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Comparing how land use change impacts soil microbial catabolic respiration in Southwestern Amazon

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ABSTRACT

Land use changes strongly impact soil functions, particularly microbial biomass diversity and activity. We hypothesized that the catabolic respiration response of the microbial biomass would differ depending on land use and that these differences would be consistent at the landscape scale. In the present study, we analyzed the catabolic response profile of the soil microbial biomass through substrate-induced respiration in different land uses over a wide geographical range in Mato Grosso and Rondônia state (Southwest Amazon region). We analyzed the differences among native areas, pastures and crop areas and within each land use and examined only native areas (Forest, Dense Cerrado and Cerrado), pastures (Nominal, Degraded and Improved) and crop areas (Perennial, No-Tillage, Conventional Tillage). The metabolic profile of the microbial biomass was accessed using substrate-induced respiration. Pasture soils showed significant responses to amino acids and carboxylic acids, whereas native areas showed higher responses to malonic acid, malic acid and succinic acid. Within each land use category, the catabolic responses showed similar patterns in both large general comparisons (native area, pasture and crop areas) and more specific comparisons (biomes, pastures and crop types). The results showed that the catabolic responses of the microbial biomass are highly correlated with land use, independent of soil type or climate. The substrate induced respiration approach is useful to discriminate microbial communities, even on a large scale.

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Introduction

The growing demand for food, fiber and biofuels has led to many environmental problems and primarily reflect the occupation of the world's greatest agricultural frontier: the border between the Amazon rainforest and the Cerrado (savanna) of central Brazil.[1] Generally, the flat topography eases the mechanization and incentivizes the occupation of this region. The southwestern Amazon, particularly the states of Rondônia (RO) and Mato Grosso (MT), still practice deforestation for agricultural land use.[2] The intensive land use invariably has negative effects on both the environment and agricultural productivity when conservation practices are not adopted.[3,4] Interest in the maintenance of soil quality, consistent with Karlen et al.,[5] is essential for the sustainability of these new agricultural areas.

Increasing evidence has shown that soil microbial attributes are potential early indicators of the changes in soil quality because these parameters are more sensitive than are the chemical and physical properties of soil.[6,7] The microbial biomass has been characterized as a sensitive index for changes in the soil organic carbon that result from management and land use. Initially, microbial biomass undergoes fluctuations until it reaches a new equilibrium.[8] One common method for measuring the metabolic function of soil microorganisms is the catabolic response profile.[9,10] According to San Miguel et al.,[11] analyzing the functional and catabolic diversity is important because it is difficult to infer whether some soil functions have been lost solely based on changes in genetic diversity. Stevenson et al.[12] showed different patterns in the catabolic capacity of the microbial community under forests and pastures in New Zealand.

In most land uses under agricultural practices (plowing, fertilizing, liming, pesticide application and other inputs), the available soil niches might be affected. Each change represents a renewal of selection pressure, which favors some components of the microbial community while eliminating others, thereby relocating the equilibrium between populations. Microbial diversity reduction implies the loss of species that metabolize certain functional groups, which results in a decrease in the resilience of the system.[13] The aim of the present study was to increase the current knowledge concerning the impact of land use and land use changes on the metabolic capacity of the soil microbial biomass. Therefore, the objective of the present study was to compare the functional diversity of the soil microbial biomass in the natural vegetation prior to human interference and after land use changes. To this end, we sampled native areas, pastures and agricultural areas in the Southwest Amazon Region.

Materials and methods

Study area

The study area focuses on the states of Rondônia and Mato Grosso, which form a transitional region between the Amazon Basin and the highlands of the Brazilian Central Plateau. The regional climate varies according to latitude and is characterized as a humid tropical regime with short dry seasons. The sites covering the main bio and geo-climatic zones of the States of Rondônia and Mato Grosso (Fig. 1) were selected according to the Intergovernmental Panel for Climate Changes "Guidelines for National Greenhouse Gas Inventories".[14] The delimitation of the zones was performed using the Geographic Information System ArcGis 9.0 with combined information on soils, native vegetation, geology, climate and relief. This methodology generated relatively homogeneous areas, thus facilitating the extrapolation of the microbiological parameters for the entire region. In each of the 11 zones, two sites were randomly selected, totaling 22 sampling points (Fig. 1). In all sites, we identified and sampled soil from one native area, one pasture and one agricultural area, totalizing 66 sampling points. In these locations, the soil of native systems was sampled to determine chemical, physical and microbiological attributes. The general characteristics of each ecoregion are provided in Table 1 (adapted from Maia et al.[15]) and in Online Appendix 1.

Soil samples collection

Soil cores were collected at 0–10 cm depths in five replicates from each area, for a total of 330 samples (110 samples in each management system). The soil samples were broken apart and sieved through a 2-mm mesh to remove rocks and plant fragments. Native areas were denominated Forest ($n = 60$); Cerrado ($n = 25$), which was defined as the tropical savanna, species-rich dense vegetation of shrubs and trees, 8–10 m high, with a grass undergrowth[16]; and Dense Cerrado or "Cerradão" ($n = 25$), which was similar to a woodland savannah, with trees up to 20 m high. The pastures were described as Improved ($n = 25$) when at least one improvement (fertilizer or lime application, irrigation) was received; Nominal ($n = 25$) when reasonable productivity was maintained, despite no improvements occurring; and Degraded ($n = 60$) when the typical management was received and a reduction in productivity due to weed infestation, bare soil and/or soil erosion.[15] The agricultural sites were divided into Conventional-Tillage ($n = 70$) when plant residue was incorporated into the soil and aggregates were routinely disrupted through tillage (physical release of protected organic matter); No-tillage ($n = 20$); and perennial crops ($n = 20$).

Substrate-induced respiration (SIR)

Estimates of the catabolic diversity in the soil microbial community were obtained based on the short-term respiratory responses of soil samples, consistent with Degens and Harris.[9] Substrates (as 2 mL solution) were added to a 1-g equivalent dry weight of soil in MacCartney bottles sealed with vacutainer stoppers. The following substrates were included in this analysis: 2 amines (glutamine and glucosamine), 6 amino acids (arginine, glutamic acid, asparagine, histidine, lysine and serine), 2 carbohydrates (glucose and mannose) and 12 carboxylic acids (citric acid, ascorbic acid, gluconic acid, fumaric acid, malonic acid, malic acid, ketoglutaric acid, ketobutyric acid, pantothenic acid, quinic acid, succinic acid and tartaric acid). An analysis with water was also performed. The CO_2 flux from each sample was measured using an IRGA (LICOR-6262 Model) after incubation for 4 h at 25 °C.