiers *et al.* 2005, Bragagnolo *et al.* 2007, Metzger *et al.* 2009, Coster *et al.* 2015, Santos *et al.* 2019). For example, substantial changes in species composition and richness was reported for mammals (Vieira *et al.* 2009), birds (Morante-Filho *et al.* 2015), ants (Leal *et al.* 2012), bees (Ferreira *et al.* 2015), butterflies (Uehara-Prado *et al.* 2007) and multi-taxa approaches (Faria *et al.* 2007, Pardini *et al.* 2009). Usually, the landscape modification affects species composition indicating that these changes is driven by species replacement between sites (species turnover) and not by species loss between sites (species nestedness). This occurs due to local species extinction, but in broad spatial scale these species are remained due the species replacement between locals, generating a pattern of high dissimilarity between local communities, while species loss between locals is low because the number of species remain the same between locals (Beca *et al.* 2017).

Species turnover indicate the replacement of species as a natural consequence of environmental filtering (climate: Qian & Ricklefs 2012), dispersion (geographic distance: McDonald *et al.* 2005, Qian & Ricklefs 2012) and/or historical constraints (biogeographic events: Qian *et al.* 2005). The anthropic perturbations, as landscape modifications, are knowing as a driver that lead to species turnover (Quintero *et al.* 2010, Morante-Filho *et al.* 2016, Beca *et al.* 2017). Environmental filtering implies in species turnover due to it action on species fundamental niche or biotic interactions (Hutchinson 1957, Leibold *et al.* 2004), while dispersion lead to species turnover because act on neutral process, where nearest sites tend to present more similar communities than distant sites (Leibold *et al.* 2004). Anthropic perturbations, as landscape modification, act as an additional factor to species turnover, changing habitats, influencing the fundamental niche (changes resources and microclimate conditions: Chen *et al.* 1999, Latimer & Zuckenberg 2017), local biotic interaction (Ferreira *et al.* 2013) and spatial dispersion (Fahrig 2007, Cranmer *et al.* 2012). So, the understanding of landscape modification driving species composition and sites dissimilarity is a crucial role to biodiversity conservation and management.

Here, we aimed to test the effect of landscape modification on grasshoppers' species composition in Atlantic Forest, hypothesizing that changes on grasshopper species composition would be resulted of species turnover rather than species nestedness. To test the hypothesis, we sampled grasshopper communities in sites with different landscape configuration along the Iguaçu National Park and then restrict spatial and environmental factors in the community analysis to assess only the effect of landscape modification on grasshoppers' species composition.

MATERIALS AND METHODS

Study area

Our study was conducted at Iguaçu National Park, Brazil (25°32'52"S – 54°35'16"W). The region is situated in Atlantic Forest domain and classified into 'semideciduous rainforest' and 'mixed ombrophilous forest' (Morellato & Haddad 2000b). The climate is consider subtropical with annual mean temperatures between 18-20°C and annual mean precipitation of 1600mm, with dry and rainy seasons from April to June and October to January respectively (Peel *et al.* 2007).

Sampling

The grasshopper community was carried out in sites with different landscape configuration (Figure 1A). The sampling sites were chosen because they are situated in a gradient of natural forest to anthropogenic matrix, agricultural and urbanized influence (Figure 1B). The authorization for sampling was granted by the Instituto Chico Mendes de Conservação e Biodiversidade - ICMBio (SISBio 13543). The sampling of grasshopper communities was done in five 100m transects (point) with a minimum distance of 100m from each other, at each of the sampled sites (n = 5; Figure 1B). In all sampling sites we active collected, with entomological net by 10 minutes, all adult grasshoppers. The sites were sampled two times, in November 2017 and January 2018, on same environmental conditions and predetermined hours (13h at 15h). After collection the individuals were conditioned on freezing at -20°C. The individuals were identified at species level by taxonomist. Additionally, we measured the relative air humidity (%) and temperature (°C) of all sampling sites. We considered the humidity (*Hum*), temperature (*Temp*) and date of sampling (*Date*) as co-variables in the adjusted models.

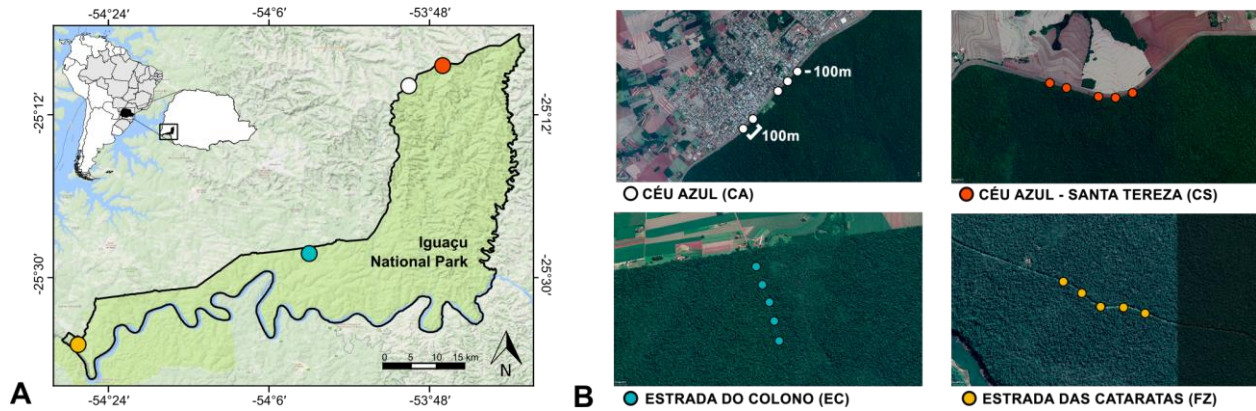


Figure 1. a) Geographical distribution of the four locals sampled along the Iguazu National Park region. b) Distribution of sites in each sampled local. *Céu Azul (CA)*: urbanized area localized in the municipality of Céu Azul, adjacent to Iguazu National Park. *Céu Azul-Santa Tereza (CS)*: agricultural matrix localized between municipalities of Céu Azul and Santa Tereza, also adjacent to the park. *Estrada do Colono (EC)*: the old road Estrada do Colono that crossed the park linking the Serranópolis do Iguazu and Capanema municipalities, that is composed by forest in regeneration since 2003, when the road was closed. *Estrada das Cataratas (FZ)*: border of BR-469, an active and paved road that takes to the Iguazu Falls, in the municipality of Foz do Iguazu.

