

## The dung beetle assemblage (Coleoptera: Scarabaeinae) is differently affected by land use and seasonality in northeastern Brazil

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### Abstract

BATISTA MC, LOPES GS, MARQUES LJP, TEODORO AV. 2016. The dung beetle assemblage (Coleoptera: Scarabaeinae) is differently affected by land use and seasonality in northeastern Brazil. ENTOMOTROPICA 31(13): 95-104.

Dung beetles have been widely used as bioindicators of environmental quality. Here, we assessed the influence of land use and seasonality on patterns of species richness and abundance of dung beetles in northeastern Brazil. Dung beetles were sampled in five different land uses (cassava, eucalyptus, alley cropping, young fallows and old fallows) in the dry and rainy seasons, using pitfall traps baited with fresh cow manure. Seasonality strongly influenced the dung beetle assemblage with a higher number of species and individuals being collected during the rainy season. Species richness was influenced by land use only in the rainy period. Additionally, except for eucalyptus, all land uses supported high dung beetle diversity during the rainy season. We conclude that seasonality and land use should be taken into consideration in bioindication studies using dung beetles since species richness and abundance vary widely depending on the period of the year and on the habitat.

**Additional key words:** Agroecosystems, bioindicators, eucalyptus, diversity, Insecta.

### Resumen

BATISTA MC, LOPES GS, MARQUES LJP, TEODORO AV. 2016. Comunidad de escarabajos (Coleoptera: Scarabaeinae) es afectada por el uso de la tierra y la estacionalidad en el noreste de Brasil. ENTOMOTROPICA 31(13): 95-104.

Los escarabajos han sido ampliamente utilizados como bioindicadores de la calidad del ambiente. En este estudio, se evaluó la influencia del uso de la tierra y la estacionalidad sobre los patrones de riqueza de especies y abundancia de escarabajos coprófagos en el noreste de Brasil. Escarabajos peloteros fueron muestreados en cinco diferentes usos de la tierra (yuca, eucaliptos, cultivos en callejón, barbechos jóvenes y barbechos viejos) en las estaciones seca y lluviosa, utilizando trampas de caída cebadas con estiércol fresco de vaca. La estacionalidad influyó en la comunidad de escarabajos con un mayor número de especies e individuos recogidos durante la temporada de lluvias. La riqueza de especies fue influenciada por el uso del suelo sólo en el período de lluvias. Además, a excepción del eucalipto, todos los usos de la tierra sostuvieron una alta diversidad de escarabajos durante la temporada de lluvias. Se concluye que la estacionalidad y el uso de la tierra deben tomarse en cuenta como aspectos claves en estudios de bioindicación usando escarabajos ya que la riqueza de especies y la abundancia, varían ampliamente dependiendo de la época del año y del hábitat.

**Palabras clave adicionales:** Agroecosistemas, bioindicadores, eucalipto, diversidad, Insecta.

## Introduction

Overall, insect community is negatively affected by anthropogenic transformation of forests and other natural habitats into agricultural fields (Shahabuddin et al. 2005, Batista Matos et al. 2013). Habitat loss and degradation resulting from human activities are considered pivotal biodiversity threats (Davies et al. 2000, Bawa et al. 2004). The comprehension that natural areas alone are not enough to sustain biodiversity has led to an increasing focus on agricultural areas to species conservation (Tylianakis et al. 2006, Tschardt et al. 2008).

Apart from land use, seasonality is another key factor that may influence arthropod populations, especially in the tropics, due to temporal variation in temperature, rainfall and resources availability (Guedes et al. 2000, Philpott et al. 2006, Spector 2006, Teodoro et al. 2008, 2010; Damborsky et al. 2015). For example, species richness and abundance of dung beetles were higher and the number of species was positively correlated with temperature in the hot rainy season in Atlantic forest of southeastern Brazil (Hernández and Vaz-de-Mello 2009). However, little is known about the effects of seasonality on the assemblage of dung beetles in traditional land use types from tropical northeastern Brazil.

Conserving biodiversity is key factor for environmental sustainability as it supports ecosystem functioning. Biodiversity loss may lead to decreasing in ecological functions and environmental services, such as nutrient cycling and seed dispersal (Nichols et al. 2008, Slade et al. 2011, Gray et al. 2014).

