Soil Biology & Biochemistry 42 (2010) 56–64

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

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

Impact of litter quality on mineralization processes in managed and abandoned pasture soils in Southern Ecuador

Karin Potthast, Ute Hamer*, Franz Makeschin

Institute of Soil Science and Site Ecology, Dresden University of Technology, Piennerstr. 19, 01737 Tharandt, Germany

ARTICLE INFO

Article history:
Received 22 May 2009
Received in revised form
22 September 2009
Accepted 28 September 2009
Available online 8 October 2009

Keywords:
^{13}C natural abundance
Priming effect
Land use change
Pastures
Soil microbial community structure
Bracken fern
Setaria sphacelata

ABSTRACT

Tropical regions are currently undergoing remarkable rates of land use change accompanied by altered litter inputs to soil. In vast areas of Southern Ecuador forests are clear cut and converted for use as cattle pastures. Frequently these pasture sites are invaded by bracken fern, when bracken becomes dominant pasture productivity decreases and the sites are abandoned. In the present study implications of invasive bracken on soil biogeochemical properties were investigated. Soil samples (0–5 cm) were taken from an active pasture with *Setaria sphacelata* as predominant grass and from an abandoned pasture overgrown by bracken. Grass (C_4 plant) and bracken (C_3 plant) litter, differing in C:N ratio (33 and 77, respectively) and lignin content (Klason-lignin: 18% and 45%, respectively), were incubated in soils of their corresponding sites and vice versa for 28 days at 22 °C. Unamended microcosms containing only the respective soil or litter were taken as controls. During incubation the amount of CO_2 and its $\delta^{13}C$-signature were determined at different time intervals. Additionally, the soil microbial community structure (PLFA-analysis) as well as the concentrations of KCl-extractable C and N were monitored. The comparison between the control soils of active and abandoned pasture sites showed that the massive displacement of Setaria-grass by bracken after pasture abandonment was characterized by decreased pH values accompanied by decreased amounts of readily available organic carbon and nitrogen, a lower microbial biomass and decreased activity as well as a higher relative abundance of actinomycetes. The $\delta^{13}C$-signature of CO_2 indicated a preferential mineralization of grass-derived organic carbon in pasture control soils. In soils amended with grass litter the mineralization of soil organic matter was retarded (negative priming effect) and also a preferential utilization of easily available organic substances derived from the grass litter was evident. Compared to the other treatments, the pasture soil amended with grass litter showed an opposite shift in the microbial community structure towards a lower relative abundance of fungi. After addition of bracken litter to the abandoned pasture soil a positive priming effect seemed to be supported by an N limitation at the end of incubation. This was accompanied by an increase in the ratio of Gram-positive to Gram-negative bacterial PLFA marker. The differences in litter quality between grass and bracken are important triggers of changes in soil biogeochemical and soil microbial properties after land use conversion.

1. Introduction

Southern Ecuador currently undergoes deforestation at one of the highest rates in South America (Mosandl et al., 2008). Over the past several decades, vast areas of forest have been converted into pastures for economic reasons by slash and burn practice. Frequently, pastures have been overgrown by tropical fern (bracken) which causes the loss of productive pastures towards abandoned pasture sites. These bracken-dominated sites are extremely difficult to recultivate, which is also the reason why farmers are forced to once more convert untouched rainforest to arable land (Beck et al., 2008). Thus, the development of sustainable management strategies for already existing pasture land (Hamer et al., 2009) and the development of recultivation strategies for abandoned pastures like re-establishment of pastures (Beck et al., 2008) or afforestation with valuable native tree species (Günter et al., 2009) is necessary. For successful recultivation an adequate nutrient supply of the plants is crucial. It is known that human-induced land use changes in the tropics strongly affect the potential of carbon and nutrient cycling of terrestrial ecosystems (Lal, 2004). In the mountain rainforest region of Southern Ecuador, the described land use changes had an impact on the stocks of soil organic carbon (SOC) and nitrogen. The SOC stocks of old pastures (about 50 years) increased significantly in the mineral top soils (0–30 cm depth) compared to natural forest. Stable

* Corresponding author. Tel.: +49 35203 3831805; fax: +49 35203 3831388.
E-mail address: hamer@forst.tu-dresden.de (U. Hamer).

0038-0717/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.soilbio.2009.09.025

C-isotope signatures ($\delta^{13}C$) switched from C_3 (forest) to C_4 (pasture grass) and again to C_3 (bracken) vegetation, indicating that this increase was due to an accumulation of new pasture derived C_4-SOC (Makeschin et al., 2008). Total stocks of forest-derived C_3-SOC remained stable when the depth interval of 0–30 cm depth is considered. 10 years after pasture abandonment the SOC stocks in the mineral topsoil declined again to forest C stock levels (Makeschin et al., 2008). Important parameters influencing the development of SOC stocks are alterations in vegetation structure and composition and the associated changes in quantity and quality of litter input to the soil. The higher input of root litter in pastures with *Setaria sphacelata* (Rhoades et al., 2000) is assumed to contribute to the observed SOC increase. Furthermore, the quality of the litter input, e.g. the access of easily available organic substrates and nutrients which soil microbes metabolize either directly for biomass growth and/or for energy requirements, has an impact on soil organic matter (SOM) build up or decomposition.

