



## Physicochemical properties of soils in the Brazilian Amazon following fire-free land preparation and slash-and-burn practices

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### ABSTRACT

Over a century, subsistence agriculture has been practiced in the Brazilian Amazon, using slash-and-burn as a traditional land clearing technique. However, fire clearing leads to nutrient losses, and the increasing demographic pressure reduces the duration of the fallow period, threatening the system sustainability. The chop-and-mulch land clearing method, combined or not with legume-enriched fallow, is a promising alternative technique as the retention of organic residues upon land clearance of fallow could promote soil fertility. The aim of this study is to assess the effect of fire-free land preparation on soil physicochemical properties by comparing the effects of traditional slash-and-burn with (i) chop-and mulch with enriched fallow in croplands and (ii) chop-and-mulch without enriched fallow in pastures. The chop-and-mulch of a legume-enriched fallow conserved soil bulk density, and significantly increased nutrient concentrations and organic matter content compared to the burnt cropland and the control forest. In the pastures, the use of chop-and-mulch of a non-enriched fallow had less impact on soil physical and chemical properties, excepted on water retention capacity and total P stock. Land clearing of fallows by chop-and-mulch, especially when enriched with legumes could significantly improve agriculture sustainability in the region and reduce the pressure on primary forests.

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### 1. Introduction

The Bragantina region is an ancient colonial region of Brazilian Amazon that covers 23,000 km<sup>2</sup>, or 2% of the surface area of Pará, but represents more than 20% of the state's agricultural productivity. Approximately 75% of land was converted to secondary forests that serve as fallows that are cleared periodically for annual crop or pasture production (Denich et al., 2004). The soils in the Bragantina region have supported this type of agriculture for approximately a century (Frizano et al., 2003). Almost 98% of farms are family-run, with a surface area less than 100 ha. The increasing demographic pressure in the region leads to a reduction of fallow period to 3–7 years, 4 years being the most common length of time (Denich et al., 2005), which is no more suitable for long term soil fertility conservation (Sommer et al., 2004; Erenstein, 2003).

Slash-and-burn is the dominant deforestation method in tropical regions. It stimulates rapid improvement in soil chemical fertility, destroys weeds, reduces the risk of parasites and disease, and is also a simple and economical land clearing method (Jordan, 1989; Kato et al., 1999). However, several studies highlight the negative consequences of slash-and-burn, including: greenhouse gas emissions, pulmonary illness caused by smoke, accidental damage or destruction of crops and homes (Brady, 1996), loss of biodiversity, accelerated deforestation (Fearnside, 1991), accelerated loss of nutrients and soil erosion, and mercury leaching into aquatic ecosystems (Farella, 1998; Farella et al., 2006; Roulet et al., 1999). Acidic tropical soils, such as those predominant in the Amazon, often show rapidly diminishing annual crop yields with time under slash-and-burn agriculture due to the loss of nutrients through volatilization and soil erosion (Mackensen et al., 1996). To achieve balanced nutrient budget in traditional slash-and-burn farming systems requires long fallow periods, which are difficult to maintain in the current context of strong demographic pressures (Sommer et al., 1999; Vielhauer et al., 2004; Lawrence et al., 2010).

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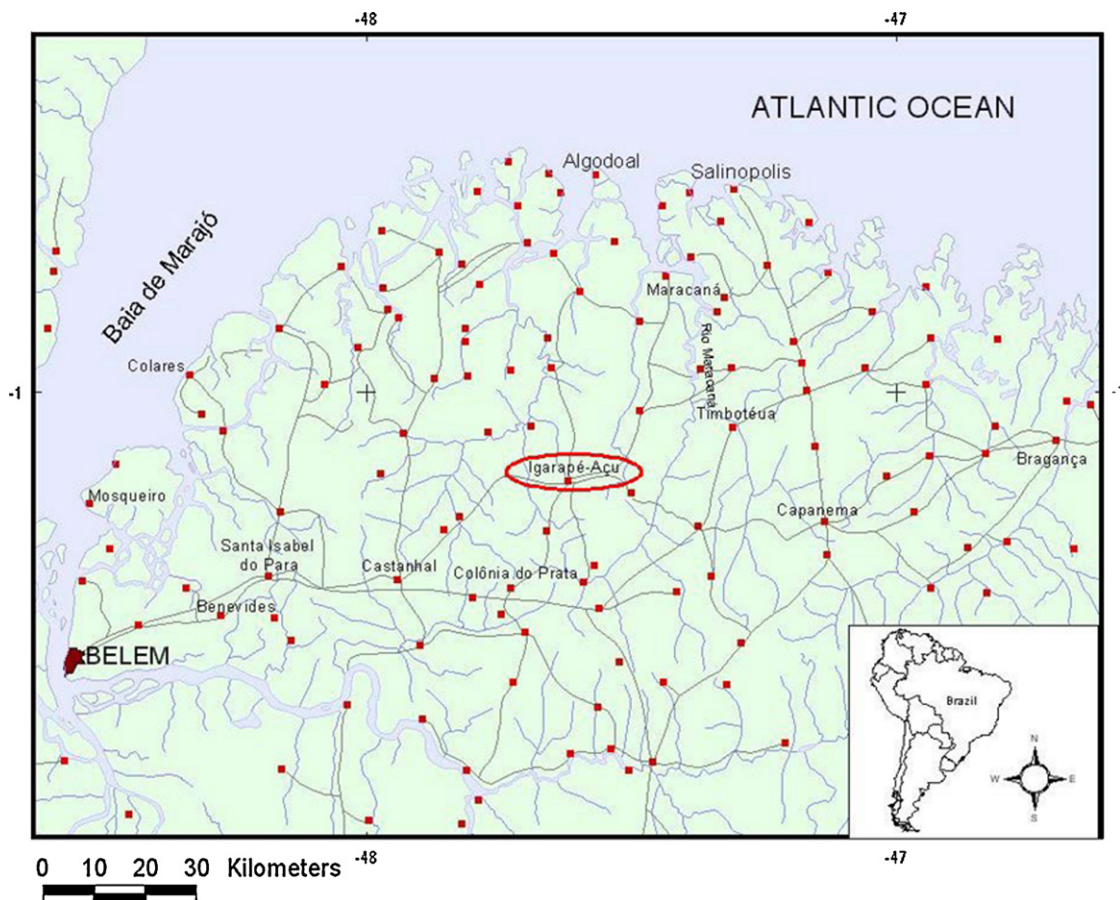