Dung beetles (Coleoptera: Scarabaeinae) play a relevant role in nutrient cycling, soil aeration, as secondary seed dispersal and as suppressor of parasites living in mammals feces and carcasses (Feer and Hingrat 2005). These insects can be divided in well-defined guilds, they have a well-established taxonomy and are easily sampled which make them good bioindicators that

reflect habitat quality differences (Klein 1989, Davis 1994, Davis et al. 2001, Shahabuddin et al. 2005, Ueda et al. 2015).

Here, we aimed to assess the influence of seasonality and land use type on patterns of species richness and abundance of the dung beetle assemblage of São Luís, Maranhão state, Brazil. We hypothesize that species richness and abundance of dung beetles vary according with land use and season in a way that less intensive land use types will harbor more species and individuals compared to more intensively-managed areas.

## Material and Methods

### Study site

The study was conducted in five land use types located at the Maranhão State University (UEMA) (lat 2° 35' S, long 44° 12' W, 24.4 m above sea level), in São Luís, Maranhão state, Brazil. The region is located in climatic zone (B1) – wet weather, with moderate water deficiency in the winter between June and September, mean annual temperature of 26.1 °C and annual average precipitation of 2 328 mm (GEPLAN 2002).

The five land use types chosen were: (i) cassava (*Manihot esculenta* Crantz) crop periodically managed by weeding and fertilizations; (ii) non-managed *Eucalyptus grandis* Hill ex. Maiden; (iii) alley cropping, characterized by alleys of the leguminous trees species *Leucaena leucocephala* (Lam) de Wit, *Clitoria fairchildiana* Howard and *Acacia mangium* Willd in which rows crops such as maize and cassava were annually cultivated; (iv) young fallow with ca. 2-years old and dominated mostly by herb and bush species and; (v) old fallow with ca. 8-years old and characterized by bush and tree species, mainly babassu (*Attalea speciosa* Mart. ex. Spreng) and tucum (*Astrocaryum vulgare* Mart.) palms. These land use types were chosen because they are representative of the region.

The natural vegetation was completely removed and old and young fallows were the only near-natural habitats available. The size of each study site was around 0.5 ha and the minimal distance between them ranged from 200 to 500 m.

### Dung beetle sampling

In each study site, five pitfall traps were placed in the vertices and center of a 5 m x 5 m quadrat located at 5 m from site boundaries, totaling 25 pitfall traps. Traps consisted of plastic cups (500 mL) filled with 200 mL of 70 % alcohol solution. Smaller plastic cups (50 mL) were filled with 25 g of fresh cow manure stapled inside the trap. The manure was used as bait and the alcohol was used to conserve trapped beetles. All traps were buried at ground level and covered with plastic plates of 20 cm of diameter, suspended at 5 cm from the ground by three wooden sticks, for rain and dirt protection. Dung beetles were trapped over a 24-hours period twice during the dry season (October and November, 2008) and twice during the rainy season (February and March, 2009).

Trapped specimens were sorted into morphospecies and identified by Dr. Fernando Z. Vaz-de-Mello from Federal University of Mato Grosso, Brazil. Voucher specimens of dung beetles were deposited in the Entomological Collection of Federal University of Mato Grosso.

### Statistical analyses

Individual-based rarefaction curves for dung beetles were computed separately for the five land use types and for each season (dry and rainy season), using the Mao Tao function of the software EstimateS 9.1.0 (Colwell 2013) to assess differences in dung beetle species richness.

Differences in the abundance of dung beetles (response variables) among land uses and seasons (explanatory variables) were tested using linear mixed-effects models (LMEs), with trap treated as a random effect, to correct for spatial pseudoreplication (Crawley 2007),

while land use and season were treated as fixed effects. The models created were subjected to analysis of variance (two-way ANOVA) with Poisson error distribution, due to the count nature of the data (Crawley 2007). To assess differences among treatments, we performed an analysis of contrasts (Crawley 2007). All these analyses were carried out using R software (R Development Core Team 2011) and subjected to residual analyses in order to assess the suitability of the models and error distributions (Crawley 2007).

