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Dung Beetles Associated with Agroecosystems of Southern Brazil: Relationship with Soil Properties

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ABSTRACT: Knowing the biodiversity of dung beetles in agricultural and livestock environments is the basis for understanding the contribution that these organisms make in nutrient cycling and ecosystem functions. The aim of the present study was to investigate the structure of copronecrophagous dung beetle communities inhabiting the main agroecosystems in southern Brazil and correlate the presence of these organisms with soil properties. From December 2012 to April 2013, samples of dung beetles were taken in the municipality of Tubarão, Santa Catarina, Brazil (28° 28′ S; 48° 56′ W) in corn, bean, and sugarcane crops, and in cattle pastures. Beetles were captured in 16 sampling sites, four from each agroecosystem, following a standardized methodology: 10 baited pitfall traps (feces and rotting meat) at a spacing of 50 m with exposure for 48 h. The beetles were identified, weighed, and measured. Soil analyses were performed in order to correlate data on organic matter, texture, macro and micronutrients, and pH with data on the abundance of beetle species using canonical correspondence analysis. A total of 110 individuals belonging to 10 species of dung beetles was found. Twenty-four individuals from seven species (with total biomass of 2.4 g) were found in the corn crop; five individuals from three species (1.8 g) were found in the bean crop; 81 individuals from nine species (30.3 g) were found in cattle pasture areas; and lastly, there were no dung beetles recorded in the sugarcane crop. In areas of cattle grazing, the tunnelers *Dichotomius nisus* and *Trichillum externepunctatum* correlated positively with organic matter content, whereas the roller species *Canthon chalybaeus* correlated positively with soil texture, preferring sandier soils. In corn crop areas, *D. nisus* was again correlated with organic matter content. Paracoprid dung beetle species were correlated with organic matter content in the soil, and species belonging to the roller functional group were associated with soil texture in the corn crop, preferring sandy soils. Information regarding the relationship of dung beetles with physical-chemical soil properties may be an important strategy for increasing fertility and management of soil conservation in agroecosystems.

Keywords: agricultural-livestock systems, dung beetles, ecology, soil attributes, species diversity.

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INTRODUCTION

Soil is the regulating center of nutrient cycling processes, both in natural ecosystems and agroecosystems (Constanza et al., 1997; Fölster and Khanna, 1997; Slade et al., 2007). This process is a result of a variety of interconnected systems (Howarth et al., 2002) that reflect the integrated metabolism of ecological communities as a whole (Delitti, 1995).

In soil, micro-, meso-, and macrofauna regulate the mineralization of nutrients from organic forms to inorganic forms assimilable by plants (Delitti, 1995; Lavelle and Spain, 2001; Lavelle et al., 2006). The role of macrofauna in nutrient cycling includes fragmentation of plant residues and stimulation of microbial activity and this has a direct effect on soil structure through redistributing organic material and microorganisms, as well as increasing soil aeration and humidification (Hendrix et al., 1990; González et al., 2001; Lavelle and Spain, 2001; Armúa de Reyes et al., 2004). Physical-chemical properties and processes are mediated by soil biota, which also affects soil quality (Brussaard et al., 2004; Decaën et al., 2006).

However, the most used indicators refer to organic matter content and macroelements (e.g., N and P), where an emphasis on knowledge of soil fauna, principally in regard to the functions executed by these organisms, is almost absent in determining the soil quality of an environment (Hendrix et al., 1990; Doran and Zeiss, 2000; Brussaard et al., 2004; García et al., 2012). In the long term, changes in the structure of soil organism communities can generate a response in the nutritional status and the physical and chemical structure of soil (Arshad and Martin, 2002; Brussaard et al., 2004).

Dung beetles of the subfamily Scarabaeinae are organisms that actively contribute to the ecological process of nutrient cycling through burial of decomposing organic matter and in construction of galleries for nesting within the soil (Halffter and Mathews, 1966; Nichols et al., 2007). The ecosystem function that many species exert in building these nesting galleries and food storage areas leads to edaphic aeration and water and nutrient infiltration, and helps contribute to nutrient cycling through mineralization (Bornemissza, 1970; Brussaard and Runia, 1984; Halffter and Edmonds, 1982; Mittal, 1993; Miranda et al., 1998; Bang et al., 2005). The influence on soil physical structure promoted by formation of these galleries can be observed directly within them, and range from 0.10 to 1.00 m in depth, depending on the species and the soil type (Brussaard and Runia, 1984; Halffter and Edmonds, 1982; Edwards and Aschencorn, 1987).

