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Moisture seasonality, soil fauna, litter quality and land use as drivers of decomposition in Cerrado soils in SE-Mato Grosso, Brazil

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ABSTRACT

In Central Brazil, over one million square kilometers of native savanna vegetation known as *Cerrado* have been cleared and converted to farmland over the past forty years. A factorial experiment was designed to assess the effects of land use, litter type, soil organisms and season on litter decay in the prevailing natural and agricultural systems (*i.e.* Cerrado remnants, grasslands and soybean croplands) in Mato Grosso. Decay rates were estimated by using the litterbag method. Two different mesh sizes were used to evaluate the effects of soil macro- and mesofauna (coarse mesh; 5 mm) and of soil microorganisms (fine; 20 μm). The original litter found in each land use area (Cerrado leaf-litter, *Brachiaria*-grass or soybean residues) was used to estimate the decay of *in situ* litter; a standard substrate (maize litter) was employed to evaluate the effect of the environment. Finally, the experiment was carried out during a dry and a rainy season to differentiate the effect of the other factors from the seasonal effect. We found that: (1) the effects of land use and management practice were only significant in the dry season; (2) decomposability of litter was not predicted by the initial C:N ratio of the litter types; (3) soil fauna contributed to the litter breakdown with 13–57%; (4) decay rates were overall higher in the rainy season; (5) all evaluated factors (in following order: season > soil organisms > litter type > land use) and their interactions explained about 70% of the variance in the decay rates in the study area. Change in land use affected litter decay mainly through a shift in the litter quality; the introduced plant species produced highly decomposable litters.

1. Introduction

Developing countries in tropical regions often obtain economic growth through the conversion of forested areas into farmland or shift between agricultural uses (DeFries et al., 2013; Matson et al., 1997). These changes affect the soil system by disrupting the nutrient cycles due to losses or high inputs of agrochemicals as well as by shifting the plant communities, and thereby altering the diversity and structure of soil fauna communities (Fernandes et al., 1997; Geissen et al., 2009; Wardle et al., 2004). Litter decomposition is one of the most important and complex processes occurring in the soil systems (Swift et al., 1979). It determines the nutrient cycling and the carbon fluxes, both storage and emissions (Harmon et al., 1999). At both global and regional scale, the factors controlling decay operate hierarchically in the following order: climate > litter quality > soil organisms (Coûteaux et al., 1995; Lavelle, 1996). Litter decay rates are sensitive to changes in the environment; therefore, they are used to assess ecosystem functions and disturbances or to compare different ecosystems or management practices (Coleman et al., 2004; Harmon et al., 1999). Standard plant materials are commonly used to isolate the effect of the environment on litter decay (Coûteaux et al., 2002; Powers et al., 2009; Wall et al., 2008).

Currently, Brazil is considered the second largest producer and exporter of soybean world-wide, concentrating its production in the savanna, locally known as *Cerrado* (Smaling et al., 2008). Nearly 55% of the original vegetation (1.1 million km^2) from the Cerrado biome has been lost since the expansion of intensive farming and cattle ranching started in the 1970s (Machado et al., 2004). Research on Cerrado soils has largely been focused on the improvement of the soil fertility and management practices for farming purposes (Carvalho et al., 2007; Goedert, 1983; Metay et al., 2007). The effects of the land use change have been studied by examining microbial activity in soils (Bresolin et al., 2010; Viana et al., 2011; Vinhal-Freitas et al., 2013), comparing soil fauna communities (Benito et al., 2004; Marchão et al., 2009) and, more recently, by characterising microbial communities through DNA sequences (Lammel et al., 2015; Rampelotto et al., 2013). In general, studies on litter decomposition in Cerrado areas are scarce, particularly those comparing natural *vs* agricultural areas. Most

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studies involve either decay in natural vegetation (Jacobson et al., 2011; Peres et al., 1983; Silva et al., 2007; Silva and Vasconcelos, 2011) or in agricultural areas (Oliveira et al., 2002; Torres et al., 2015), but not in both.

The state of Mato Grosso is the leading producer of soybean and cattle in Brazil, with 8.6 million hectares planted with soybean (IBGE, 2015a) and 28.6 million head (IBGE, 2015b), respectively. There is an urgent need to study the consequences of these changes in land use on litter decomposition because litter decay directly and indirectly influences nutrient storage and release. To date, no study has compared the effects of land use on the decomposition process between the Cerrado vegetation and the two main land conversion-types, namely grassland and cropland. Hence, the aim of this study was to assess the effects of land use, litter quality, soil organisms and climate seasonality on litter decay rates in farms in Mato Grosso. For this purpose, we tested four hypotheses: (i) the land use influences litter decomposition; (ii) litter of lower C:N ratio decomposes more rapidly; (iii) soil fauna accelerates the breakdown of litter; and (iv) decay rates are faster in the rainy season in comparison to the dry season.