### Results

A total of 2 899 individuals and 20 species belonging to eight genera of Scarabaeidae family were collected across all study sites during both seasons. Apart from one species from the subfamily Aphodiinae (Tribe: Aphodiini), all the species belonged to the subfamily Scarabaeinae. Alley cropping, cassava, young fallow, old fallow and eucalyptus had 17, 16, 16, 13 and 10 dung beetle species each, respectively. Two dung beetle species were captured only in the old fallow (Table 1). The most diverse and abundant genera were *Canthon* (six species, 1 329 individuals), and *Canthidium* (six species, 497 individuals).

Individual-based rarefaction curves revealed that dung beetle species richness increases with the number of dung beetle individuals collected both on dry and rainy seasons (Figure 1), indicating that the sample size was sufficient. Seasonality affected the species richness of dung beetles where more species were found in the rainy season compared to the dry season (Figure 1).

There was no effect of land use type on dung beetle species richness in the dry season (Figure 2). Nevertheless, species richness was clearly influenced by the land use on the rainy season where a higher number of species was found in

**Table 1.** Dung beetles species sampled in relation to land use type (AL - Alley cropping, EU - Eucalyptus, CA - Cassava, YF - Young Fallow, OF - Old Fallow) and season.

Species	Land use type					Total
	AL	EU	CA	YF	OF	
APHODIINI	29	8	-	-	-	37
<i>Canthidium</i> aff. <i>ardens</i> (Bates, 1887)	18	24	11	8	73	134
<i>Canthidium</i> aff. <i>manni</i> (Arrow, 1913)	11	1	2	1	-	15
<i>Canthidium</i> aff. <i>moestum</i> (Harold, 1867)	-	-	6	14	-	20
<i>Canthidium</i> aff. <i>splendidulum</i> (Borre, 1880)	14	3	19	33	-	69
<i>Canthidium humerale</i> (Germar, 1813)	42	-	5	22	-	69
<i>Canthidium manni</i> (Arrow, 1913)	54	5	53	19	22	153
<i>Canthon</i> aff. <i>octodentatus</i> (Schmidt, 1920)	2	-	4	3	-	9
<i>Canthon</i> aff. <i>pilluliformis</i> (Blanchard, 1845)	-	-	-	-	2	2
<i>Canthon chalybaeus</i> (Blanchard, 1843)	-	-	1	5	2	8
<i>Canthon histrio</i> (Serville, 1828)	1	-	-	-	27	28
<i>Canthon lituratus</i> (Germar, 1813)	146	38	301	343	7	835
<i>Canthon obscuriellus</i> (Schmidt, 1922)	71	20	149	197	10	447
<i>Dichotomius</i> aff. <i>lycas</i> (Felsche, 1901)	-	-	-	-	6	6
<i>Dichotomius geminatus</i> (Arrow, 1913)	80	1	45	51	19	196
<i>Ontherus appendiculatus</i> (Mannerheim, 1829)	9	-	15	47	6	77
<i>Onthophagus ranunculus</i> (Arrow, 1913)	69	72	78	43	13	275
<i>Pseudocanthon xanthurus</i> (Blanchard, 1846)	1	-	3	6	-	10
<i>Trichillum externepunctatum</i> (Borre, 1880)	2	-	47	163	16	228
<i>Uroxys</i> aff. <i>corporaali</i> (Balthasar, 1940)	38	2	45	109	177	371

alley cropping, cassava, young fallow and old fallow in comparison with *Eucalyptus* (Figure 3).

Land use type affected dung beetle abundance, with a higher number of individuals in young fallow and cassava, followed by alley cropping, old fallow and *Eucalyptus* (ANOVA:  $X^2_{4,8} = 17.03$ ,  $P < 0.01$ ; Figure 4). Seasonality strongly influenced the dung beetles abundance, with a higher number of individuals trapped in the rainy season compared to the dry season (ANOVA:  $X^2_{1,8} = 1999.40$ ,  $P < 0.0001$ ). There was an interaction between land use and seasonality for the abundance of dung beetles (ANOVA:  $X^2_{4,12} = 391.93$ ,  $P < 0.0001$ ; Figure 5) where more individuals were found in alley cropping, cassava and young fallow compared to *Eucalyptus* and old fallow during the rainy

season. In the dry season, however, the highest dung beetle abundance was found in the old fallow, intermediate values in alley cropping, cassava and young fallow, while the lowest abundance was recorded in *Eucalyptus*.

