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Effects of heating on soil physical properties by using realistic peak temperature gradients

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ABSTRACT

Fire has been recognized as an important environmental process that affects soil systems. Here, we have reported the effects of temperature on soil aggregate properties of aggregate stability, mean weight diameter, water repellency, water retention, and soil carbon depletion due to soil heating. The study was performed under laboratory conditions by using a muffle furnace. However, realistic temperature gradients from 25 to 650 °C were obtained previously through measurements in the field. The soil tested here is a subtropical Humic Cambisol with 500 g kg^{-1} clay content. Most of our results were different from those reported in the literature. Following the temperature gradient, we found a sharp threshold at ~550 °C. The threshold indicated two different mechanisms that affect soil aggregate properties. The first mechanism, which affects the physical characteristics of the aggregates, was associated with organic matter and water repellency reduction (≤550 °C). The second mechanism was due to the thermal fusion of particles and recrystallization of mineral clays at 650 °C. The reduction in soil organic carbon had a linear effect on aggregate stability, mean weight diameter, and water retention following a temperature gradient. We noted that the longer exposure time at moderate to high temperatures could not compensate for the effect of a very high peak temperature lasting for a short time on soil aggregates. For the tested soil, we found a mixed response pattern explaining the effect of soil heating on aggregate stability.

1. Introduction

Fire can cause changes to the physical, chemical, and biological properties of soils (Certini, 2005; DeBano et al., 1998; Neary et al., 1999). Aggregate stability is a soil structure-related parameter of utmost importance to the functioning of soil systems and is related to several subprocesses, including topsoil hydrology, water retention, carbon stocks, biogeochemical dynamics, and root development. Therefore, understanding the soil dynamics in areas subject to fire is important to soil management and sustainability.

Many advances in the understanding of the effect of fire on soil systems, especially its effect on aggregate stability, have been made in recent years (Bento-Gonçalves et al., 2012; Mataix-Solera et al., 2011).

Majority of the studies concerning the effects of fire on soil aggregates have been carried out on sandy soil (Albalasmeh et al., 2012; García-Corona et al., 2004; Zavala et al., 2010). Few studies have been conducted on soil with considerable clay content (Mataix-Solera et al., 2008). Studies on the effects of wildfire on soil systems are far more abundant (Bento-Gonçalves et al., 2012; Cerdà and Robichaud, 2009; Shakesby and Doerr, 2006) than studies on soils cultivated under slash-and-burn systems (Are et al., 2009; Obale-Ebanga et al., 2003). In addition, many studies on slash-and-burn systems have focused on soil fertility, but not on aggregate stability (Borggaard et al., 2003; Ketterings et al., 2002; Reuler and Janssen, 1993). The slash-and-burn system persists and is still important in tropical areas (Thomaz, 2013; van Vliet et al., 2012), so understanding the effects of fire on soil systems that are cultivated in this way can lead to better soil conservation.

Another important issue to consider is how temperature and time exposure are chosen in laboratory soil heating experiments. Generally, the temperature can be more reliably selected than the time duration. Different durations have been reported in the literature: 5, 10, 15, and 20 min (Debano and Krammes, 1966); 6 to 24 h (Kang and Sajjapongse, 1980); 1 to 930 min (Ketterings and Bigham, 2000); 30 min (García-Corona et al., 2004); and 20 min (Mataix-Solera et al., 2008). However, no explanation was given to support the chosen time exposures in these studies.

In order to fill some of the gaps highlighted above, the objective of this study was to apply a representative temperature gradient to soil heating. The temperature gradient (temperature and duration) that was previously obtained in the field was transferred to laboratory conditions in order to detect the effect of soil heating on physical aggregate properties (e.g., aggregate stability, mean weight diameter, water repellence, soil carbon depletion, and water retention).

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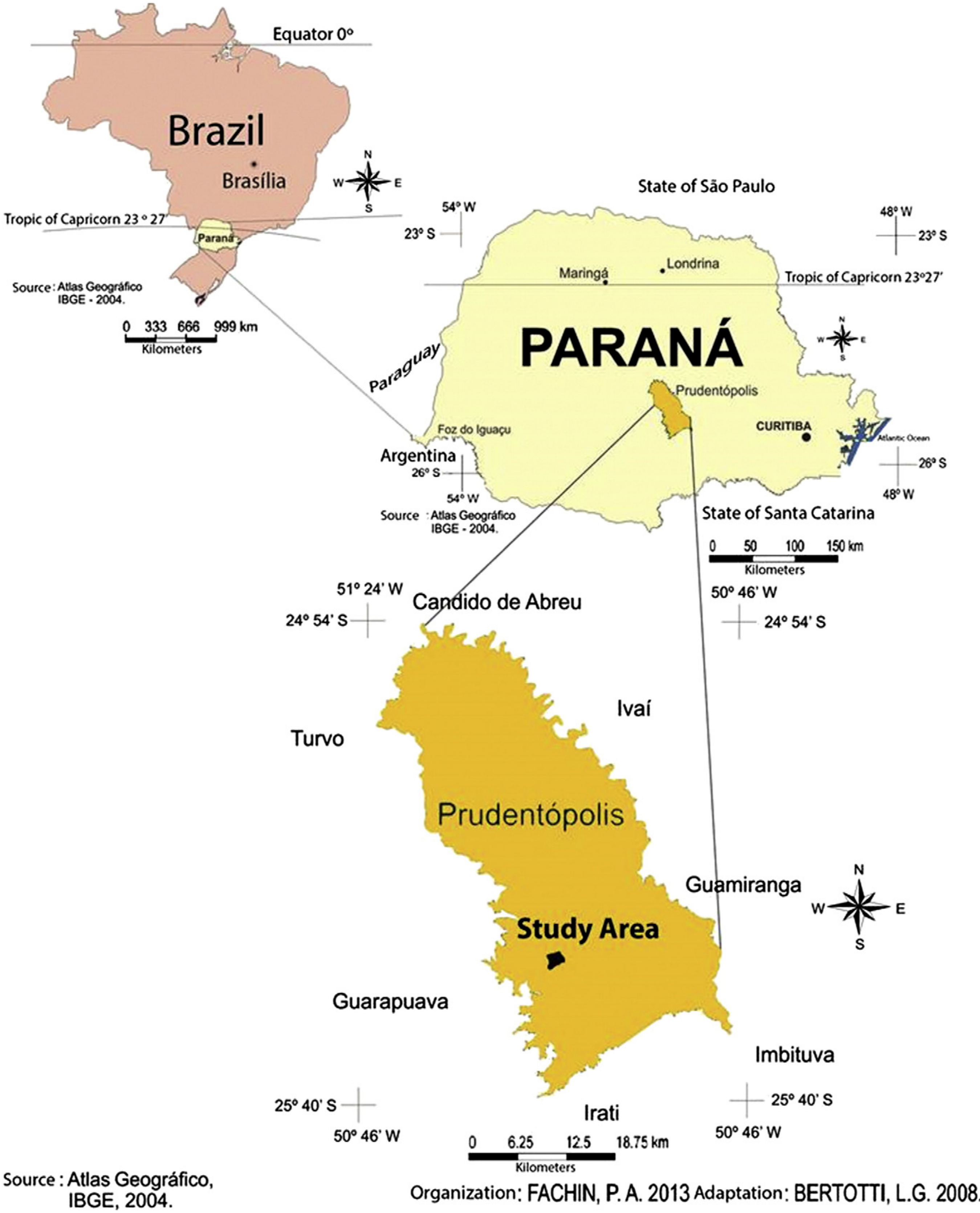

Fig. 1. Location of Prudentópolis municipality.