Species composition, turnover and nestedness

The grasshopper's species composition was obtained considering all individuals and species sampled in each site, resulting in a matrix with abundance of each species. Whereas, species turnover and nestedness was calculated by 'Jaccard distance' with *betapart* package of software R (Baselga & Orme 2012) under a matrix of community of presence and absence of species. This distance method was selected due to its larger weight to rare species, more suitable for our community matrix because there were several "rare" species in our sampling. Additionally, we calculate the value of β -diversity (β_{jac}) and the partitioning β -diversity: turnover (β_{jtu}) and nestedness (β_{nes}).

Explanatory variables

i) Landscape configurations

The landscape configuration around sampled sites (150m radii circular sectors) from high-resolution categorical vectors (30m) was obtained via database of Fundação Brasileira para o Desenvolvimento Sustentável – FBDS (<https://www.fbds.org.br/>). This database classifies the landscape-use in six categories: forest, grassland, waterbodies, urbanized area, anthropic area and silviculture (Table S1). We calculate the total area for each landscape-use category for all sites with the *landscapemetrics* package (Hesselbarth *et al.* 2019). Only three categories of landscape were present in our sampled sites: forest, urbanized and anthropic area. We sum urbanized and anthropic area to access the total of impacted area in each sampled site. Four synthetic variables ($Land_1$, $Land_2$, $Land_3$ and $Land_4$) resulted from a multivariate ordination analysis (Principal

Component Analysis - PCA) of landscape conditions (Figure 2, Table S2-3). The first two axis explained 100% of the variation and were selected for statistical analysis. $Land_1$ represents a forest-impacted (urbanized + anthropic area) gradient, while $Land_2$ represents an anthropic-forest-urbanized gradient. This PCA was used due correlation between variables (Pearson correlation coefficients >0.6 ; Table S4).

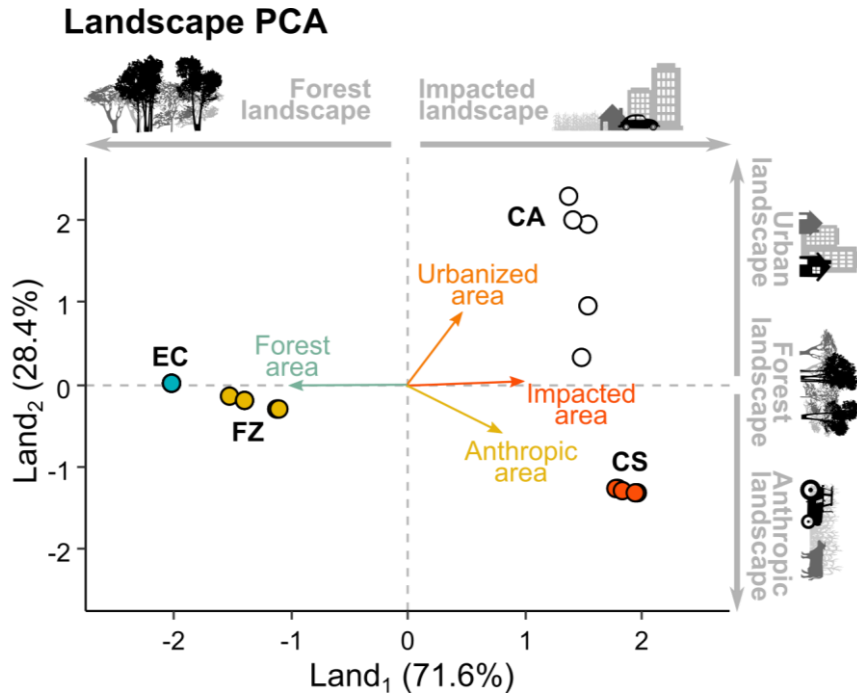


Figure 2. Principal Component Analysis (PCA) of landscape-use conditions of sampled sites. $Land_1$ was composed mainly by forest (34.88%) and impacted area (34.88%). $Land_2$ is mainly composed for urbanized (68.30%) and anthropic area (31.52%; Table S2-3).

ii) *Spatial autocorrelation*

Ignoring spatial autocorrelation in ecology field studies may lead to bias of results interpretation (Keitt *et al.* 2002, Dormann 2007). Thus, we calculated Moran's Eigenvector Maps (MEMs) with the aim to use it as a proxy of spatial autocorrelation. MEMs were set using the method of Principal Coordinates of Neighbour Matrices (PCNM; Brocard *et al.* 2004), package *vegan* of software R (Wagner *et al.* 2009). Six variables resulted from MEM analysis (Table S5, Figure S1), but we use to represent spatial autocorrelation only the first variable (MEM_1) that represents 86.07% of explained variation. MEM_1 was chosen because it describes broad spatial structures, encompassing the spatial variation in the whole sampled area, while the remaining variables represent fine spatial structures (Dray *et al.* 2012), and were not representative of our spatial distribution sites.

iii) *Environmental conditions*

Nineteen bioclimatic variables that represent the environmental conditions were obtained, for each site, from *Worldclim* database in 1km resolution (Fick & Hijmans 2017). Seven synthetic variables resulted from a multivariate ordination analysis (Principal Component Analysis - PCA) of bioclimatic variables (Table S6, Figure S2), the first variable (*Bioclim*₁) represent 81.22% of explained variation and were selected for represent environmental conditions in statistical analysis, because, analogous to *MEM*₁, *Bioclim*₁ represent broad bioclimatic conditions, encompassing the bioclimatic variation in the whole sampled area.