## Discussion

Our results show that land use and seasonality affect both species richness and abundance of dung beetles differently. The higher dung beetle species richness during the rainy season when compared to the dry season reflects the influence of environmental conditions in species activity. These results are in line with other studies reporting a higher dung beetle species richness during the rainy season (e.g. Andresen

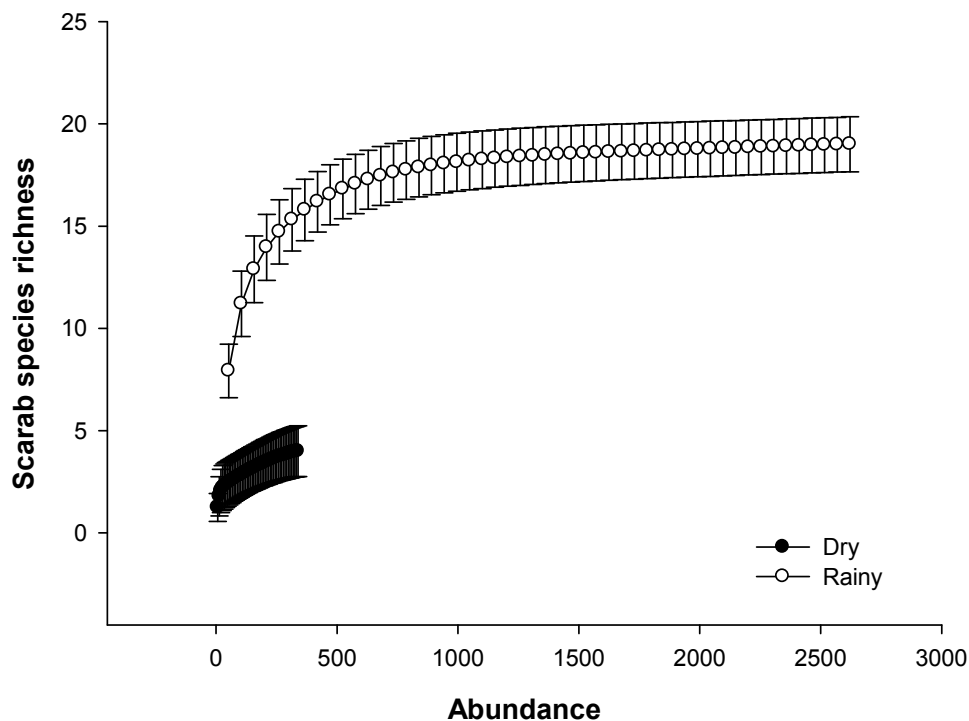


Figure 1. Individual-based rarefaction curves standardized for the number of species of dung beetles generated from the Mao Tao estimator in the dry and rainy seasons. Error bars denote 95 % SE.

