Soil & Tillage Research 161 (2016) 71–78

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Soil aggregation and root growth of perennial grasses in a constructed clay minesoil

Lizete Stumpf*, Eloy Antonio Pauletto, Luiz Fernando Spinelli Pinto

University of Pelotas, "Eliseu Maciel" College of Agronomy, Campus Universitário, s/n. CEP 96160-000, Capão do Leão, Rio Grande do Sul, Brazil

ARTICLE INFO

Article history:
Received 15 October 2015
Received in revised form 13 March 2016
Accepted 21 March 2016

Keywords:
Degradation
Compaction
Soil reclamation
Roots

ABSTRACT

Studying constructed soils (anthropogenic) in mined areas provides an opportunity to expand the existing knowledge about the formation and stabilization of aggregates, due to the magnitude of ecosystem disruption, that creates a "zero time" scenario. The aim of this study was to evaluate the relationship between the aggregation and the root growth of perennial grasses 103 months after the reconstruction of a constructed minesoil, in a coal mining area located in Candiota/Rio Grande do Sul State, Brazil. The evaluated plant species were *Hemarthria altissima*, *Paspalum notatum* cv. Pensacola, *Cynodon dactylon* cv. Tifton, and *Urochloa brizantha*. The grass roots promoted the recovery of the soil physical condition in the 0.00–0.10 m layer, with a decrease in dry bulk density and an increase in soil macroporosity related to the formation of new aggregates. The decrease in root development of all species below 0.10 m depth is the result of the restrictive soil physical conditions, with high bulk density and low macroporosity related to aggregates formed originally by compression. The results of root and soil attributes found in this study suggest a different soil-aggregation hierarchy in compacted constructed minesoils, where first a disintegration occurs of large cohesive aggregates formed by compression followed by a re-aggregation process, with sequential re-formation and stabilization of aggregates. The *Urochloa brizantha* showed a greater root density, volume, length and area, thus presenting a greater potential to recover the physical attributes of the degraded areas, especially those in the compacted layer below 0.10 m depth. The recommendation of this and other species in the reclamation of constructed soils after coal mining should take into account the thickness of the topsoil layer because the roots of these species can grow into the overburden layers and thus accelerate the sulfurization process. The recovery of physical attributes of the constructed minesoil, especially below the 0.00–0.10 m layer, is a slow process, possibly due to the low accumulation rates of organic carbon in this layer.

1. Introduction

Surface mining generates a large impact on the landscape, removing vegetation and permanently altering the topography, geology and hydrological regime of the area, due to the handling and removal of large volumes of soil and rocks (Zhang et al., 2015; Mukhopadhyay et al., 2013; Zhao et al., 2013; Izquierdo et al., 2005. In addition to the visual impact, there are problems associated with development of acid mine drainage in the surface and groundwater (Daniels and Zipper, 2010; Daniels et al., 2002; Limpitlaw et al., 1997), and erosion and compaction of the constructed minesoil (Krümmelbein and Raab, 2012; Sheoran et al., 2010; Limpitlaw et al., 1997). Moreover, carbon losses occur during the removal, storage and placement of the topsoil in the mined area, both by soil erosion and by breakdown of the natural soil aggregates, exposing this to the action of microorganisms (Maharana and Patel, 2013; Wick et al., 2009; Anderson et al., 2008).

Acid mine drainage has negative impacts on the development of vegetation and restoration of the degraded area (Daniels et al., 2002), generating high concentrations of Fe, Mn and Al in the soil solution (Chen et al., 2013; Limpitlaw et al., 1997). This chemical condition can be corrected through the application of limestone (Iakovleva et al., 2015), or through the use of other alkaline materials such as ash from burning coal; however, the latter may not be effective to maintain the pH at appropriate levels if the oxidation of pyrite continues to occur (Daniels et al., 2002).

In addition to acidity, another severe problem that affects the revegetation is soil compaction, which can be considered the main negative physical impact generated by the coal extraction process

* Corresponding author.
E-mail addresses: zete.stumpf@gmail.com (L. Stumpf), pauletto@ufpel.edu.br (E.A. Pauletto), lfspin@ufpel.edu.br (L.F.S. Pinto).

http://dx.doi.org/10.1016/j.still.2016.03.005

and topographical recomposition of the mined area (Sena et al., 2014; Borůvka et al., 2012; Krümmelbein and Raab, 2012; Sheoran et al., 2010; Wick et al., 2009; Daniels et al., 2002; Limpitlaw et al., 1997; Cleveland and Kjelgren, 1994).