Statistical analysis

The partial distance-based redundancy analysis (partial-dbrDA) were used to tested the effects of landscape modification on grasshopper's community composition. We constructed models with tree different response variables (y-axis): species composition, species turnover and nestedness. The explanatory variables (x-axis) included in model were *Land*₁ and *Land*₂, *MEM*₁ and *Bioclim*₁ were include as constrained factors. *Hum*, *Temp* and *Date* covariables were tested separately and none was significant and therefore did not compose the hypothesis to test model described before (Table S7). Species composition data were Hellinger-transformed prior to the analysis (Legendre & Gallagher 2001). For each model we use a forward selection to access the significant variables. The permutational ANOVA with 10000 randomizations was used to test the significance of each model. We built a variance partition analysis for each response variable with three components: landscape-use (landscape-use variable significant), spatial (*MEM*₁), environmental (*Bioclim*₁). Partial dbrDA was used to test the effect of each component and the results were interpreted together with the values of β -diversity (β_{jac} , β_{jtu} e β_{jne}). Additionally, we used partial correlation for each component (landscape-use variable significant; *MEM*₁ and *Bioclim*₁) to access individual effects of these factors on each grasshopper species. Partial-dbrDA was calculated using the function 'capscale' with 'Bray-Curtis' distance, forward selection with 'ordistep', variance partitioning with 'varpart' and surface graphics with 'ordisurf', all functions of *vegan* package (Wagner *et al.* 2009). Partial correlation was calculated using 'pcor.test' with Pearson correlation of *ppCor* package (Seongho 2015). All analysis were conducted using the software R, version 3.6.0 (R Development Core Team 2018), considering a significance of $\alpha < 0.05$.

RESULTS

Grasshopper's species composition was affected by the anthropic-forest-urbanized gradient (*Land*₂; $R^2_{Adj} = 0.027$; $F_{1,36} = 1.8710$; $p = 0.039$; Table 1, Figure 3). Thus, species composition differed between sites with anthropic and urbanized areas, while forest areas was intermediate to this gradient showing that forest areas had both anthropic and urbanised species. *Land*₂ also had an effect on the grasshopper's species turnover ($R^2_{Adj} = 0.039$; $F_{1,36} = 1.9944$; $p = 0.015$; Table 1, Figure 5). No explanatory variables were significant on the nestedness species (Table 1).

The variance partitioning demonstrated that anthropic-forest-urbanized gradient ($Land_2$) was an additional factor that affect grasshopper's species composition, acting on species turnover together with spatial (MEM_1) and environment conditions ($Bioclim_1$), while on species nestedness all variables were no-significant (Figure 6). The total beta-diversity was $\beta_{jac} = 0.8119$, demonstrating that the sampled communities are 81.9% different in species composition, while species turnover showed $\beta_{jtu} = 0.713$ (71.3%) and nestedness $\beta_{jne} = 0.106$ (10.6%). Thus, the landscape turnover explains 3.87% of the dissimilarity in grasshopper's species composition, while distance (MEM_1) and environmental conditions ($Bioclim_1$) explain 7.17% and 9.9% of species dissimilarity, respectively. In a total, our results explained 34.69% of the found variation in grasshopper's communities sampled and the 65.31% of the variation remained may be explained by factors not reported in the study or random effects.

The partial correlation for each species shows that five species were significantly affected by anthropic-forest-urbanized gradient ($Land_2$), while nine species were affected by environmental conditions and five by spatial conditions (Figure 7, Table S8-10). Eight species were not affected by any explanatory variable and none of them was affected by the three factors.

Table 1. Summary of partial-dbrDA of grasshopper's species composition (y-axis) and explanatory variables (x-axis).

Response variables	Explanatory variables	AIC	R^2_{Adj}	F-value	P-value
Species composition	$Land_2$	99.687	0.027	1.8710	0.039*
	$Land_1$	100.462	0.009	1.1437	0.316
Species turnover	$Land_2$	105.3	0.039	2.0149	0.023*
	$Land_1$	106.31	0.012	1.0656	0.385
Species nestedness	$Land_2$	63.44	0.116	1.1222	0.323
	$Land_1$	63.638	0.09	0.9392	0.472

Significance values of the model term are: * P-value < 0.05.

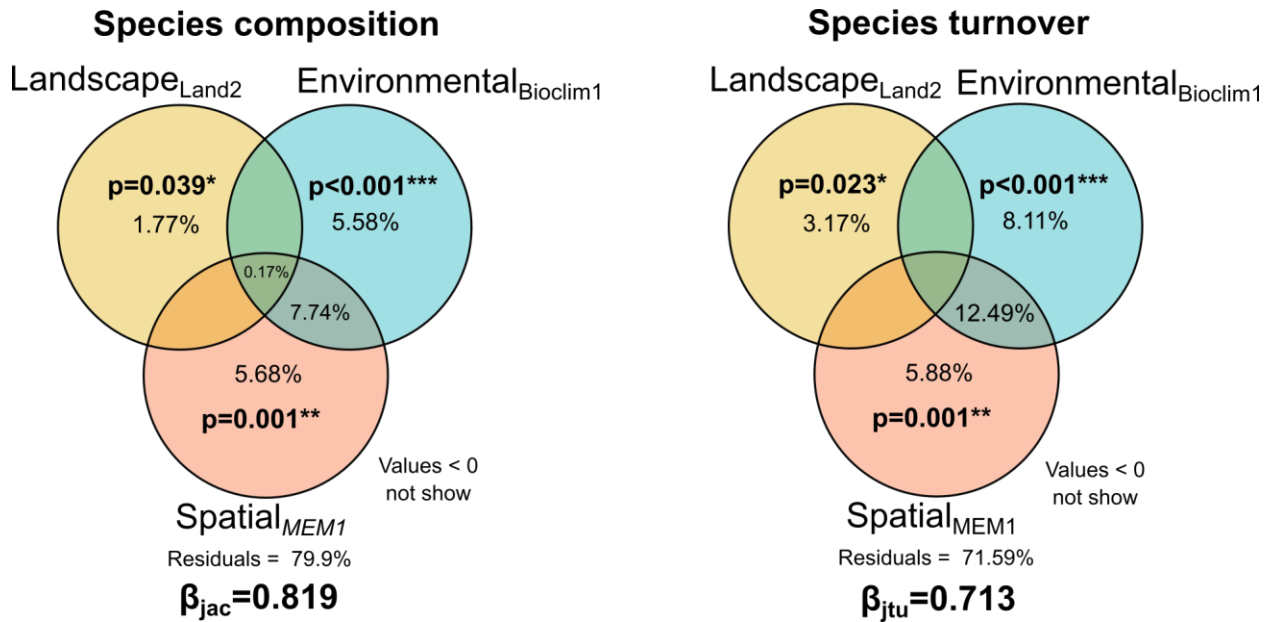


Figure 6. Variation partitioning of grasshopper's species composition and turnover showing the unique and shared percentage of explanation (R^2_{adj}) of landscape configuration ($Land_2$), environmental ($Bioclim_1$) and spatial (MEM_1) autocorrelation. *P-values < 0.05; **P-values < 0.01; ***P-values < 0.001.