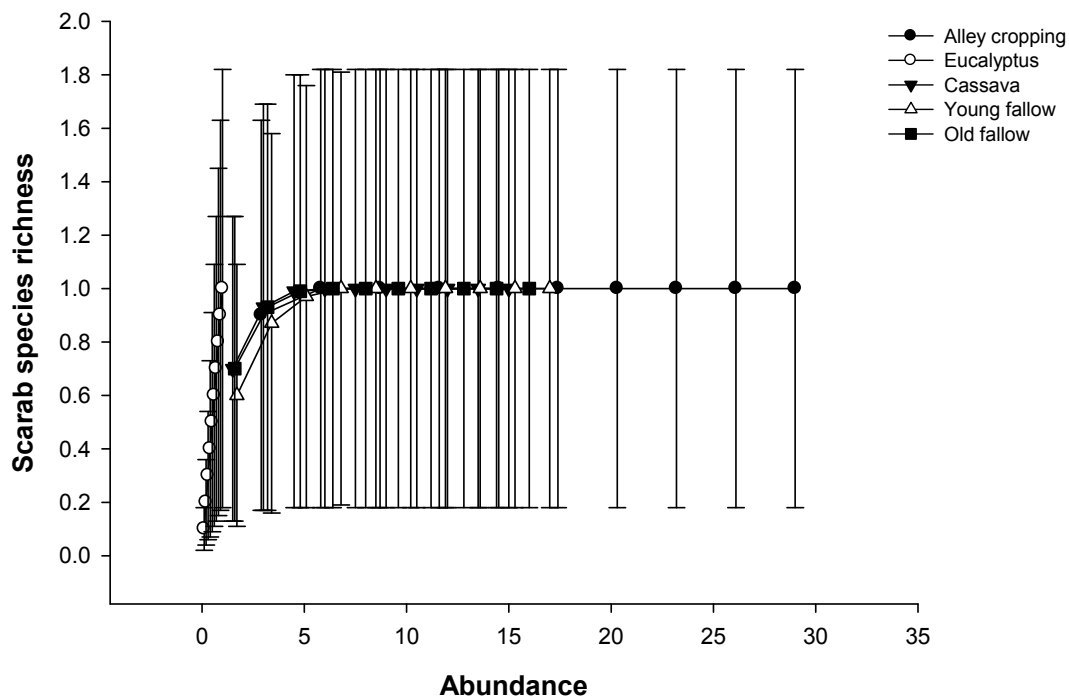


Figure 2. Individual-based rarefaction curves standardized for the number of species of dung beetles generated from the Mao Tao estimator in the dry season. Error bars denote 95 % SE.

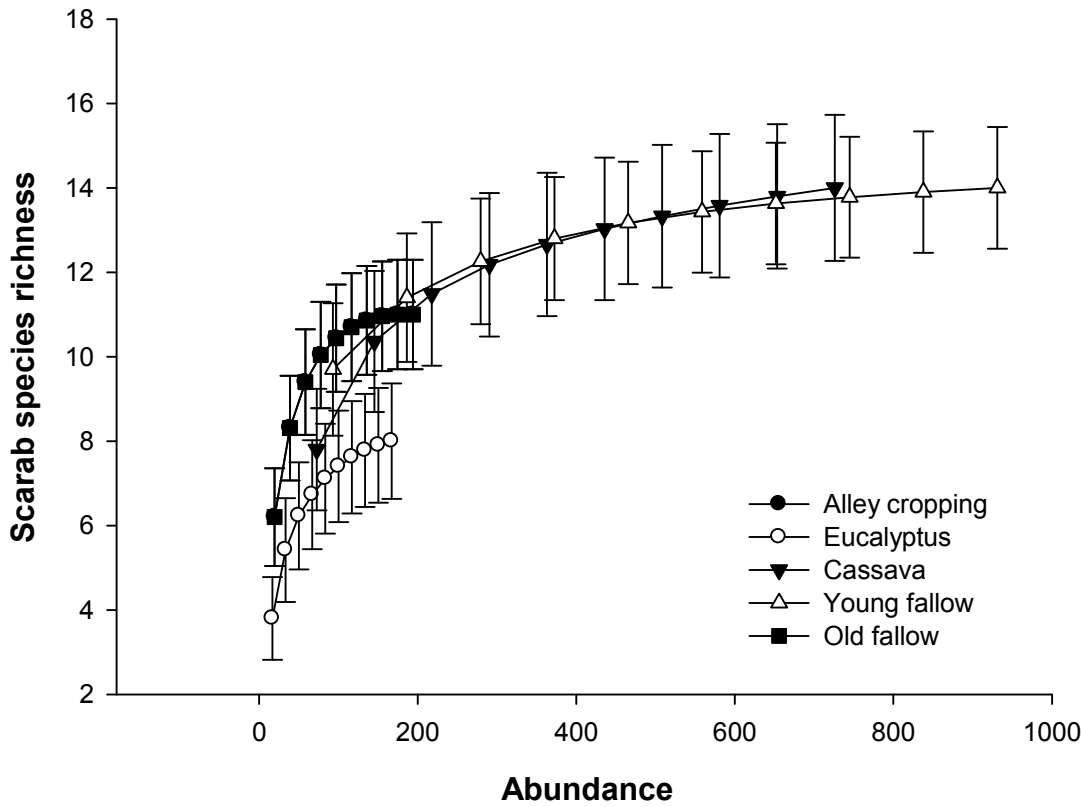


Figure 3. Individual-based rarefaction curves standardized for the number of species of dung beetles generated from the Mao Tao estimator in the rainy season. Error bars denote 95 % SE.