2. Materials and methods

2.1. Research area

The study was carried out on three farms in the State of Mato Grosso in the Central-West Region of Brazil from May 2012 to April 2013. Two farms were located in the municipality of Campo Verde (SL, RE) and one in Primavera do Leste (IG), which are situated between 100 and 260 km southeast from the capital of Cuiabá (Table 1).

According to Köppen climate classification, this region is characterised by a strongly seasonal tropical climate, Aw (Cole, 1960). During the course of the experiment the mean monthly temperature was 23.3 °C. The accumulated rainfall was 355 mm and 1190 mm in the dry (May–October) and rainy (November–April) seasons, respectively (data provided by the National Institute of Meteorology – INMET Brazil, weather station A912 at Campo Verde).

The farms are typical for the region: all were founded in the mid-1980s; Cerrado vegetation was cleared to a great extent; rainfed rice was grown for 1–3 years; pastures were established afterwards, then gradually converted to arable land; and have nearly 20-year history of soybean/maize double-crop system under minimum or no-tillage. Hence, we selected the predominant land uses for our study: remnants of Cerrado (*cerrado stricto sensu*), grasslands (genus *Brachiaria* sp.) and soybean/maize croplands.

2.2. Characterisation of study sites

2.2.1. Croplands

Farms are highly mechanised and profit from precision agriculture technologies. The planting cycle starts with soybean during the onset of rains (mid-September to mid-October) and is harvested in early to mid-February. Maize is planted directly after the soybean and harvested from mid-June to late July. Annual agricultural inputs include: dolomitic lime (1 t ha^{-1}); peat-based inoculant for soybean seeds and PK fertilisers (250–400 kg ha^{-1}); NPK (100–200 kg ha^{-1}) and urea (120 kg ha^{-1}) for maize; and additionally, depending on the need of the crop, 1–3 doses of herbicides and fungicides (1–2 lt ha^{-1} per crop).

2.2.2. Grasslands

Only one grassland (SLG) was used for cattle ranching (1.2 heads ha^{-1}), the other two were left fallow since the late 1990s. Management practices in SLG included liming (1 t ha^{-1} 5 yr) and reseeding every 7–10 years.

2.2.3. Cerrado

Areas were not suitable for cultivation and, thus, left for conservation. The Brazilian Forest Code binds farmers to keep a permanent forest reserve (*Reserva Legal*) of 35% of the total farm area. Still, all areas have been disturbed by cattle grazing, fuelwood collection and fires.

Soils are predominantly Red-Yellow Latosols (Brazilian System of Soil Classification), equivalent to Ferralsols (WRB) and Oxisols (USDA) (Ker, 1997). Soil texture was sandy clay or clay, only the Cerrado at farm SL was distinctively sandy (Table 2). Bulk density ranged from 0.90 (clayed soils) to 1.48 g cm^{-3} (sandy soils). The soil moisture gradient in farms SL and RE was: Cerrado < grasslands < croplands; whereas both cropland and Cerrado had similar soil moisture content that were lower than grasslands in farm IG. All soils were acidic. Cerrado sites showed the lowest pH-values and croplands the highest. Nutrient contents and CEC were low in general; high levels of P in croplands were associated to fertilisation.

2.3. Experimental design

We designed an experiment to compare litter breakdown across three land use systems by means of litterbags (Bocock and Gilbert, 1957) and to determine whether the land use or selected environmental factors had a stronger effect on decay rates. Even though several authors have questioned the accuracy of decay rates estimated through the litterbag method (Bradford et al.,

Table 1
Description of the study sites in southeastern Mato Grosso, Brazil.

Mun[a]	Farm[b]	Total area (ha)	Land use	Site[c]	Area (ha)	Altitude (m asl)	Coordinates
CV	*Santa Luzia* (SL)	10,000	Cerrado	SLC	85	771	15°42′01” S, 55°21′26” W
			Grassland	SLG	4,000	754	15°42′54” S, 55°20′18” W
			Cropland	SLA	2,500	746	15°43′47” S, 55°20′57” W
CV	*Rio Engano* (RE)	1,422	Cerrado	REC	140	663	15°23′36” S, 54°50′21” W
			Grassland	REG	270	648	15°23′29” S, 54°51′09” W
			Cropland	REA	825	652	15°22′07” S, 54°50′49” W
PL	*Ilha Grande* (IG)	1,150	Cerrado[d]	IGC	280	605	15°30′08” S, 54°03′56” W
			Grassland	IGG	3	593	15°29′37” S, 54°07′30” W
			Cropland	IGA	1,112	603	15°29′40” S, 54°08′11” W

[a] Mun: municipality (CV: *Campo Verde*; PL: *Primavera do Leste*).
[b] Farm name and abbreviation in parentheses.
[c] Site code was created by the initials of the farm and the first letter of the land use. In the case of croplands, the letter “A” stands for agricultural area.
[d] Belongs to the neighbouring farm “*Falcão II*”.