Adults and larvae from this subfamily are detritivores and use decaying organic material, such as mammal excrement, dead animal carcasses, rotting plant matter, and other resources, as food (Halffter and Mathews, 1966). According to feeding habits, the Scarabaeinae dung beetles can be categorized as saprophagous, coprophagous, necrophagous, or generalists. Furthermore, depending on how the resource is used for feeding and reproduction, they can be divided into three functional groups: telecoprids or rollers (food balls are conducted until burial occurs), paracoprids or tunnelers (tunnels are dug next to or below the food source), and endocoprids or residents (feed and reproduce inside the food resource) (Halffter and Mathews, 1966; Halffter and Favila, 1993; Simmons and Ridsdill-Smith, 2011). They live in a great variety of habitats and exhibit significant variation in spatial and temporal characteristics depending on the availability of food, as well as its quality, and dung, especially connected with the presence of mammals that contribute to this resource base (Barbero et al., 1999).

In general, the structure of beetle communities is influenced by the high competition for scarce and ephemeral food resources (Hanski and Cambefort, 1991; Simmons and Ridsdill-Smith, 2011). In addition, communities are strongly affected by habitat loss and, in areas with agricultural or forestry practices, there is a decrease in the abundance, richness, and total biomass of these beetles (Kalisz and Stone, 1984; González et al., 2001).

Consequently, this affects the ecological functions they provide, such as removal and burial of organic material and secondary seed dispersion (Swift, 1997; Braga et al., 2013).

Changes also occur in species composition, with possible local extinction of some species (Hernández and Vaz-de-Mello, 2009), and since these organisms respond quickly to the effects of habitat degradation, such as destruction, fragmentation, and isolation, they are used as bioindicators of environmental quality (Halffter and Favila, 1993; Gardner et al., 2008; Barlow et al., 2010).

Studies have shown that physical and chemical soil properties affect the diversity, structure, and reproduction of dung beetles (Arellano et al., 2008; Martínez et al., 2009; Brown et al., 2010; Arellano and Castillo-Guevara, 2014; Farias et al., 2015; Silva et al., 2015). Properties such as moisture content can promote the survival and reproductive success of some dung beetle species (Sowig, 1995; Martínez et al., 2009). In crop areas and pastures, it has been observed that the recycling of nutrients and soil bioturbation exerted by Scarabaeinae beetles allows plants to use soil resources in a more efficient way, and they show better performance (Bornemissza 1970; Galbiati et al., 1995; Bang et al., 2005; Hanafy, 2012).

Studying dung beetles associated with agricultural and livestock environments promotes greater appreciation of the ecosystem functions that these organisms provide in agroecosystems, and elucidates their relationship with soil properties, enabling the adoption of conservation practices in soil use.

Our hypothesis is that the abundance and biomass of dung beetles are influenced by the characteristics of the soil environment, especially the physicochemical properties of the soil. It is expected that in soils with low quality, in which the physicochemical properties are below or above the levels recommended for crops, there is a decrease in both the abundance and the biomass of beetles. Therefore, the aim of this study was to describe the structure of dung beetle communities inhabiting the main agroecosystems of southern Brazil and correlate the presence of these organisms to the physical and chemical properties of the soils in these environments.

MATERIALS AND METHODS

Characterization of the study area and sampling site

The study was conducted in the municipality of Tubarão, state of Santa Catarina, in southern Brazil (28° 28′ S; 48° 56′ W) from December 2012 to April 2013. The climate in the region according to the Köppen climate classification system is humid subtropical (Pandolfo et al., 2002) and the soil is classified as a *Cambissolo argiloso* (clayey Cambisols). Crops such as sugarcane, corn, cassava, beans, vegetables, pasture, and eucalyptus and Atlantic Forest fragments characterize the regions of the rural landscape. Sixteen sampling sites were selected in four agroecosystems: four areas of corn (*Zea mays* L.), four areas of beans (*Phaseolus vulgaris* L.), four areas of sugarcane (*Saccharum officinarum* L.), and four areas of cattle pasture [grass species used: *Urochloa decumbens* (Stapf) R.D. Webster and *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster].