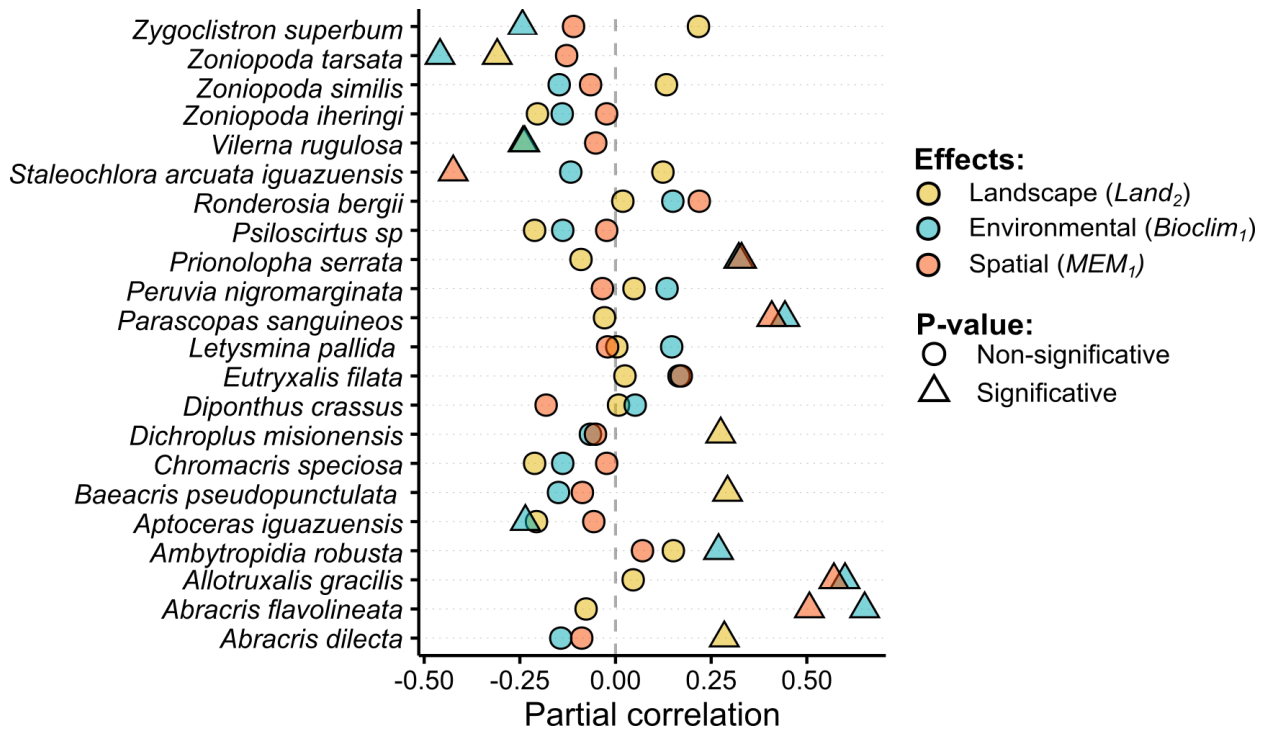


Figure 7. Species partial correlation for landscape configuration ($Land_2$), environmental condition ($Bioclim_1$) and spatial (MEM_1) autocorrelation (see summary data in tables S7-9).

DISCUSSION

Our findings suggest that landscape modification affects grasshopper's communities by species turnover. Here, we identified that the gradient of anthropic-forest-urbanized landscapes was the main anthropic factor acting on species turnover, beyond the naturally expected spatial and environmental turnover. Also, our results show that anthropic and urbanized sites benefit different species.

Contrast between urbanized-anthropic and natural habitats

Although the FBDS distinguish anthropic and urbanized areas, both are anthropized areas that acts as a biodiversity threat. Urbanized areas are characterized by intensive pollution and perturbation as vehicles traffic and constructions, while anthropic areas are characterized by low vehicles traffic, but are greater influenced by pesticide, soil modification and herbicides pollution derived of agricultural activities. In relation to natural habitats, the urbanized areas have sparse and discontinuous vegetation, mainly of grass, inserted in a matrix of buildings, areas inhabited by species that can overcome these barriers. The anthropic areas are composed by continuous exotic cultivate vegetation, mainly corn and soybean, as observed in our study sites.

Our findings show that five species are significantly benefited by urbanized areas. *Abracris dilecta*, is a polyphagous species (Sperber 1996), frequently found in agricultural landscapes (Nunes-Gutjahr & Braga 2012) and urbanized areas (Almeida & Câmara 2008). *Beacris pseudopunctulata*, also polyphagous (Mariottini *et al.* 2013, Martínez 2004), occur in agricultural landscapes (Scuffi *et al.* 2012) and is favoured by intensely anthropized pastures (Wysiecki *et al.* 2004). *Dichroplus misionensis* is frequently associate to monoculture (Garcia 2004), silviculture (Lutinski *et al.* 2009) and wildfire areas (Ferrando *et al.* 2016). While, *Zoniopoda tarsata* has only species related to anthropic areas. This species is frequently associate to monoculture and silviculture areas (Garcia 2004, Chiaradia 2010, Lutinski *et al.* 2011). No data was found about *Vilerna rugulosa* but the genera *Vilerna* occur in open area in range of 0-1m of soil and are reported also as polyphagous (Amédégnato 2003). Additionally, these five species have records of occurrence in savanna and grassland areas (Carbonell *et al.* 2019, Cigliano *et al.* 2019), suggesting its preference to impacted areas, probably because they present biological adaptations to survive in open-vegetation areas being benefits from the conversion of natural Atlantic Forest to areas of anthropic activities with open-vegetation.

Why species turnover and not nestedness?

