Journal of Environmental Management 114 (2013) 505–511

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Combined effects of leaf litter and soil microsite on decomposition process in arid rangelands

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ARTICLE INFO

Article history:
Received 20 April 2012
Received in revised form
25 September 2012
Accepted 3 October 2012
Available online 24 November 2012

Keywords:
Grazing disturbance
Perennial grasses
Nitrogen
Shrubs
Secondary compounds
Vegetation states

ABSTRACT

The objective of this study was to analyze the combined effects of leaf litter quality and soil properties on litter decomposition and soil nitrogen (N) mineralization at conserved (*C*) and disturbed by sheep grazing (*D*) vegetation states in arid rangelands of the Patagonian Monte. It was hypothesized that spatial differences in soil inorganic-N levels have larger impact on decomposition processes of non-recalcitrant than recalcitrant leaf litter (low and high concentration of secondary compounds, respectively). Leaf litter and upper soil were extracted from modal size plant patches (patch microsite) and the associated inter-patch area (inter-patch microsite) in *C* and *D*. Leaf litter was pooled per vegetation state and soil was pooled combining vegetation state and microsite. Concentrations of N and secondary compounds in leaf litter and total and inorganic-N in soil were assessed at each pooled sample. Leaf litter decay and soil N mineralization at microsites of *C* and *D* were estimated in 160 microcosms incubated at field capacity (16 month). *C* soils had higher total N than *D* soils (0.58 and 0.41 mg/g, respectively). Patch soil of *C* and inter-patch soil of *D* exhibited the highest values of inorganic-N (8.8 and 8.4 μg/g, respectively). Leaf litter of *C* was less recalcitrant and decomposed faster than that of *D*. Non-recalcitrant leaf litter decay and induced soil N mineralization had larger variation among microsites (coefficients of variation = 25 and 41%, respectively) than recalcitrant leaf litter (coefficients of variation = 12 and 32%, respectively). Changes in the canopy structure induced by grazing disturbance increased leaf litter recalcitrance, and reduced litter decay and soil N mineralization, independently of soil N levels. This highlights the importance of the combined effects of soil and leaf litter properties on N cycling probably with consequences for vegetation reestablishment and dynamics, rangeland resistance and resilience with implications for management and conservation.

1. Introduction

A substantial fraction of the annual net primary production senesces and enters to the decomposition subsystem in most terrestrial ecosystems (McNaughton et al., 1989). Plant litter decomposition and mineralization are important processes for ecosystem functioning regulating nutrient availability and carbon cycling (Lambers et al., 2000). The rates of these processes depend on climate, quality and composition of litter mixtures, and soil biotic and abiotic components (Ald, 2003).

In most arid and semiarid ecosystems vegetation displays a patchy structure consisting of dense plant patches dominated by shrubs and perennial grasses distributed on a matrix of scattered vegetation or bare soil (Whitford, 2002). Both life forms differ in structural and physiological traits and in mechanisms of N conservation contributing with different amount and quality of leaf litterfall (Aerts and Chapin, 2000; Campanella and Bertiller, 2008; Carrera et al., 2009). Shrubs with long-lasting leaves and low leaf N resorption rates produce recalcitrant leaf litter with high concentration of secondary compounds such as lignin and soluble phenolics (Aerts and Chapin, 2000; Carrera and Bertiller, 2010; Carrera et al., 2009; Moreno et al., 2010). In contrast, perennial grasses with short lived leaves, produce non-recalcitrant leaf litter with low concentration of secondary compounds (Aerts and Chapin, 2000; Campanella and Bertiller, 2008; Carrera et al., 2005). High concentrations of secondary compounds may reduce litter decomposability by either toxic effects on microorganisms or by retarding microbial breakdown of organic matter (Lambers et al., 2000). Accordingly, some plant chemical traits reflecting

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http://dx.doi.org/10.1016/j.jenvman.2012.10.059

physiological and biochemical adaptations to the environment could be used as predictors of rates of litter decomposition and nutrient release (Lambers et al., 2000; Xu and Hirata, 2005). However, in litter mixtures, chemical properties of single species could have strong effects on decomposition and nutrient release enhancing or retarding the rates expected by the relative contribution of individual species to litter mixtures (Gartner and Cardon, 2004; Pérez-Harguindeguy et al., 2000; Wardle, 2002).

Arid and semiarid ecosystems are usually grazed by domestic herbivores at low stocking rates (Reynolds et al., 1997). Selective grazing reduces plant cover of preferred species and induces the replacement of herbaceous plants by long-lived evergreen woody plants with slow growth rates (Bertiller and Ares, 2011; Bertiller and Bisigato, 1998; Schlesinger et al., 1996). This in turn, leads to increasing contribution of shrubs to leaf litterfall and recalcitrance of leaf litter mixtures (Carrera et al., 2008, 2009). Accordingly, grazing could indirectly affect the input and output fluxes to soil organic matter (Milchunas and Lauenroth, 1993). Moreover, grazers could also have direct effects on soil properties increasing bulk density by trampling or increasing labile N concentration through urine and faeces inputs (Prieto et al., 2011; Steffens et al., 2008). The combined effects of changes in soil and litter mixture properties induced by grazers may affect the metabolic functioning of soil microorganism communities thus controlling the rates of leaf litter decomposition and nutrient release in grazed ecosystems (Carrera et al., 2009; Li et al., 2011; Pucheta et al., 2004; Whitford, 2002). Since both animal depositions and leaf litterfall are not homogeneously spatially distributed, different combinations of soil and litter properties could induce small spatial differences in soil resource levels which could differentially affect plant processes (Luzuriaga and Escudero, 2008). This is an important issue related to processes leading to plant recovery (i.e. emergence, establishment, growth) and to ecosystem resistance and resilience (Gregory et al., 2009) that has been scarcely explored in grazed ecosystems. The objective of this study was to evaluate the combined effects of leaf litter quality and soil properties on leaf litter decomposition rates and soil potential N mineralization in conserved and disturbed by grazing vegetation states in arid rangelands of the Patagonian Monte. It was hypothesized that spatial differences in soil inorganic-N levels have larger impact on decomposition processes of non-recalcitrant than recalcitrant leaf litter (low and high concentration of secondary compounds, respectively). It was predicted that leaf litter from conserved vegetation states would be less recalcitrant and its decomposition rates and N mineralization in the associated soil would have larger variation among soil microsites differing in the levels of inorganic-N than leaf litter from disturbed by grazing vegetation states.

