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# Short-term changes in nitrogen availability, gas fluxes ($CO_2$, NO, $N_2O$) and microbial biomass after tillage during pasture re-establishment in Rondônia, Brazil

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## Abstract

Anthropogenic conversion of primary forest to pasture for cattle production is still frequent in the Amazon Basin. Practices adopted by ranchers to restore productivity to degraded pasture have the potential to alter soil N availability and N gas losses from soils. We examined short-term (~35 days) effects of tillage prior to pasture re-establishment on soil N availability, $CO_2$, NO and $N_2O$ fluxes and microbial biomass C and N under degraded pasture at Nova Vida ranch, Rondônia, Brazilian Amazon. We collected soil samples and measured gas fluxes in tilled and control (non tilled pasture) 12 times at equally spaced intervals during October 2001 to quantify the effect of tillage. Maximum soil $NH_4^+$ and $NO_3^-$ pools were 13.2 and 6.3 kg N $ha^{-1}$ respectively after tillage compared to 0.24 and 6.3 kg N $ha^{-1}$ in the control. Carbon dioxide flux ranged from 118 to 181 mg C–$CO_2$ $m^2$ $h^{-1}$ in the control (non-tilled) and from 110 to 235 mg C–$CO_2$ $m^2$ $h^{-1}$ when tilled. Microbial biomass C varied from 365 to 461 $\mu g\ g^{-1}$ in the control and from 248 to 535 $\mu g\ g^{-1}$ when tilled. The values for $N_2O$ fluxes ranged from 1.22 to 96.9 $\mu g$ N $m^{-2}$ $h^{-1}$ in the tilled plots with a maximum 3 days after the second tilling. Variability in NO flux in the control and when tilled was consistent with previous measures of NO emissions from pasture at Nova Vida. When tilled, the NO/$N_2O$ ratio remained $<1$ after the first tilling suggesting that denitrification dominated N cycling. The effects of tilling on microbial parameters were less clear, except for a decrease in $qCO_2$ and an increase in microbial biomass C/N immediately after tilling. Our results suggest that restoration of degraded pastures with tillage will lead to less C matter, at least initially. Further long-term research is needed.
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*Keywords:* Tillage; Nitrogen; Gas fluxes; Pasture re-establishment; Amazon; Microbial biomass; Brazil

## 1. Introduction

Dramatic land use changes have occurred in the tropics (Foley et al., 2005), especially in Central and South America, where deforestation has converted forests to pastures at an annual rate of ~25,000 $km^2$ in

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the last decades (William and Turner, 1994). Within the Legal Amazon region of Brazil, conversion of primary forest to pasture is still frequent, with the highest proportion of area deforested found in the state of Rondônia (INPE, 2004).

Current pasture management practices common in Rondônia have resulted in wide-spread soil degradation and loss of productivity (Passianoto et al., 2003). Today researchers and ranchers in Rondônia are working to restore pasture productivity. Although a variety of management tools are available for restoration (Kluthcouski et al., 1991), tillage is the most common restoration practice in this region.

Many studies have shown that tillage affects the dynamics of C and N in a number of different ways: through alteration of soil structure (Kristensen et al., 2000; Six et al., 2004) and alteration of the factors (temperature, moisture, nitrogen availability) that control soil N transformation processes (Matson et al., 1998; Davidson et al., 2000b; Garcia-Montiel et al., 2001). Tillage makes previously protected organic matter available and results in changes in microbial composition, as well as increased rate of N mineralization (Ladd et al., 1993; Calderón et al., 2001; Balota et al., 2004). Due to this impact on soil organic matter there is a strong relationship between the physical disturbance associated with tilling and elevated $CO_2$ emission (Passianoto et al., 2003) in the period directly after tilling (Calderón et al., 2001).

Nitrogen cycling through the ecosystem is clearly important to N availability and potential N losses by denitrification (De Vos et al., 2000). Tillage can induce higher nitrate availability in the short-term; however, it is not usually synchronized with plant uptake and soil denitrification rates can increase the likelihood of gaseous N loss (Estavillo et al., 2002; Pinto et al., 2004). According to Davidson et al. (2000a, b), nitric oxide (NO) and nitrous oxide ($N_2O$) are predominantly produced by nitrification and denitrification, respectively. Together nitrification and denitrification in tropical soils contribute 8–12 Tg $N_2O$–N and 12–21 Tg NO–N to the atmosphere annually (Davidson and Kingerlee, 1997). Tillage promotes soil organic N mineralization, which can lead to $N_2O$ production from nitrification and denitrification (Estavillo et al., 2002).

However, little is known about the short-term effects of tilling on N pools, microbial biomass and gas fluxes in Amazonian pastures. Our objectives were: (1) to evaluate the effect of soil tillage during pasture re-establishment on soil N transformations and microbial biomass, and (2) to determine if there is a relationship between soil N dynamics in this system and gas fluxes, particularly $CO_2$, NO and $N_2O$.

## 2. Materials and methods

### 2.1. Study area

The field experiment was conducted at Fazenda (Ranch) Nova Vida, km 472 along the highway BR-364, in the state of Rondônia in the western Amazon (10°30′S, 62°30′W). The predominant soil in this region is classified as Ultisol by the U.S. taxonomy (Moraes et al., 1996). Climate of the area is characterized as humid tropical forest, with an annual precipitation of 2270 mm and a pronounced dry season from May to September. Mean annual maximum and minimum temperatures are 25.6 and 18.8 °C, respectively, with a seasonal variation of approximately 4 °C (Bastos and Diniz, 1982).

Sixty-three hectares of 18-year-old cattle pasture created in 1983 by cutting, burning the slash, and planting with *Brachiaria brizantha* grass, were characterized using a geostatistical design to investigate the spatial variation of soil chemical and physical properties. Soils were sampled at the 0–5 cm depth in July of 2001 with total C and N pools, pH in $CaCl_2$, bulk density and clay content measured (Table 1). Within this pasture we selected a ''homogeneous'' area of 3 ha, in which a series of experimental treatments were established in October 2001 (Cerri et al., 2004). On 7 November 2001, the entire area was seeded with *Brachiaria brizantha* and fertilized with 76 kg P $ha^{-1}$ in the form of magnesium termophosphate. At the onset of our study the vegetation in the experimental plots was a mixture of *B. brizantha*, *Panicum maximum* and other plants, including palms which are considered weed plants in a pasture.

### 2.2. Experimental design

The experiment consisted of five treatments, distributed randomly in four blocks in the 3 ha experimental area. Each block was divided into five plots of 40 m × 40 m, with each plot receiving a different treatment. In this study we report data from the control (no tilling, no fertilizer additions) and tilled treatments (soil was mouldboard ploughed at 20 cm on October 8 2001 followed by disking and harrowing on 29 October 2001) only. Soil temperature was determined at 2, 5 and 10 cm depth at all sampling times. Rainfall was determined daily in two collectors placed in the experimental area.

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