The main litter types in the considered ecosystem of the study area are grass litter from *S. sphacelata* and bracken litter from *Pteridium arachnoideum*, which are different in quality. According to the review of Maharning et al. (2009), grass usually provides organic C and N available for rapid microbial decomposition. In contrast, bracken is known to contain also substances which are at least toxic to cattle (Potter and Baird, 2000) and might affect decomposition processes in soils (Engel et al., 2007; Smart et al., 2007). Differences in quality of organic compound inputs to the soil might have an impact on ecosystem functioning in the long-term. Thereby, Smart et al. (2007) detected a decrease in the easily available organic C and N amounts after the invasion of bracken in pasture sites in UK uplands. It has also been shown that an addition of plant residues to soil can temporarily either accelerate (Perelo and Munch, 2005; Bernard et al., 2007) or retard (Nicolardot et al., 2007) SOC mineralization, which is referred to as a positive or negative priming effect, respectively (Jenkinson et al., 1985; Kuzyakov et al., 2000). Furthermore, microorganisms as basic mediators of decomposition processes in soils have been shown to respond to altered litter amendments by changing the composition of their community structure as well as their mineralization activities. Nicolardot et al. (2007) incorporated residues of wheat straw and young rye differing in specific analytical characteristics, such as, C:N ratio, water-soluble C, polysaccharide and lignin fractions. After the loss of 50% dry mass of added residues to soil, the authors detected that not only the soil's C and N pools, microbial biomass content and mineralization processes were changed, but also shifts in the structure of the soil microbial community were induced within one month of incubation depending on the litter decomposition rates. Considering different studies, some general patterns in microbial response to litter addition are evident. Hu et al. (1999), Marschner et al. (2003) and Bastian et al. (2009) showed that addition of fresh organic substrate with a high C and/or nutrient availability to the soil initially activated a copiotrophic microbial community. High growth rates under this ready supply of substrate were associated with this community, with Gram-negative bacteria belonging to this group. As substrate quantity and/or quality decreased including a decline of nutrient availability, the influence of oligotrophic microorganisms increased. Gram-positive bacteria, as a part of this group, were characterized by slow growth rates and were able to adapt to poor nutrient conditions (Fierer et al., 2003). Using ^{13}C-PLFA analysis direct evidence of links between substrate utilization and certain microbial groups has been provided (Kramer and Gleixner, 2008; Nottingham et al., 2009).

Regarding land use changes in tropical ecosystems, the lasting impact of altered litter entering the soil on soil microbial processes is not yet well understood. Generally, knowledge is scarce about decomposition rates of grass and bracken litter in soils of tropical ecosystems, the effects on the soil microbial community structure and their function and/or the types or amounts of SOC consumed and respired. To quantify the impact of differences in litter quality on mineralization processes, bracken (*P. arachnoideum*) and grass (*S. sphacelata*) litter – differing in their biochemical compounds as characterized in the present study by their lignin content, C:N and C:P ratio as well as by their availability of organic C and N sources – were incorporated in top soils of their corresponding origin sites and vice versa. Thereby, the specific objectives of this study were (1) to quantify how far the quality of the different litter input to soil is responsible for possible shifts in the microbial community structure, (2) to examine if changes in mineralization patterns (litter versus SOM) are related to compositional changes of the soil microbial community, and (3) to determine the proportion of mineralized C_3- versus C_4-derived SOC after land use change.

2. Materials and methods

2.1. Study site and sampling

The study area is situated in the mountain rainforest region of the Southern Ecuadorian Andes, placed around the San Francisco joint research station (ECSF, 3°58′ S and 79°04′ W) halfway between the two provincial capitals Loja and Zamora, at an altitude of 2000 m above sea level. At this elevation the local climate is characterized by a mean annual precipitation of 2176 mm and a mean annual air temperature of 15.3 °C. There is a less humid period between September and December, although mean monthly rainfall never falls below 100 mm (Bendix et al., 2006). Since several decades slash and burn practice has been used to establish cattle pastures with *S. sphacelata* (Schumach) as the dominant grass species. On the pasture land the fire-tolerant, tropical bracken *P. arachnoideum* (Kaulf) (C_3 plant species) often spreads out seriously after repeated burning which finally results in an abandonment of these pastures (Beck et al., 2008). In 2007 samples were taken from an actively managed pasture with Setaria-grass covering 98% of the site and from an abandoned pasture, 80% overgrown by bracken. The pasture site has been used as cattle pasture for 17 years and the abandoned site is dominated by bracken-bush vegetation over the last 10 years. The soils of the sites were classified as Cambisols according to WRB (2006) with a similar soil texture (29% sand and 39% silt). The parent material is formed by quartzites, sandstones, metasiltstones and layers of clay schist and phyllite (Makeschin et al., 2008). At both site types, four replicate plots were chosen. Above-ground biomass of the grass and of the bracken was collected and cut into pieces (2 cm), referred to as grass and bracken litter in the following. Ten mineral soil samples were randomly taken with a soil corer (5 cm in diameter) from 0 to 5 cm depth. For analyses, these 10 sub-samples of each plot were thoroughly mixed and all visible root fragments and stones were immediately sorted out by hand. An aliquot of each litter and soil sample was dried and ground to analyze organic carbon (OC) and total nitrogen (TN) with a CNS-Analyzer (vario EL III/elementar, Heraeus). Furthermore, moisture content (105 °C) and soil pH (H_2O) were determined. To characterize the differences in litter quality in more detail, the lignin content (Klason-lignin) (Theander and Westerlund, 1986) as well as the total phosphorus content (P) had been analyzed in advance (Table 1).

2.2. Soil microcosm experiment

In the laboratory, a microcosm experiment was conducted over 28 days at 22 °C in darkness to examine the impact of different litter quality on soil biogeochemical parameters at different time intervals. The experiment comprised four replicates of unamended microcosms of soils and litters which served as controls, as well as of soil