The areas, over 10,000 m^2, were located at 9 to 50 m altitude, with a minimum distance of 1 km and a maximum of 10 km between areas/agroecosystems. These areas had been subjected to conventional management systems, with application of pesticides-insecticides (acetamiprid, neonicotinoid, alpha-cypermethrin, benfuracarb, acephate, carbaryl, fipronil), herbicides (ametryn, glyphosate), fungicides (carbendazim, fludioxonil, kresoxim-methyl), and chemical fertilizers. Cattle grazing areas were characterized by extensive livestock systems, and only agrochemicals were used [e.g., herbicide (glyphosate), veterinary pharmaceutical products (ivermectin and triclorfon), and insecticides (chlorpyrifos, benzofuranyl methyl carbonate)], without the addition of chemical fertilizers.

In each agroecosystem (all sampling sites), soil samples were collected at a depth of 0.00-0.20 m to correlate soil properties, such as organic matter content, texture, macro- and micronutrients, and pH, with variables of the beetle community (species, richness, abundance, and biomass) captured in each agroecosystem. The procedure for collecting a simple soil sample was established by Chitolina et al. (2009). In each sampling area, 20 soil samples were collected in a zigzag spatial distribution every 15 m; for each sample, 500 g of soil was collected using an auger. Subsequently, 10 kg of soil from each area were homogenized and reduced to an appropriate amount to form a composite sample (around 500 g). The material was stored in plastic bags and sent to the laboratory for analysis to obtain the physical and chemical properties of the agroecosystem environments (Table 1). The physical-chemical properties of the agroecosystem soils studied showed that the soil texture of corn and bean crops was within class 3, while the sugarcane and cattle grazing areas were class 4. According to the Brazilian Soil Classification System, class 3 refers to arable land, while class 4 is occasionally arable land. In all the environments sampled, the soils were considered acidic (mean pH of 5.1) and characterized as sandy soils in accordance with soil texture. They exhibited characteristics of mean CEC (8.7 ± 1.75 $mmol_c\ dm^{-3}$) and had low organic matter content (details can be found in table 1).

Soil quality can be defined as the capacity of a soil to function within the limits of natural and managed ecosystems to sustain the productivity of plants and animals, maintain or increase the quality of air and water, and promote the health of plants, animals, and man (Karlen et al., 1997). With the results obtained from soil analysis, soil quality was determined for the sites sampled, where soil of quality is considered one that lies within the limits necessary for

Table 1. Soil properties (mean ± standard deviation - SD) in cattle pasture, corn, bean, and sugarcane agroecosystems in the region of Tubarão, Santa Catarina, southern Brazil

Agroecosystem	OM	pH	P	Na^+	Mg^{2+}	Ca^{2+}	Al^{3+}	K^+	CEC	Clay
	$g\ dm^{-3}$		mg dm^{-3}			$mmol_c\ dm^{-3}$				$g\ kg^{-1}$
					Pasture					
A1 P	23	5.8	47.7	37	17.0	35.0	<3	1180.0	91.4	140
A2 P	13	4.5	>50.0	8	3.0	7.0	10.0	780.0	55.0	160
A3 P	22	5.0	6.6	7	3.0	7.0	5.0	600.0	50.8	130
A4 P	22	4.5	2.6	7	4.0	12.0	10.0	510.0	61.2	140
Mean ± SD	22.0 ± 0.23	5.0 ± 0.30	18.9 ± 11.24	14.8 ± 7.42	6.0 ± 0.34	15.0 ± 0.66	8.3 ± 0.23	768.0 ± 14.85	64.6 ± 0.91	143 ± 6.2
					Corn crop					
A1 C	10	6.2	41.9	6	10.0	22.0	< 3.0	700.0	47.9	220
A2 C	31	4.8	30.5	22	15.0	28.0	19.0	1820.0	135	210
A3 C	28	5.1	41.2	17	15.0	33.0	13.0	3460.0	126.6	280
A4 C	27	5.1	37.6	18	15.0	32.0	16.0	3150.0	117.4	280
Mean ± SD	24.0 ± 0.47	5.3 ± 0.30	37.8 ± 2.60	15.8 ± 3.42	13.0 ± 0.12	28.0 ± 0.24	16.0 ± 0.41	2283.0 ± 63.62	106.8 ± 2.00	248 ± 18.8
					Bean crop					
A1 B	15	4.9	43.1	4	4.0	7.0	5.0	720.0	43.9	220
A2 B	24	4.8	> 50.0	5	6.0	9.0	14.0	1610.0	74.3	250
A3 B	13	5.1	42.3	4	4.0	7.0	5.0	570.0	34.5	150
A4 B	9	4.7	37.9	3	4.0	6.0	5.0	340.0	28.4	150
Mean ± SD	15.0 ± 0.31	4.9 ± 0.08	41.1 ± 10.33	4.0 ± 0.40	5.0 ± 0.05	7.0 ± 0.06	7.0 ± 0.22	810.0 ± 27.78	45.0 ± 1.01	193 ± 25.2
					Sugarcane crop					
A1 SC	29	4.9	41.4	22	15.0	36.0	16.0	1840.0	154.1	250
A2 SC	30	4.9	40.6	20	15.0	35.0	16.0	2230.0	154.0	260
A3 SC	42	6.1	> 50.0	9	15.0	35.0	< 3.0	3390.0	86.6	170
A4 SC	29	5.9	> 50.0	9	14.0	34.0	< 3.0	1960.0	84.3	16
Mean ± SD	15.0 ± 0.31	4.9 ± 0.08	41.1 ± 10.33	4.0 ± 0.40	5.0 ± 0.05	35.0 ± 0.06	7.0 ± 0.22	810.0 ± 27.78	45.0 ± 1.01	193 ± 25.2