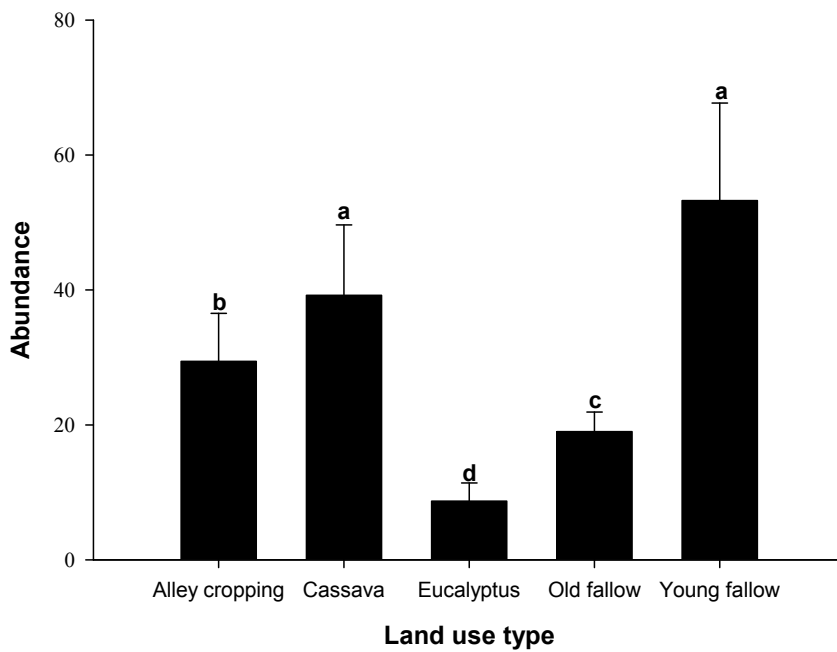


Figure 4. Abundance of dung beetles according to land use. Means  $\pm$  standard error are presented. Different letters indicate difference in the abundance of dung beetles among land use types ( $P < 0.05$ ).



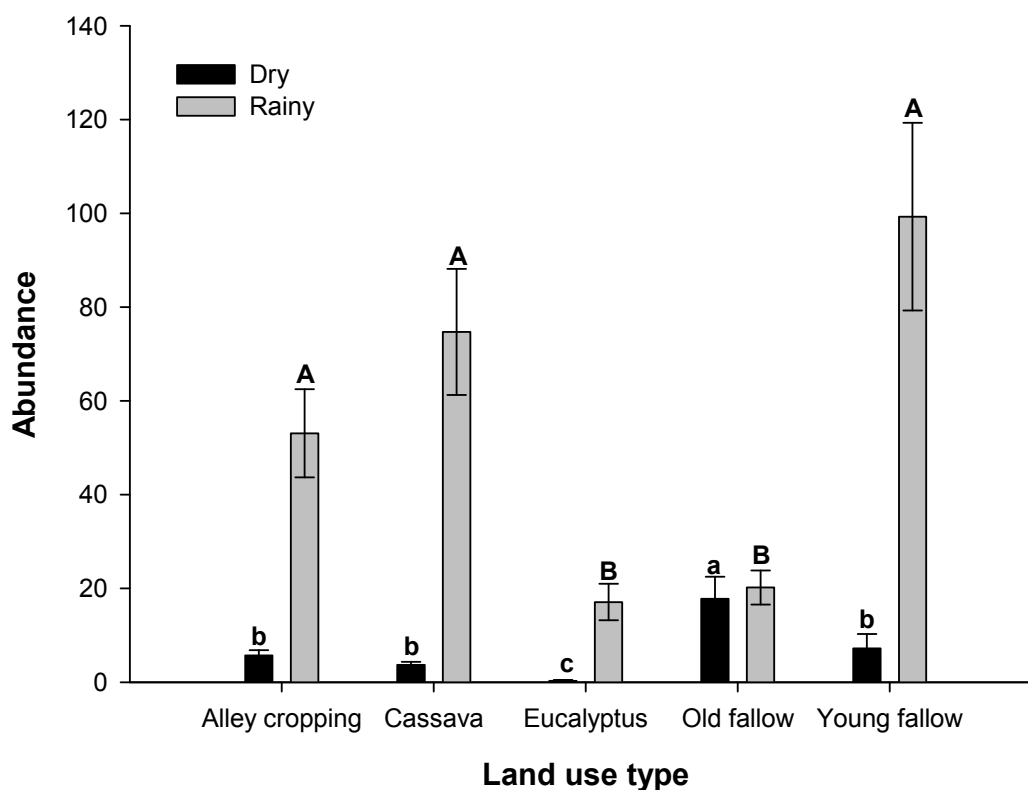


Figure 5. Abundance of dung beetles according to land use in the dry and rainy seasons. Means  $\pm$  standard error are shown. Different upper and lower case letters indicate differences in the abundance of dung beetles among land uses within the rainy and dry seasons, respectively ( $P < 0.05$ ).