Grasshopper's species turnover was the key process to assembly the communities' study here. Each component (landscape: $Land_2$; environmental: $Bioclim_1$; spatial: MEM_1) independent explained a portion of species turnover, with no overlap with the explained variance by landscape and others components, while a considerably overlap between explained variance by spatial and environmental was observed. This suggest that landscape is a driver not correlated with spatial and environmental questions, affecting the turnover of species from different way (Figure 7). This occurs due to landscape modification, that acts as an artificial filter to species, favouring some

species and disfavours others, as demonstrated in our results (Figure 7). This artificial filter can be result of landscape modification, that alter resources and microclimate conditions (Chen *et al.* 1999, Latimer & Zuckerberg 2017), local biotic interaction (Ferreira *et al.* 2013) and spatial dispersion (Fahrig 2007, Cranmer *et al.* 2012). As result, in species composition is observed high species turnover due the local species extinction and species replacement between locals, while in broad spatial scale these pool species not changed (Beca *et al.* 2017). However, it is difficult to known if the extent the landscape modification will generate only species replacement between locals or species loss, since we do not know how much habitat is enough for these species (Fahrig 2001), as well as it is not possible to know if some species had extinct in the sampled sites because of landscape modification history. This may indicate two differs situations i) so far, no species extinction has occurred, only their habitat was reduced and in a regional scale all species are represented or ii) remain only the species that tolerate the level of conversion and fragmentation landscape current in the study sites. Therefore, the maximum maintenance of the natural landscape is the better way to conserve these biological communities, since at the moment we do not know in which of these two situations these communities are.

The overlap between the explained variance by spatial and environmental observed is due to the spatial (MEM_1) that represent a portion of environmental conditions ($Bioclim_1$), because there was strong correlation between these variables MEM_1 and $Bioclim_1$ (Pearson correlation coefficient > 0.9). Pure variance explained by environmental conditions may represent an environmental filtering acting on grasshopper's species turnover (Qian & Ricklefs 2012), probably by the environmental transition between 'semideciduous rainforest' (FZ and EC sites, Figure 1) and 'mixed ombrophilous forest' (CA and CS sites), situated in an contrasting altitudinal gradient (Morellato & Haddad 2000a). Pure variance explained by spatial autocorrelation may indicate endogenous and exogenous factors spatially correlated. The endogenous factors is represented by environmental conditions that we did not characterize in our study, such as soil type, stochastic disturbances or even solar activity (Ranta *et al.* 1997, Fleishman & Mac Nally 2006). Endogenous factors is represented by biological attributes, such as dispersion, home-range size and biotic interactions (Wilkinson & Edds 2001). In this way, our findings suggest that complex set of factors (spatial, environmental and landscape) act on assembly of grasshopper's communities by turnover.

Perception of ecological patterns and implications for conservation

Spatial and environmental autocorrelation between sampled locals was expected due arrangement of samples on geographical space, but our results show that is possible to access the effects of landscape modification on biological communities. Here, we observed that, despite less effect on grasshopper's species composition than natural expected effects (spatial and environmental autocorrelation), the landscape-use had more effect than natural factors in some species (Figure 6,7). Thus, the complex set of factors (spatial, environmental and landscape) may lead to bias in biological communities analysis specially in locals geographically distant, because the synergy between these factors may lead the interpretation errors (Dormann 2007, Dormann *et*

al. 2007). This is more evident in environments with fast and intense landscape modification, such as the Atlantic Forest.

In the past 500 years, Atlantic Forest had been suffer intensive deforestation and consequent landscape modification (Bueno 1998). Our results show that biological communities are associate to different anthropic areas (artificial) and differs of forest areas (natural habitat in Atlantic Forest). This may indicates that new species communities are forming in association with anthropic areas (Tabarelli *et al.* 2012), which leads us to believe that the remaining 11% in the Atlantic Forest (Ribeiro *et al.* 2009) preserve the natural grasshopper's communities of this biome, while 89% (anthropized areas) may contain these new synanthropic communities. In the point-of-view of ecosystems functioning this is alarming, because grasshoppers are important herbivores of the food chain, acting in control of some plant species and promote the increase in plant species diversity (Schmitz 2008). Also, grasshoppers are alimentary resource for many species of birds (Repenning *et al.* 2009, Bock *et al.* 2013), small mammals (Bonato *et al.* 2004), canids (Bueno & Motta-Junior 2004), frogs (Brandão *et al.* 2003, Siqueira *et al.* 2006) and reptiles (Acosta *et al.* 1991). So, the alteration of grasshopper's communities along a gradient of anthropic-urbanized to forest areas, permit to suppose that the ecosystem functioning may be change in parallel. Therefore, for conservation and management actions it is necessary to maintain natural communities to the maximum in order to avoid possible changes in the entire regional ecosystem.

CONCLUSION

Landscape modification affects grasshopper's communities by species turnover in a gradient of anthropic-forest-urbanized area, with some species being benefited by certain landscape configuration, probably due to biological adaptations specifics for each species. This may indicate that natural grasshopper's communities, and probably others groups, are in only 11% remaining of Atlantic forest, while others new and contrasting synanthropic communities are formed in with association with anthropic and urbanized areas. In the point-of-view of ecosystems functioning the alteration of grasshopper's communities may lead loss of process and species associated with this group, such as plants and vertebrates. Therefore, for conservation and management actions it is necessary to maintain natural communities to the maximum in order to avoid possible changes in the entire regional ecosystem.

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SUPPLEMENTARY MATERIAL

1. Tables

Table S1. Categories landscape of FBDS database description.

Category	Description
Forest	Native tree vegetation with continuous canopy
Grassland	Native shrub or herbaceous vegetation
Waterbodies	Continuous waterbodies
Urbanized area	Built areas and/or urban influence area
Anthropic area	Areas without native vegetation cover and/or agricultural influence area
Silviculture	<i>Eucalyptus</i> sp. or <i>Pinus</i> sp crops.

Table S2. Landscape PCA eigenvalues individual and cumulative contributions.

Variables	Explained variance (%)	Explained variance (%)
<i>Land</i> ₁	71.60	71.60
<i>Land</i> ₂	2.84	100
<i>Land</i> ₃	2.88e-18	100
<i>Land</i> ₄	6.41e-28	100

Table S3. Landscape PCA eigenvalues variables contributions.

Landscape variables	<i>Land</i> ₁	<i>Land</i> ₂	<i>Land</i> ₃	<i>Land</i> ₄
Forest area	34.881953	0.08595544	65.032092	6.59E-42
Impacted area	34.881953	0.08595544	18.802443	1.19E-30
Anthropic area	22.411596	31.52579601	10.647241	9.08E-31
Urbanized area	7.824499	68.3022931	5.518224	4.71E-31

Table S4. Pearson correlation matrix of the landscape-use included in landscape PCA.

