Agriculture, Ecosystems and Environment 225 (2016) 54–61

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

The effect of 72 years of sugarcane residues and fertilizer management on soil physico-chemical properties

Sandile Mthimkhulu[a,*], Pascal Podwojewski[b,f], Jeffrey Hughes[a], Louis Titshall[a,c], Rianto Van Antwerpen[d,e]

[a] Soil Science, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa
[b] IRD, UMR 242 IEES-Paris, 32 Av. H. Varagnat 93143, Bondy cedex, France
[c] Institute for Commercial Forestry Research, PO Box 100281, Scottsville 3209, South Africa
[d] South African Sugarcane Research Institute, Private Bag X02, Mount Edgecombe 4300, South Africa
[e] Department of Soil, Crops and Climate Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, South Africa
[f] Hydrology, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa

ARTICLE INFO

Article history:
Received 17 October 2015
Received in revised form 1 April 2016
Accepted 5 April 2016
Available online 14 April 2016

Keywords:
Soil carbon saturation
Mean weight diameter
Soil fertilizer
Management practices
Humid subtropical
Cationic bridging

ABSTRACT

This study, carried-out in KwaZulu-Natal, South Africa, investigated changes in selected soil properties and their effect on aggregation induced by 72 years of residue burning or mulching, with and without fertilizer application on a sugarcane trial arranged in a split-plot design with four replications. The main plot treatments were a) green cane harvesting with all residues mulched, b) cane burnt prior to harvest with cane-tops left scattered evenly over the plots and c) cane burnt prior to harvest with all the residues removed from the plots. Split-plot treatments consisted of fertilized and unfertilized plots. Soil samples for physico-chemical and aggregate stability analysis were collected at depths of 0–10 and 10–20 cm from 24 plots. In comparison with burning, significant effects of mulching were only observed on total nitrogen and exchangeable potassium and sodium, mainly at 0–10 cm. Aggregate stability estimated by mean weight diameter (MWD), exchangeable cations (especially calcium and magnesium) and pH were significantly affected by fertilizer application. An increase in acidity and a decrease in MWD and exchangeable calcium and magnesium on fertilized plots were attributed to mining of nutrients by sugarcane, nitrification and subsequent base cation leaching. The significant positive correlation between calcium and magnesium and MWD, and the lack of correlation between organic carbon (OC) and MWD, indicated that bases contributed more to soil aggregation than OC. Total carbon and OC showed no differences across all treatments. It was concluded that (i) annual fertilizer applications may lead to soil structure deterioration under sugarcane regardless of the harvesting method practiced and (ii) increasing additions of organic matter (through mulching) do not always correspond to an improvement of soil aggregate stability and related soil properties.

1. Introduction

Sugarcane (*Saccharum officinarum* L.) is grown commercially in over 90 countries and nearly 20 million ha are harvested annually, with Brazil, India and China the main producers (Galdos et al., 2009). Sugarcane production is of major agricultural importance in South Africa, where much of the cane land has been converted from indigenous forest and grassland. Traditionally, sugarcane is burned prior to harvest in order to remove leafy non-sucrose containing biomass, but this can be detrimental to soil aggregate stability and nutrient availability due to the loss of organic matter and nutrients through particulate dispersal or volatilisation (Blair, 2000; Cerri et al., 2011; Wiedenfeld, 2009). In the South African sugar industry, the loss of soil organic matter (SOM) and the resulting reduced microbial activity under sugarcane subjected to pre-harvest burning are considered to be major factors contributing to soil aggregate destabilization (Graham and Haynes, 2005). Concerns have been raised regarding the loss of SOM occurring under continuous mono-culture sugarcane production (Dominy et al., 2001; Graham and Haynes, 2005; Kimetu et al., 2009; Paradelo et al., 2013; van Antwerpen and Meyer, 1996). For instance, van Antwerpen and Meyer (1996) reported a decrease in SOM, from 2.40% to 1.88%, and aggregate stability in the 0–150 mm

* Corresponding author. Current address: South African Sugarcane Research Institute, Private Bag X02, Mount Edgecombe 4300, South Africa
E-mail address: Sandilemthimkhulus@gmail.com (S. Mthimkhulu).

http://dx.doi.org/10.1016/j.agee.2016.04.002
0167-8809/

layer in irrigated land under sugarcane compared to nearby non-irrigated, virgin grassland in northern KwaZulu-Natal, South Africa. Similarly, reductions of SOM induced by the change in land use from grassland to sugarcane were observed in Queensland, Australia (Bell et al., 2007; Blair, 2000; Wood, 1985). Numerous studies have associated the reduction in SOM with a decrease in soil aggregate stability (Barthes and Roose, 2002; Boix-Fayos et al., 2001; Le Bissonnais, 1996). Silva et al. (2007) reported such a relationship under long-term sugarcane production.

An alternative to pre-harvest burning is green cane harvesting, whereby leafy and non-sucrose containing biomass is retained on the soil surface as a mulch, potentially increasing SOM and nutrient content (Graham and Haynes, 2005). Numerous researchers have found that green cane (unburnt) harvesting and the retention of crop residues as a mulch can improve SOM content when compared to traditional burnt cane harvesting practices (Ball-Coelho et al., 1993; Blair, 2000; Graham et al., 2002; Torres et al., 2013; Vallis et al., 1996). According to Thorburn et al. (2012), mature sugarcane crops consist of a large amount of residues (13–20 t DM ha^{-1}) at harvest that contain about 42% carbon that can potentially be returned back to the soil under green cane harvesting.