Fig. 1. Map of the northeastern part of the Amazonian State of Pará, Brazil. The study area (municipality of Igarapé-Açu) is identified by a circle.

Source: Cattanio (2002).

The German–Brazilian project SHIFT-Tipitamba, spearheaded by the Brazilian research institute EMBRAPA, proposes fire-free alternative technologies to slash-and-burn, called chop-and-mulch which may be combined or not with the enrichment of fallow forests by sowing fast-growing legumes (Denich et al., 2001). The chop-and-mulch technique uses an adapted tractor to chop and shred forest vegetation, then spread it evenly on the soil surface as organic mulch (Denich et al., 2004). Some studies showed that this technique may have the following advantages: (1) to lengthen the growing period because nutrients are slowly released for several years as the original plant biomass decomposes (Vielhauer et al., 2000), (2) to reduce erosion because organic mulch covers the soil surface (de Vleeschauwer et al., 1978), (3) to maintain humidity in the soil (Olasantan, 1999), (4) to preserve soil biodiversity (Acharya et al., 2005; Rousseau et al., 2010), (5) to decrease the regrowth of weeds (Ramakrishna et al., 2006) and (6) to reduce the incidence of accidental fires (Denich et al., 2000).

Few studies examined the impacts of chop-and-mulch clearing method on the soil in the Amazon and fewer envisaged the combination of this clearing method with the enrichment of forest fallows by planting legumes (Denich et al., 2001; Vielhauer et al., 2004). We hypothesize that, compared to traditional slash-and-burn, the chop-and-mulch combined or not with legume enriched fallow will improve soil physical properties, such as bulk density and water retention capacity, as well as chemical properties such as organic matter and plant-available nutrients. The aim of this study is to assess the effect of fire-free land preparation on soil physicochemical properties by comparing the effects of traditional slash-and-burn with (i) chop-and mulch with enriched fallow

in croplands, (ii) chop-and-mulch without enriched fallow in pastures.

## 2. Materials and methods

### 2.1. Study area

The study site was in the municipality of Igarapé-Açu ( $0^{\circ}55'–1^{\circ}20'S$ ,  $47^{\circ}20'–47^{\circ}50'W$ ), in the Bragantina region in the eastern Brazilian Amazon (Fig. 1). The climate of this region is humid equatorial, with average temperatures of 25–27 °C. Annual precipitation varies between 2000 and 3000 mm. The rainy season extends from January to April and the dry season from August to December. Soils in this region are Kandiuults (Ultisols) according to American soil classifications (Soil Survey Staff, 1999) and Argilosolos Amarelos according to Brazilian classification (EMBRAPA, 1999), and started to form more than one million years ago (Frizano et al., 2003). Soil texture ranges from loamy sand in the top 30 cm and sandy loam at deeper depths in the profile. Surface soils are nutrient poor and acidic ( $pH < 5.3$ ) with low soil organic matter content ( $< 2\%$ ) (IBGE, 2011).

### 2.2. Experimental design

The land uses considered in this study included: (1) an alternative sequence to traditional slash-and-burn (AS) installed on a 15 years old natural fallow followed by a first chop-and-mulch episode, crop cultivation for 20 months, legume-enriched fallow forest growing back for 17 months, a second chop-and-mulch episode followed by a second sequence of annual crops of 22

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