	Forest	Impacted	Anthropic	Urbanized
Impacted	-1			
Anthropic	-0.78	0.78		
Urbanized	-0.5	0.5	-0.147	

Table S5. PCNM eigenvectors with individual and cumulative contributions.

Variables	Explained variance (%)	Explained variance (%)
<i>MEM₁</i>	86.702	86.702
<i>MEM₂</i>	9.935	96.637
<i>MEM₃</i>	3.339	99.976
<i>MEM₄</i>	0.023	99.999
<i>MEM₅</i>	0.0001	99.9991
<i>MEM₆</i>	1.728e-06	100

Table S6. Environmental PCA eigenvalues with individual and cumulative contributions.

Component	Explained variance (%)	Explained variance (%)
<i>Bioclim₁</i>	81.225	81.225
<i>Bioclim₂</i>	18.298	99.523
<i>Bioclim₃</i>	0.350	99.873
<i>Bioclim₄</i>	0.103	99.978
<i>Bioclim₅</i>	0.013	99.989
<i>Bioclim₆</i>	0.006	99.996
<i>Bioclim₇</i>	0.004	100

Table S7. Summary of partial-dbrDA for co-variables: humidity (*Hum*), temperature (*Temp*) in moment of sample and date of sample (*Date*).

Response variables	Explanatory variables	AIC	R²_{Adj}	F-value	P-value
Species composition	<i>Hum</i>	107.42	0.004	0.9879	0.4402
	<i>Temp</i>	107.68	-0.003	0.7402	0.6847
	<i>Date</i>	107.75	-0.005	0.6747	0.7524
Species turnover	<i>Hum</i>	112.60	0.004	0.8776	0.543
	<i>Temp</i>	112.63	0.004	0.8547	0.569
	<i>Date</i>	112.81	-0.002	0.6751	0.758
Species nestedness	<i>Hum</i>	61.133	0.084	0.9387	0.4788
	<i>Date</i>	61.310	0.064	0.7669	0.6411
	<i>Temp</i>	61.646	0.026	0.4422	0.8927

Table S8. Summary of species partial correlation for landscape ($Land_2$), controlling environmental ($Bioclim_1$) and spatial (MEM_1) variables.

Species	Pearson correlation	T-value	P-value
<i>Abracris dilecta</i>	0.284	2.602	0.011
<i>Abracris flavolineata</i>	-0.077	-0.677	0.501
<i>Allotruxalis gracilis</i>	0.046	0.405	0.687
<i>Ambytropidia robusta</i>	0.151	1.342	0.184
<i>Aptoceras iguazuensis</i>	-0.206	-1.852	0.068
<i>Chromacris speciosa</i>	-0.211	-1.897	0.062
<i>Dichroplus misionensis</i>	0.275	2.508	0.014
<i>Diponthus crassus</i>	0.008	0.07	0.945
<i>Eutryxalis filata</i>	0.025	0.216	0.83
<i>Letysmina pallida</i>	0.003	0.029	0.977
<i>Baeacris pseudopunctulata</i>	0.293	2.687	0.009
<i>Peruvia nigromarginata</i>	0.048	0.424	0.673
<i>Psiloscirtus sp</i>	-0.211	-1.897	0.062
<i>Prionolopha serrata</i>	-0.09	-0.794	0.429
<i>Ronderosia bergii</i>	0.019	0.168	0.867
<i>Staleochlora arcuata iguazuensis</i>	0.124	1.096	0.277
<i>Parascopas sanguineos</i>	-0.029	-0.252	0.801
<i>Vilerna rugulosa</i>	-0.242	-2.184	0.032
<i>Zoniopoda iheringi</i>	-0.204	-1.828	0.071
<i>Zoniopoda similis</i>	0.133	1.178	0.242
<i>Zoniopoda tarsata</i>	-0.309	-2.852	0.006
<i>Zygoclistron superbum</i>	0.217	1.949	0.055

Table S9. Summary of species partial correlation for environmental (*Bioclim₁*), controlling landscape (*Land₂*) and spatial (*MEM₁*) variables.

Species	Pearson correlation	T-value	P-value
<i>Abracris dilecta</i>	-0.143	-1.267	0.209
<i>Abracris flavolineata</i>	0.651	7.525	<0.001
<i>Allotruxalis gracilis</i>	0.6	6.577	<0.001
<i>Ambytropidia robusta</i>	0.269	2.453	0.016
<i>Aptoceras iguazuensis</i>	-0.236	-2.127	0.037
<i>Chromacris speciosa</i>	-0.138	-1.222	0.226
<i>Dichroplus misionensis</i>	-0.066	-0.577	0.566
<i>Diponthus crassus</i>	0.051	0.452	0.653
<i>Eutryxalis filata</i>	0.166	1.476	0.144
<i>Letysmina pallida</i>	0.147	1.302	0.197
<i>Baeacris pseudopunctulata</i>	-0.149	-1.323	0.19
<i>Peruvia nigromarginata</i>	0.135	1.192	0.237
<i>Psiloscirtus sp</i>	-0.138	-1.222	0.226
<i>Prionolopha serrata</i>	0.322	2.986	0.004
<i>Ronderosia bergii</i>	0.15	1.33	0.188
<i>Staleochlora arcuata iguazuensis</i>	-0.117	-1.033	0.305
<i>Parascopas sanguineos</i>	0.443	4.333	<0.001
<i>Vilerna rugulosa</i>	-0.237	-2.143	0.035
<i>Zoniopoda iheringi</i>	-0.139	-1.234	0.221
<i>Zoniopoda similis</i>	-0.147	-1.306	0.195
<i>Zoniopoda tarsata</i>	-0.459	-4.529	<0.001
<i>Zygoclistron superbum</i>	-0.243	-2.199	0.031

Table S10. Summary of species partial correlation for spatial (MEM_1), controlling landscape ($Land_2$) and environmental ($Bioclim_1$) variables.