OM: organic matter; colorimetric; pH in water or $CaCl_2$; P, K, and Na: extractor Mehlich-1 (HCl 0.05 mol L^{-1} + H_2SO_4 0.025 mol L^{-1}); Ca^{2+}, Mg^{2+}, Al^{3+}: extractor KCl 1 mol L^{-1}; CEC: cation exchange capacity; clay: pipette method.

preservation of productivity and biodiversity (CQFS-RS/SC, 2004). Soil quality was deemed medium for the agroecosystem sites studied, according to the parameters of the soil collected.

Sampling of dung beetles

Pitfall traps were baited with human feces (20 g) and with decaying pork (20 g) to attract coprophagous and necrophagous species, respectively. Pitfall traps consisted of a plastic container (0.20 m in diameter, 0.20 m deep) placed with the rim at soil level. Water and a 3 % neutral liquid detergent solution were placed within each trap. This is the method most commonly used to collect dung beetles, and it is effective in capturing most species from this group (Lobo et al., 1988). Each bait was wrapped in a voile-type tissue and suspended from a rain protection cover at a height of 0.10 m.

The sampling protocol, with four replicates for each agroecosystem studied, respecting a border of 20 m in each sampling area and a minimum distance of 1,000 m from native forest, consisted of five sampling points, corresponding to a pair of traps spaced at 50 m and between each point; this distance reduces the influence of one trap on another in sets of traps in sampling of Scarabaeinae (Larsen and Forsyth, 2005), although recently a proposal was made to increase the distance in the sampling protocol to 100 m (Silva and Hernández, 2015). Two samples were taken at each site. For bean and corn crops, one sample was taken at the beginning of the season (two weeks after planting) and another near harvest. In sugarcane crop and cattle grazing areas, one sample was collected at the beginning of summer, and a second was taken at the end of the season. A total of 80 traps per agroecosystem were placed in this effort.

At 48 h after placement of the traps, the beetles captured in them were preserved in a 70 % alcohol solution. In the laboratory, all the beetles were weighed (dry weight) and body size was measured (from the clypeus to pygidium) for each individual. The individuals were dried at 40 °C for at least 72 h. The species were identified at the genus level using the indications of Vaz-de-Mello et al. (2011). The material collected was deposited in the Entomological Collection of the Centro de Ciências Biológicas of the Universidade Federal de Santa Catarina, Brazil, and in the Entomological Collection of the Centro de Desenvolvimento Tecnológico Amael Beethoven Villar Ferrin of the Universidade do Sul de Santa Catarina; duplicates can be found in the Entomological Collection of the Universidade Federal de Mato Grosso.

Statistical analysis

The copronecrophagous dung beetle community was described through measures of species richness, abundance, and biomass, and the total abundance observed and the biomass of captured beetles were compared among agroecosystems using analysis of variance, followed by the Tukey test. Biomass data was transformed using $\sqrt{x+1}$ to reduce heteroscedasticity. Dominance-diversity graphs (in log10) were used to explore the relationship between species in the community through measures of species abundance and biomass in the agroecosystems studied. Species accumulation curves were constructed to evaluate sampling efficiency, and calculations of the Chao 1 and Jackknife 1 estimators (with a confidence interval of 95 %) were made to estimate the richness of the species in the agroecosystems. The analyses were performed using EstimateS v.9.1.0 (Colwell et al., 2012).

