Agriculture, Ecosystems and Environment 233 (2016) 370–380

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Land use effects on subtropical, sandy soil under sandyzation/desertification processes

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ARTICLE INFO

Article history:
Received 11 May 2016
Received in revised form 28 September 2016
Accepted 30 September 2016
Available online xxx

Keywords:
Desertification
Fragile soil
Organic matter
Soil management

ABSTRACT

Very fragile sandy soils have high erosion susceptibility, low water retention, and low nutrient and carbon storage. In southern Brazil, substitution of native grassland by grain production in conventional tillage has caused severe degradation, even reaching an extreme state of "sandyzation" or non-vegetated sand. We measured indicators to assess soil quality in a Quartzipsamment ("Neossolo Quartzarênico") under different uses and also in extreme state of "sandyzation" or non-vegetated sand, where annual average rainfall is 1511 mm with regular distribution throughout the year. Four land uses/conditions were evaluated: (i) native grassland (NG) (4% clay); (ii) nine years-old eucalyptus forest (EF) (4% clay); (iii) corn production in conventional tillage (CT) (3% clay); and (iv) extreme state of "sandyzation" or non-vegetated sand (NVS) (2% clay). Measured soil chemical properties were soil organic carbon (SOC) in 0–2.5, 2.5–5, 5–7.5, 7.5–10 and 10–20 cm soil layers, Ca, Mg, K, Al saturation, and effective cation exchange capacity (CEC) in 0–2.5 cm layer. Measured soil physical properties were soil bulk density (BD), total porosity (TP), macroporosity (Macro), microporosity (Micro), water retention, and saturated hydraulic conductivity (Ks) in 0–3, 5–8, and 10–13 cm soil layers, whereas aggregate stability in water was measured in 0–5 cm soil layer. Soil chemical and physical properties indicate an extreme state of degradation of NVS, which had significantly lowest SOC and thus low CEC, associated to leaching of exchangeable bases and high aluminum saturation. CT also provided a significant decrease in SOC in all soil layers, and other in chemical properties in the 0–2.5 cm layer, whilst EF was the most efficient system to build up SOC compared to NG in surface layers (0–2.5 and 2.5–5 cm) and presented better chemical conditions. In general, soil physical quality was degraded in NVS and improved in EF, whilst there were no significant differences in CT compared to NG for most soil physical properties. Soil physical properties were closely related to surface SOC of the different land uses. NVS provided a significant decrease in Micro, whilst EF provided a significant increase in TP and Macro in 0–3 and 5–8 cm soil layers. High TP and Macro, low Micro, and very high Ks were observed in NVS. The CT provided significant decrease in water aggregate stability compared to NG and the water aggregate stability rank was EF > NG > CT, whereas NVS soil was completely devoid of aggregation. NVS restricts plant growth, root development, plant nutrient uptake and soil cover, thus creating an environment prone to wind erosion and soil degradation. Management practices that include permanent soil cover, restore SOC, improve soil aggregation and create pores for water retention and availability, increase base saturation and promote nutrient cycling are necessary to preserve these fragile lands.

1. Introduction

Parent material and climate conditions in the Holocene Epoch – Cenozoic Era (Bombin and Klamt, 1974) – resulted in the genesis of sandy sediments in the southernmost Brazilian state (Fig. 1), bordering with Uruguay and Argentina, where sandy areas lacking vegetation are found (Suertegaray, 1995). Under currently more humid weather conditions, these sediments led to the formation of

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http://dx.doi.org/10.1016/j.agee.2016.09.039
0167-8809/