2. Materials and methods

2.1. Study area

The study was carried out in the southern portion of the Monte Phytogeographic Province (Patagonian Monte), Argentina (42° 39′S, 65° 23′W, 115 m a.s.l). The mean annual temperature is 13.7 °C and the mean annual precipitation is 235.9 mm (22-year average, Centro Nacional Patagónico, 2009). Soils are a complex of Typic Petrocalcids- Typic Haplocalcids (del Valle, 1998; Soil Survey Staff, 1998). Vegetation corresponds to the shrubland of *Larrea divaricata* Cav. and *Stipa* spp. (Soriano, 1950). Plant canopy covers less than 40% of the soil and presents a random patchy structure (Bisigato and Bertiller, 1997; Mazzarino et al., 1998). These ecosystems have been grazed by sheep since the beginning of the last century with a historical stocking rate of ca. 0.10–0.14 sheep/ha (Ares et al., 1990; Bertiller et al., 2002). The study was carried out on an area of 2500 ha corresponding to a floristically homogeneous vegetation stand submitted to continuous grazing all year round with a stocking rate of ca. 0.14 sheep/ha (Bertiller et al., 2002). Within the area, two sites ca. 2.5 h each were selected. One of them corresponded to a site excluded from domestic herbivores since 1993. The other was a grazed site with signs of high grazing disturbance adjacent to the site excluded from grazing. The selection of this latter was based on sheep fecal counts (Bisigato and Bertiller, 1997), perennial grasses cover (Bertiller and Bisigato, 1998; Carrera et al., 2008; Larreguy et al., 2012), soil indicators (Mazzarino et al., 1998), and remote sensing analyses (Ares et al., 2003). Disturbance by sheep grazing led to plant cover reduction, species substitution within the same plant life form, and plant life form replacement, especially perennial grasses by evergreen shrubs (Bertiller and Ares, 2008; Bertiller and Bisigato, 1998; Bertiller et al., 2002; Bisigato and Bertiller, 1997; Carrera et al., 2008) as well as to reductions in soil N fertility (Carrera et al., 2008). Both sites are representative of conserved (*C*) and disturbed by grazing (*D*) vegetation states (*sensu* Westoby et al., 1989) of the Patagonian Monte (Bertiller et al., 2002; Bisigato and Bertiller, 1997). In terms of reversibility of vegetation dynamics and ecological thresholds, *D* could be considered as an overgrazed site (Bertiller and Bisigato, 1998; Milchunas, 2006; Westoby et al., 1989). Both vegetation sites differed in canopy traits. Total, shrub, and grass covers were significantly higher at *C* (24.8, 18.8, and 5.8%, respectively) than *D* (13.7, 12.7, and 0.9%, respectively), but the relative cover of shrubs was significantly higher at *D* than *C*. The floristic list was highly similar between *C* and *D* (21 species and 22 species, respectively) with nineteen species in common (Table 1) but the relative dominance of shrub and perennial grass species changed between *C* and *D*. All perennial grass species had lower cover at *D* than at *C*. *Nassella tenuis* was the dominant perennial grass at *C* while *Pappostipa speciosa* dominated at *D*. Twelve shrub species had lower cover at *D* than at *C*. Six shrub species (*Chuquiraga avellaneadae, Chuquiraga erinacea, Junellia seriphioides, Larrea nitida, Prosopis alpataco* and *Schinus johnstonii*) and one perennial herb (*Aster haplopappus*) had higher cover at *D* than at *C*, but this increase did not compensate the decrease in cover of the other shrub species (Carrera et al., 2008). Both vegetation states had leguminous species (three at *C* and two at *D*), however *C* had higher cover of leguminous species than *D* (2.7 and 0.1%, respectively, Table 1).

2.2. Litterbag decomposition experiment and chemistry of leaf litter and soil

Sixty microsites were randomly selected within each vegetation state, a half of them (30) corresponded to plant patches of modal size (1.8–2.4 m diameter) and the other half (30) to the associated inter-patch areas of bare soil ca. 1 m diameter (Bisigato and Bertiller, 1997; Prieto et al., 2011). This sampling defined four microsite types with different characteristics: microsite 1 and 3 (patch microsites in *C* and *D*, respectively) and microsites 2 and 4 (inter-patch microsites in *C* and *D*, respectively).

Leaf litter accumulated on the soil was collected in plots of 0.50 × 0.25 m at each microsite during the period March–June 2008. Leaf litter was cleaned of attached soil particles, pooled per vegetation state (two pooled litter types: litter of *C* and litter of *D*) and dried at 45 °C for 48 h. Simultaneously, the upper 2 cm of soil was extracted with a metallic tube (2 cm height and 10 cm in diameter) at the center of the plot at each microsite. Soil samples were air-dried, sieved to 2 mm and pooled per microsite (four pooled soil samples, one per microsite). One hundred and sixty microcosms were constructed by filling glass flasks (6 cm diameter, 13 cm height) with 100 g of air-dried soil of each microsite (40 microcosms per microsite). A litterbag (5 cm diameter, 0.3 mm