In order to test the hypothesis that the distribution of species abundance and biomass of the dung beetle are influenced by soil attributes, a canonical correspondence analysis (CCA) for each agroecosystem was performed in the R program (R Core Team, 2014).

RESULTS

A total of 110 dung beetles belonging to six genera and 10 species were collected. In cattle pastures, nine species were found; in the corn crop, seven species; and in the bean crop, only three species (Table 2). In the sugarcane crop, no dung beetles were collected. The most abundant species in the region were *Dichotomius nisus* (Olivier, 1789) and *Canthon chalybaeus* Blachard (1845), together representing 68.1 % of the total number of individuals captured. Five species of telecoprids were captured, four paracoprids, and only one endocoprid. In regard to eating habits, five coprophagous species were collected, two necrophagous species, and three generalists. The size of the species ranged from 3.6 mm (*Trichillum externepunctatum* Preudhomme de Borre, 1886) to 22 mm in length (*D. nisus*), with a mean dry weight from 1.7 to 560.6 mg (Table 2).

The species accumulation curves demonstrated sample efficiency in dung beetle richness in the agricultural and livestock environments (Figure 1). The number of species observed in each agroecosystem was similar to the number of species expected based on richness estimators (Chao 1, Jacknife 1) and indicate sampling efficiency in capturing local richness, with observed richness of at least 75 % of estimated richness (Table 3). In addition, the confidence intervals indicate species richness was significantly greater in pasture areas, intermediate in the corn crop, and smaller in the bean crop (Table 3).

Dung beetle abundance was significantly greater in cattle grazing areas in comparison with the other agroecosystems ($F=16.02$; $df=3$; $p<0.0001$), possibly because pasture is an environment with greater availability of resource for beetles, but greater abundance was observed in the corn crop than the bean crop. Consequently, total biomass per agroecosystem was also greater in livestock systems in comparison to crop areas ($F=7.47$; $df=3$; $p=0.0029$) (Table 3).

Dichotomius nisus was the species with the greatest abundance in pasture areas and in the bean crop (Figure 2a). Two species were dominant in cattle grazing areas, *D. nisus* (61.7 %) and *C. chalybaeus* (13.6 %), which together represented 75.3 % of the total number of individuals sampled in this agroecosystem. In the corn crop, the dominant species were *C. chalybaeus* and *Canthon rutilans cyanescens* Harold (1868), which

Table 2. Copronecrophagous beetles (Coleoptera: Scarabaeinae) from agroecosystems in Tubarão, Santa Catarina, southern Brazil, and ecological characteristics of the species

Specie	Size	MDW	FP	FG	Agroecosystem				N/B
					Pasture N/B	Corn N/B	Bean N/B	SC N/B	
	mm	mg							
Canthon aff. *mutabilis* Lucas, 1857	6.3	22.0	C	T	0/0	1/22.0	0/0	0/0	1/22.0
Canthon chalybaeus Blanchard, 1845	8.5	20.6	G	T	11/226.6	9/185.4	0/0	0/0	20/412.0
Canthon luctuosus Harold, 1868	6.7	16.0	N	T	1/16.0	2/32.0	0/0	0/0	3/48.0
Canthon rutilans cyanescens Harold, 1868	10.8	45.5	G	T	4/182.0	4/182.0	0/0	0/0	8/364.0
Deltochilum multicolor Castelnau, 1840	16.3	227.3	N	T	5/1136.5	3/681.9	1/227.3	0/0	9/2045.7
Dichotomius aff. *sericeus* (Harold, 1867)	17.2	134.0	G	P	1/134.0	0/0	0/0	0/0	1/134.0
Dichotomius nisus (Olivier, 1789)	22.4	560.6	C	P	50/28030.0	3/1681.8	2/1121.2	0/0	55/30833.0
Eurysternus parallelus Castelnau, 1840	14.6	32.2	C	E	4/128.8	0/0	0/0	0/0	4/128.8
Ontherus sulcator (Fabricius, 1775)	15.5	96.1	C	P	2/192.2	2/192.2	2/192.2	0/0	6/576.6
Trichillum externepunctatum Preudhomme de Borre, 1886	3.6	1.7	C	P	3/5.1	0/0	0/0	0/0	3/5.1
Abundance and total biomass					81/30051.2	24/2977.2	5/1540.7	0/0	110/35728.4
Species richness					9	7	3	0	10