2005, Hernández and Vaz-de-Mello 2009, Damborsky et al. 2015).

The lowest number of species of dung beetles was found in the *Eucalyptus* in the rainy season while species richness was not affected in the dry season. Overall, homogenous systems such as *Eucalyptus* are unable to sustain high species diversity (Romero-Alcaraz and Ávila 2000, Gardner et al. 2008, Ueda et al. 2015). More diverse systems such as young fallow, old fallow and alley cropping may support more ecological niches and had more micro habitats that favored food availability, which in turn resulted in high dung beetle diversity. Moço et al. (2005) found that natural forest cover, preserved or unpreserved, showed higher fauna species richness compared to *Eucalyptus* and pasture. Intriguingly, the cassava field also supported a high species richness, which could be possibly

related to the high weed diversity observed in that land use type contrasting to the low weed cover present under the *Eucalyptus* canopy during the rainy season.

During the dry season in the region, conditions are harsh for arthropods as a combination of high temperatures and low relative humidity values could limit their activities. This was clearly the case here, as the number of dung beetle species found in the rainy season was drastically reduced during the dry season.

Patterns of biodiversity loss related to anthropogenic habitat alterations have been observed for other organisms, emphasizing the importance of less degraded environments to biodiversity conservation (Philpott et al. 2006) as well as the use of dung beetles to assess the environmental quality of habitats (Navarrete

and Halffter 2008, Otavo et al. 2013, Filgueiras et al. 2015).

The abundance of dung beetles was influenced by land use type, with low number of individuals in *Eucalyptus* and old fallows in comparison with young fallows, cassava, and alley cropping. Medri and Lopes (2001) also compared different land use types on dung beetles and they found that the abundance of these insects were higher in the primary forest compared to anthropogenic area (pasture), probably due to microclimatic conditions and to food resources availability.

Our study showed that dung beetles were more abundant during the rainy season. Although there are studies where the abundance of dung beetles was not related to rain (Orozco and Pérez 2008, Silva et al. 2013), most studies (e.g. Milhomem et al., 2003, Hernández and Vaz-de-Mello 2009) positively correlates rainfall with the abundance of dung beetles as food availability usually increases over the course of the rainy season.

During the rainy season, the highest abundance was found in young fallow, cassava and alley cropping and the lowest abundance was found in *Eucalyptus* and old fallows. However, during the harsh dry season, old fallows harbored more individuals of dung beetles highlighting the potential of near-natural habitats in harboring populations of such insects under unfavorable environmental conditions. Moço et al (2005) also detected higher densities and species richness of soil fauna in the litter fall of fallows in the dry season. It is possible that this high abundance of dung beetles found in old fallows during dry season in our study may be explained by amenable conditions of temperature and humidity provided by this land use compared to the other ones.

During the rainy season the highest abundance were observed in alley cropping, cassava and young fallow, which may be explained by the

soil coverage and resources availability found in those land use types (Silva et al. 2007).

The most abundant and diverse genus found was *Canthon*. This genus was also well represented in a study conducted by Orozco and Pérez (2008) in a National Park of Colombia, being *Canthon politus* Harold, 1868 the most abundant species. According to Milhomem et al. (2003) and Endres et al. (2007), the presence of a dominant species is considered a pattern to assemblages of dung beetles in the Neotropical region.

## Conclusion

Seasonality and land use should be taken into account in bioindication studies using dung beetles since species richness and abundance vary widely depending on the period of the year and habitat. Except for *Eucalyptus*, all land uses supported a high dung beetle diversity during the rainy season, but not during the harsh dry season. *Eucalyptus* and old fallows had the lowest abundance of dung beetles during the rainy season, however, during the dry season, old fallows harbored the highest number of individuals emphasizing the potential of near-natural habitats to sustain populations of these insects.

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