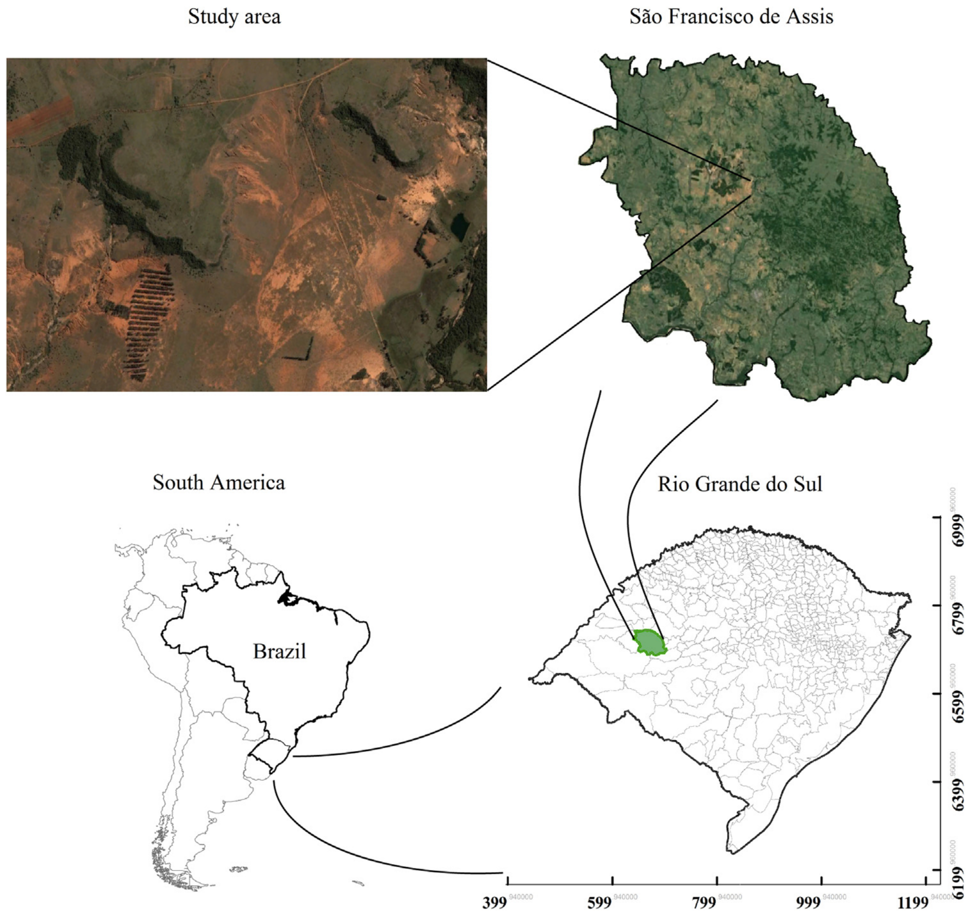

Fig. 1. Study area with sandyzation sites, in São Francisco de Assis municipality, in the southwestern region ("Campanha") of Rio Grande do Sul State, Southern Brazil.

sandy-textured soils, highly susceptible to degradation by water and wind erosion to such an extent that desertification is possible. However, these areas are of relatively high rainfall (over 1300 mm per year), and have edaphological and geobotanic properties distinctive from deserts.

Although associated to desertification since the 1970′s, sandyzation is a single phenomenon associated to hydrological and eolian processes, and to climate regimes that are different from those that characterize desertification (Suertegaray and Verdu, 2008). In humid climate there is the formation of "islands" or patches of exposed, loose sand ("areais" or sandynized soil), thus erroneously called areas of desertification (Suertegaray, 1995), especially on slopes and valleys with sandstone rocks prone to water erosion, with potential subsequent wind activity (Suertegaray, 1987).

Sediments are mobilized by water during rainy days and by wind on dry, windy days, hindering vegetation establishment. Reworking of these quaternary deposits resulted from morphogenetic dynamics, where surface runoff, particularly concentrated flow in gullies, expose, transport and deposit sand particles, further enhanced by wind erosion processes. There are indications that the sandynized areas are formed by natural or geological erosion (Marchiori, 1995; Bellanca and Suertegaray, 2003; Suertegaray et al., 2005) and accelerated erosion by anthropic effects (Cordeiro and Soares, 1975; Souto, 1984; Verdum, 1997).

These "sandynized" or "non-vegetated sand" areas occupy an estimated area of 3000 ha in ten municipalities in the Rio Grande do Sul state, with some of them having up to 229 patches of sand (Andrades et al., 2005), in much larger area of sandy soils highly susceptible to erosion (around 250 thousand ha).

Prevailing agroecosystems in the region include the use of extensive, low productivity livestock and agriculture, and minor presence of forestry. Regional climate and sandy soils of low natural fertility, undulated relief, with natural vegetation of grasses and with low winter growth characterize the agroecosystem as naturally fragile and even more when in agriculture or animal husbandry (Souto, 1984). In the 1970's and 80's there was intense agricultural use of sandy soils, where native grasslands were replaced by conventional tillage for soybean and wheat cropping, resulting in severe soil and ecosystem degradation.

Loss of vegetative cover, exposing sandy material to erosive agents, is the main factor encouraging soil degradation (Souto, 1984). In a sandynized area, sand movement by wind from September to December of 2001 was 5.05 Mg ha^{-1}, while in the whole year of 2002 this movement was 11.08 Mg ha^{-1}. With the use of cover plants, sand movement was, respectively, only 0.36 and 0.77 Mg ha^{-1}, which corresponds to a decrease of around 93% (Rovedder and Eltz, 2008a). High rainfall intensity associated to high wind intensity favors the movement of soil particles, but high precipitation and low wind intensity may result in less sand movement and erosion (Rovedder and Eltz, 2008a). Local rainfall average is highest (153.6 mm) in September and October (Souto, 1984), and greatest average wind speed of 2.89 m s^{-1} is in September to November (Instituto Nacional de Meteorologia (INMET), 2012).

Sandy soils are characterized by weak aggregation (Capurro et al., 2002; Wohlenberg et al., 2004; Reichert et al., 2009a), poor water retention properties (Tomasella and Hodnett, 1998; Reichert et al., 2009b, 2015b; Fidalski et al., 2013), high permeability (Bruand et al., 2005), water infiltration (Reichert