Species	Pearson correlation	T-value	P-value
<i>Abracris dilecta</i>	-0.088	-0.78	0.438
<i>Abracris flavolineata</i>	0.507	5.162	<0.001
<i>Allotruxalis gracilis</i>	0.571	6.098	<0.001
<i>Ambytropidia robusta</i>	0.071	0.622	0.535
<i>Aptoceras iguazuensis</i>	-0.057	-0.5	0.618
<i>Chromacris speciosa</i>	-0.023	-0.203	0.84
<i>Dichroplus misionensis</i>	-0.052	-0.461	0.646
<i>Diponthus crassus</i>	-0.181	-1.614	0.111
<i>Eutryxalis filata</i>	0.172	1.53	0.13
<i>Letysmina pallida</i>	-0.02	-0.18	0.858
<i>Baeacris pseudopunctulata</i>	-0.087	-0.764	0.447
<i>Peruvia nigromarginata</i>	-0.034	-0.298	0.767
<i>Psiloscirtus sp</i>	-0.023	-0.203	0.84
<i>Prionolopha serrata</i>	0.329	3.06	0.003
<i>Ronderosia bergii</i>	0.219	1.967	0.053
<i>Staleochlora arcuata iguazuensis</i>	-0.424	-4.103	<0.001
<i>Parascopas sanguineos</i>	0.408	3.925	<0.001
<i>Vilerna rugulosa</i>	-0.052	-0.456	0.65
<i>Zoniopoda iheringi</i>	-0.023	-0.205	0.838
<i>Zoniopoda similis</i>	-0.065	-0.574	0.567
<i>Zoniopoda tarsata</i>	-0.128	-1.135	0.26
<i>Zygoclistron superbum</i>	-0.11	-0.971	0.335

2. Figures

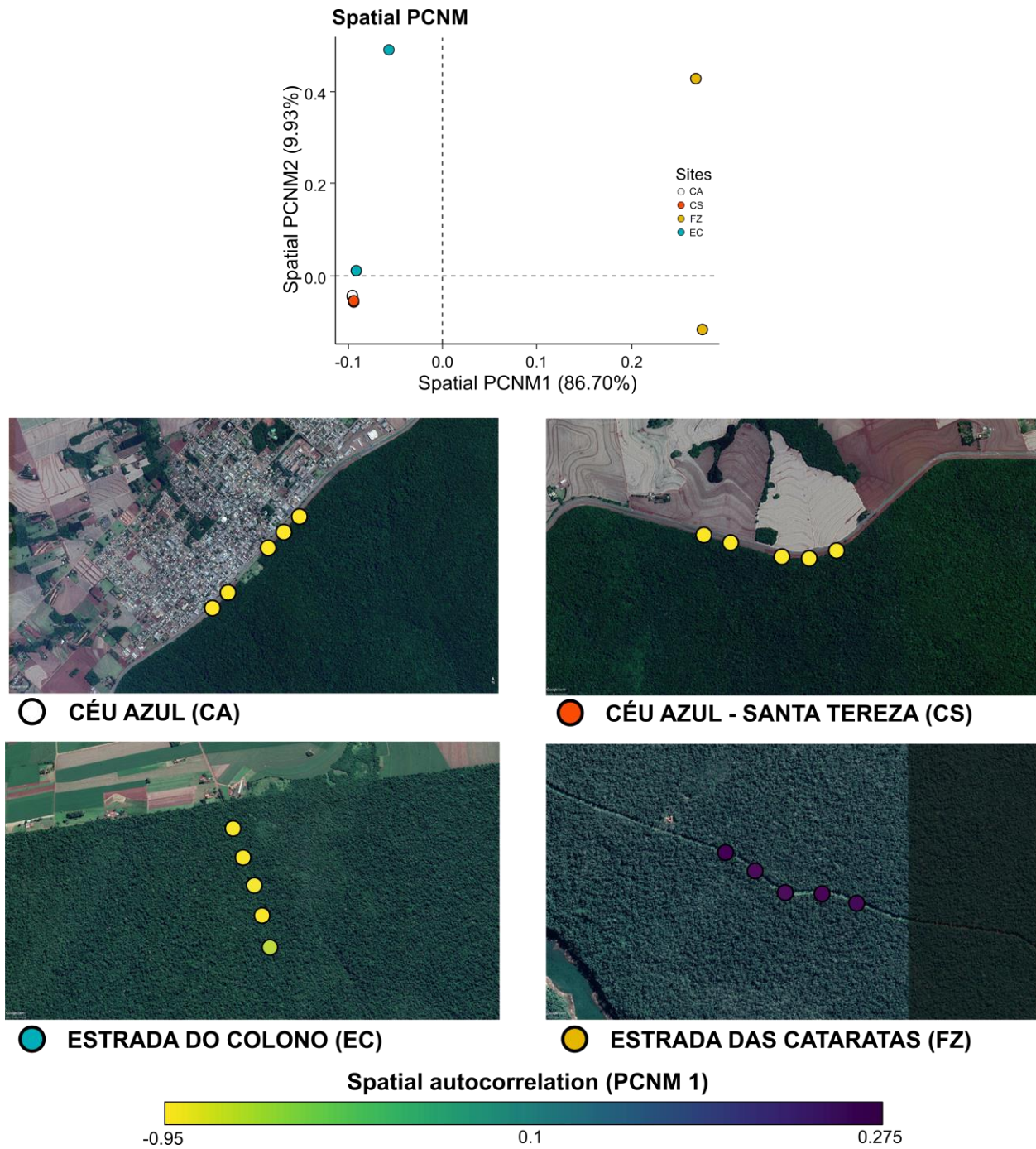
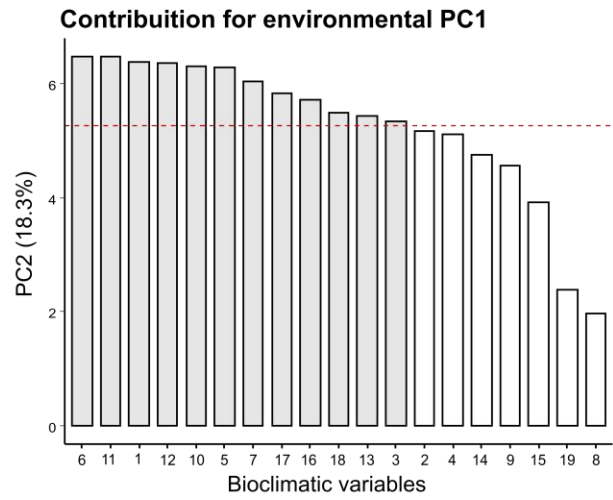
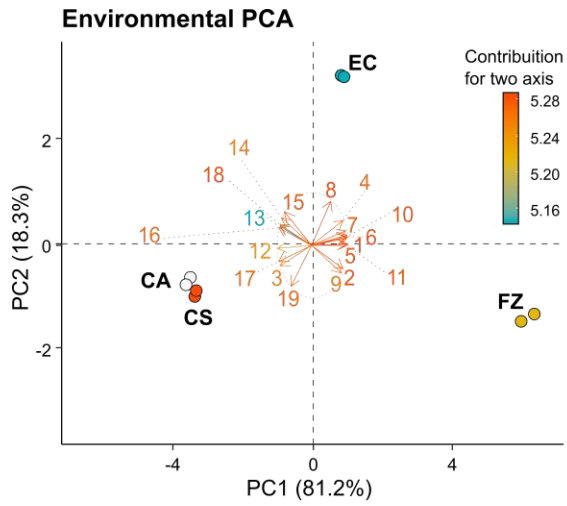
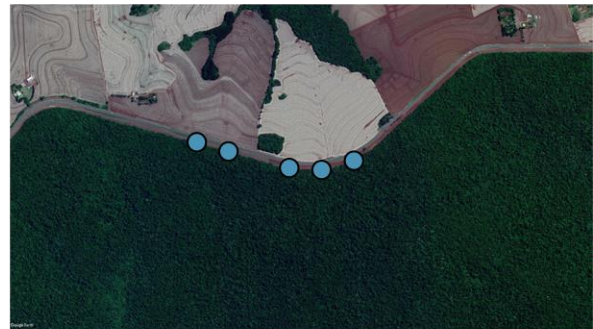