MDW: mean dry weight (mg). Size: Mean size (mm). FP: Food preference based on literature (C: coprophagous, G: generalist, N: necrophagous). FG: Functional guild based on literature (P: paracoprid, T: telecoprid, E: endocoprid). N: number of individuals. B: total biomass (mg). SC: sugarcane.

represented 29.2 % of the total abundance. In the bean agroecosystem, the dominant species of dung beetle was *D. nisus* (40 %) (Figure 2a). In terms of biomass, all the environments studied had strong participation of *D. nisus* and *Deltochilum multicolor* Balthasar (1939) (Figure 2b).

The distribution of dung beetle species in accordance with the agroecosystem demonstrated that certain species are related to certain soil attributes. For pasture areas, the canonical correspondence analysis was significant (F=2.12; p=0.0018), where the first axis explained 41 % of the variance and the second axis 29 %. *Dichotomius nisus* and *T. externepunctatum* were positively related to this agroecosystem with organic matter content, with a mean of 2.0 ± 0.23 % (F=3.25; p=0.004), whereas *C. chalybaeus* was positively correlated with clay soil content (F=3.50; p=0.003). In corn crop areas, this analysis was also significant (F=2.25; p=0.003), where the first axis explained 62 % of the variance. In this environment, *D. nisus* showed positive correlation with organic matter content (F=2.25; p=0.036). For the bean cultivation area, the analysis was not significant (F=0.54; p=0.86), due to the low number of individuals collected. No correlation was observed between abundance and soil nutrient content in the agroecosystems. In regard to the biomass of the species of dung beetles observed in agroecosystems, we recorded that only the species *D. nisus* was correlated with soil properties. The canonical correspondence

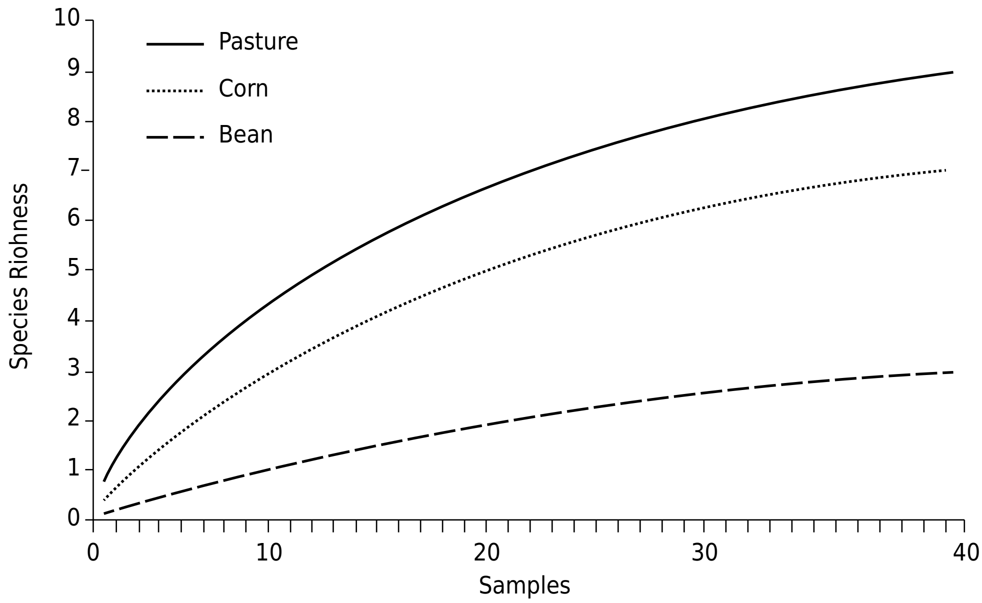

Figure 1. Species accumulation curve for dung beetles present in four agroecosystems: cattle pasture areas (pasture), corn crops (corn), and bean crops (bean), sampled from baited pitfall traps in the region of Tubarão, Santa Catarina, southern Brazil. No dung beetles were collected in sugarcane crops.