However, little is known about the long-term consequences of fertilizer application and green cane harvesting (mulching), and associated changes in SOM on soil aggregation and structural stability under continuous sugarcane cultivation. A sugarcane management trial that was established in 1939 on the eastern seaboard of South Africa offered an ideal and rare opportunity to study the comparative long-term effect of conservation practices (no tillage and mulch residues) against continuous residue burning. Furthermore the long-term effects of mineral fertilizer inputs against no fertilizer application on soil physico-chemical properties were also assessed.

2. Materials and methods

2.1. Experimental site

The experimental site (BT1) is situated at the South African Sugarcane Research Institute (SASRI) at Mount Edgecombe near Durban, KwaZulu-Natal, South Africa (31°04′20″E, 29°04′20″S). It was established on the 25th October 1939 and is the oldest long-term, continuously monitored sugarcane production and soil management trial in the world (Graham et al., 2002). The climate of the region is humid subtropical and is characterized by summer (October to March) rainfall. The average annual precipitation is 950 mm, and the average annual temperature is 20.4 °C (Graham et al., 2002). The site is located on a south-west facing slope (13.5% and 18.5% at upper slope and lower slope, respectively). Control soil pits were dug in the east side of the trial. On the upper slope, the soil was classified as a Mollic Cambisol (IUSS Working Group WRB, 2014), locally known as Mayo form (Glenecho family) (Soil Classification Working Group, 1991), with a dark (2.5 YR 3/1 to 3/2) 50 cm thick A horizon extending to a dark reddish brown (2.5 YR 3/3 to 3/4) AC transitional horizon overlying weathered dolerite. The profile contained a 5–10 cm thick stoneline at about 50 cm depth. On the lower slope, the soil was a Mollic Nitisol (deeper than the Mollic Cambisol found on the upper slope) (IUSS Working Group WRB, 2014), locally known as Bonheim form (Rockvale family) (Soil Classification Working Group, 1991), with the same A horizon as on the upper slope overlying a red (2.5 YR 3/4 to 10R 3/6) B horizon. The <2 μm clay fraction of both soil types consists of mostly kaolinite, with a lesser amount of vermiculite and small amounts of lepidocrocite, and interstratified vermiculite-smectite and illite-vermiculite.

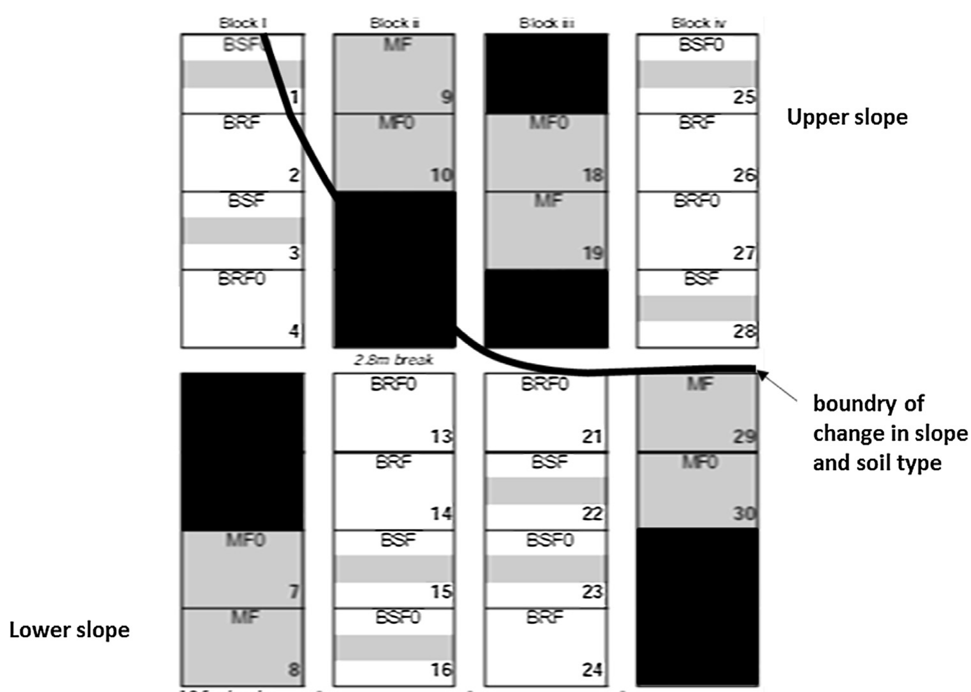

Fig. 1. The layout of the BT1 sugarcane trial situated at SASRI, Mount Edgecombe. BRF0: burnt with residues removed and not fertilized; BRF: burnt with residues removed and fertilized; BSF0: burnt with residues scattered and not fertilized; BSF: burnt with residues scattered and fertilized; MF0: mulched and not fertilized; MF: mulched and fertilized. Plots that are shaded black were not sampled for the present study.