Figura 1S. MEM_1 with 86.70% spatial autocorrelation representation.



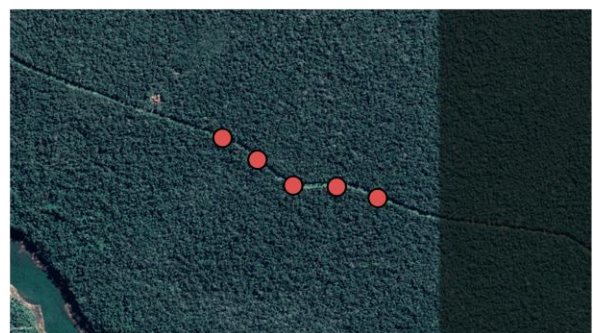
○ CÉU AZUL (CA)



● CÉU AZUL - SANTA TEREZA (CS)



● ESTRADA DO COLONO (EC)



● ESTRADA DAS CATARATAS (FZ)

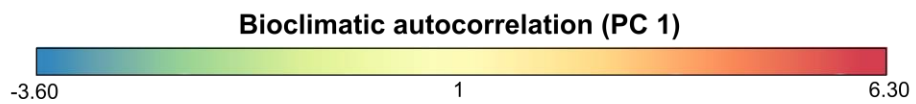


Figura 2S. $Biolcim_1$ with 81.2% environmental autocorrelation representation.

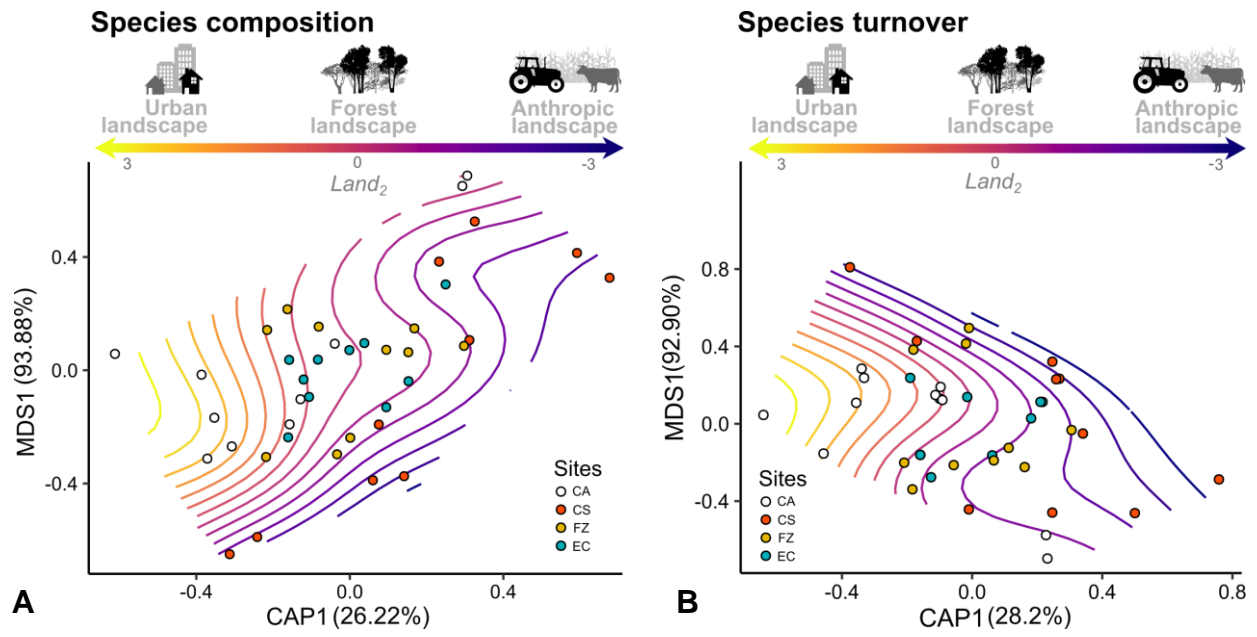


Figure 3. Result of partial-dbrDA show effect of landscape ($Land_2$: anthropic-forest-urbanized gradient) on grasshopper's species composition (A) and turnover (B).

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RRH: Seed Dispersal by Primates

(use capitals; may not exceed 50 characters or six words)

Title: No more than 12 words (usually), flush left, near the middle of the page. Use Bold Type.

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‘Invasion of African savanna woodlands by *Medusagyne oppositifolia* (Medusagynaceae)’

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‘Effect of habitat fragmentation and pollination networks on Flores’.

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BRUNA E. M., IZZO T. J., INOUE B. D., URIARTE M., VASCONCELOS H. L. 2011b. Asymmetric dispersal and colonization success of Amazonian plant-ants queens. *PLoS ONE* 6: e22937.

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