Table 3. Observed and estimated species richness calculated using the Chao 1 and Jackknife 1 estimators (with 95 % confidence intervals), total biomass (sum of all the individual masses) per agroecosystem of dung beetle communities in agroecosystems in the region of Tubarão, Santa Catarina, southern Brazil

	Pastures	Corn crop	Bean crop
Abundance (N)	81	24	5
Richness (S)	9	7	3
Estimated richness			
Chao 1	9.5 (9.0-17.2)	7.0 (7.0-8.0)	3.0 (3.0-5.3)
Jackknife 1	11.9 (10.2-13.5)	8.9 (7.0-10.9)	3.9 (3.0-4.9)
Total biomass	30.346 g	2.386 g	1.811 g

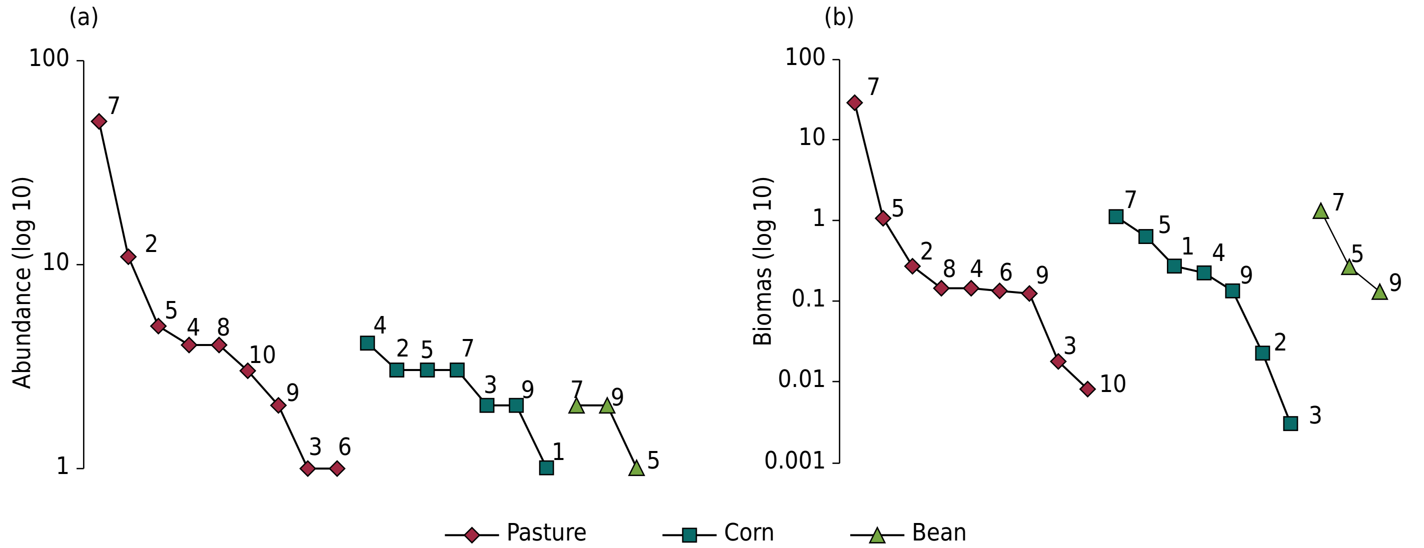

Figure 2. Relative dominance-diversity among dung beetle species present in agroecosystems in the region of Tubarão, Santa Catarina, southern Brazil. (a) Dominance-abundance per agroecosystem; and (b) dominance-biomass per agroecosystem. The numbers represent dung beetle species in table 2.

analysis was significant only for livestock grazing areas (F=3.99; p=0.001), where the first axis explained 62 % of variance and the second axis, 21 %; other agroecosystems were not significant (corn, F=1.32, p=0.321; beans, F=0.94, p=0.999). *Dichotomius nisus* was positively related to organic matter content (F=4.31; p=0.001) and P content (F=5.32; p=0.005).

DISCUSSION

The livestock environment, as expected, showed the greatest dung beetle richness, abundance, and biomass among the ecosystems studied since it provides a greater quantity of food resources (cattle feces). Because that the selection of excreta to the consumption of these organisms is closely related to the provision of resources for habitat type used (Barbero et al., 1999). Biomass reflects the contribution of dung beetles to ecological functions and thus their provision of ecosystem services, especially in regard to nutrient cycling (Nervo et al., 2014). The dominant species in pasture areas was *D. nisus*; it is a large (more than 2 cm in length) tunneler and nocturnal species from the Coprini tribe. This beetle species is important in livestock areas because it has been considered efficient in removal of cattle dung (Mariategui et al., 2001; Silva et al., 2008; Nervo et al., 2014). These characteristics suggest that *D. nisus* is the species that most contributes to the nutrient cycling process and organic matter mineralization in this environment. Species in the paracoprid (tunneler) functional group often have large body size, making them more efficient and capable of greater removal of fecal matter (Slade et al., 2007; Dangles et al., 2012). Furthermore, this species favors the soil aeration process through the digging of tunnels for resource storage and use.

The areas under corn cultivation had seven of the ten species found in this study of the region, which makes it an environment that may offer food resources to dung beetles since the stalk residue deposited attracts small rodents. The most abundant species was *C. chalybaeus*, a species from the Deltochilini tribe, with body size of around 1-cm in length; this species is a roller with diurnal habits and is frequently found in carcasses (Mittal, 1993). The low species richness and abundance in the bean crop could be due to a lack of food resources for dung beetles within this crop. The fact that no species were registered in the sugarcane crop may be attributed to the management system in these areas, in which straw is burned, a practice used by most farmers. Fire may have negative effects on species, and not only directly through animal death, but also long-term indirect effects, such as habitat loss (Armúa de Reyes et al., 2004; Bodí et al., 2012; Boulanger et al., 2013). Arellano and Castillo-Guevara (2014) reported no effect on the species richness of dung beetles in forest areas that underwent uncontrolled fires, but there have been important changes in the C/N ratio in the soil of these environments.

Our results confirm our hypothesis that the abundance and biomass of dung beetles are influenced by the physicochemical properties of the soil. The abundance and biomass of dung beetles species from the paracoprid functional group (tunnelers), *D. nisus* and *T. externepunctatum*, correlated with organic matter content in the soil, suggesting the importance of these organisms in the process of nutrient cycling. This analysis suggests that dung beetle species not only utilize environments with greater availability of resources but that they also influence soil quality. The distribution of dung beetle species in accordance with the agroecosystem demonstrated that certain species are related to certain soil characteristics. The study of this relationship is an innovative tool that allows explanation of how different soil quality compounds affect the presence of or colonization by dung beetles.

Dung beetles depend on soil porosity and moisture for nesting, and, consequently, the viability of their larvae (Osberg et al., 1993; Sowig, 2005). In our study, *C.chalybaeus,* a ball-roller species, was associated with soil texture (clay, silt, and sand) in the corn crop, possibly suggesting that the porosity and permeability of the types of soil are important in maintaining dung beetles in agroecosystems. In semideciduous forests, the structure of functional guilds is influenced by changes in the proportion of clay in the soil on a local scale. A recent study found that in clayey soils, the abundance of small paracoprid beetles was low and that of the small telecoprids was high (Silva et al., 2015). Compact soils may limit execution of this function of incorporation of organic matter performed by dung beetles; nevertheless, upon overcoming physical soil barriers, the beetles may contribute to improvement of soil chemical properties, and therefore provide plants with nutrients (Haynes and Williams, 1993). Soil tillage for crops, including pasture areas (except native pastures), modify biota and the nutrient dynamic present in the soil since it principally consists of soil aeration with a disk harrow, as well as the use of agricultural fertilizers and corrective agents. Our study shows that a few dung beetle species are influenced by the soil quality of the agroecosystem studied. Conservation of these organisms in agricultural livestock environments, together with the adoption of conservation management practices, allows maintenance of ecosystem services. Information regarding the relationship between dung beetles and physical-chemical soil properties may be an important strategy for increasing soil fertility and management of soil conservation in agroecosystems. Our findings also contribute to the study of the behavioral ecology of these organisms since knowing the relationship between physical and chemical soil conditions and the abundance of dung beetles provides an understanding of factors that may influence the nesting and allocation of resources for that group, since the soil is the environment in which these organisms live.

CONCLUSIONS

The abundance and biomass of dung beetles are influenced by the physicochemical properties of the soil in agroecosystems.

Dichotomius nisus plays an important role in the bean crops and pasture areas, refereed at the abundance and presence, moreover was the first record in this kind of agroecosystems of South of Santa Catarina.

Our results are pioneer in to relate physical-chemical properties of soils and different uses of soil (corn, bean and pastures).

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