In constructed minesoils aggregates can be formed by compression, especially resulting from machinery traffic during the topographical recomposition of the mined area under too wet soil conditions (Stumpf et al., 2013). Therefore, the development of soil structure in mined areas provides a unique opportunity to expand the existing knowledge about the formation and stabilization of aggregates, as well as the accumulation and distribution of organic matter, because the magnitude of ecosystem disturbance creates a "zero time" scenario (Wick et al., 2010).

Thomas et al. (2000) compared the development of horizons of minesoils 2, 7, 11 and 23 years old with a natural undisturbed soil in the southeastern United States and found that the thickness of the A horizon and aggregation increased with the age of the constructed soils, and also that the structure of the older minesoils tended to be similar to the natural soil. Zhang et al. (2015) analyzed the effects of vegetation on the reclamation of constructed minesoils in a coal mining area in China and observed that after five years there was an increase in organic matter content and an improvement in soil physical properties. Krümmelbein and Raab (2012), studying constructed minesoils after coal mining in Germany, recommended using perennial species with deeper rooting systems to improve the formation of soil structure.

The recovery of soil physical properties can be enhanced by plant species with extensive and deep root systems, that do not only yield a high biomass (Ralisch et al., 2010), but that can also form a zone of multiple interactions due to a close plant/soil contact, and through root hairs, mucilage and the presence of microorganisms (Gregory, 2006). However, the degree of influence of roots on soil structure varies greatly with the composition and production of mucilage, which depends on the water content of the plant species and the stage of soil development and depth (Six et al., 2004).

The hypothesis of this study is that the root system of perennial grasses can influence the aggregation and help to alleviate the compaction in a constructed clay minesoil. In this context, the aim of this study was to evaluate the relationship between the aggregation and the root growth of perennial grasses at 103 months after the beginning of the experiment in a recently constructed minesoil.

2. Material and methods

2.1. Study area

The study was conducted in a coal mining area under concession of Riograndense Mining Company (CRM), located in Candiota/Rio Grande do Sul State, Brazil, with the following coordinates: 31° 33′ 56" S and 53° 43′ 30"W.

The main stages involved in the strip mining coal extraction process and the subsequent topographic recomposition of the mined area are: (a) removal of the A, B and C horizons of the natural soil, which are transported by truck to cover the previously topographically leveled area; (b) removal of saprolite and rocks (overburden) through a large dragline excavator; (c) extraction of the coal seams; (d) placement of the overburden spoils to fill the excavation produced by the previous strip, which are leveled by bulldozers for topographic recomposition; (e) to finish the landscape restoration of the area, the natural soil A horizon (and B and C horizons) removed during stage (a) are deposited, and revegetated, thus creating the "constructed minesoil".

The soil was constructed in early 2003 and the soil layer placed over the overburden came from the B horizon of the natural soil of the pre-mined area (Fig. 1d), a Rhodic Lixisol, with the high clay content (465.50 g kg^{-1} clay), dark red color (2.5 YR 3/6) and low organic matter content (11.5 g kg^{-1}).

The experiment with different plant species (grasses and legumes) was installed in November/December 2003, using 20 m^2 (5 m × 4 m) plots, in a randomized block design with four replications. Due to the severe compaction caused by the intense movement of machinery during the soil construction (trucks loaded with 20 Mg of soil and Caterpillar D8T model bulldozer with 38 Mg mass, 259 kW gross power, with length and width of track on ground of 3.20 m and 0.56 m per shoe, respectively, and ground contact area of 3.6 m^2), the soil was chiseled with a bulldozer to a depth of approximately 0.15 m. Then the area received dolomitic limestone equivalent to 10.4 Mg ha^{-1}effective calcium carbonate rating and 900 kg ha^{-1} of a 5-20-20 fertilizer (45 kg N, 180 kg P_2O_5, and 180 kg K_2O), based on results obtained by soil testing. Annually, all plots of the experimental area also received 250 kg ha^{-1} of a

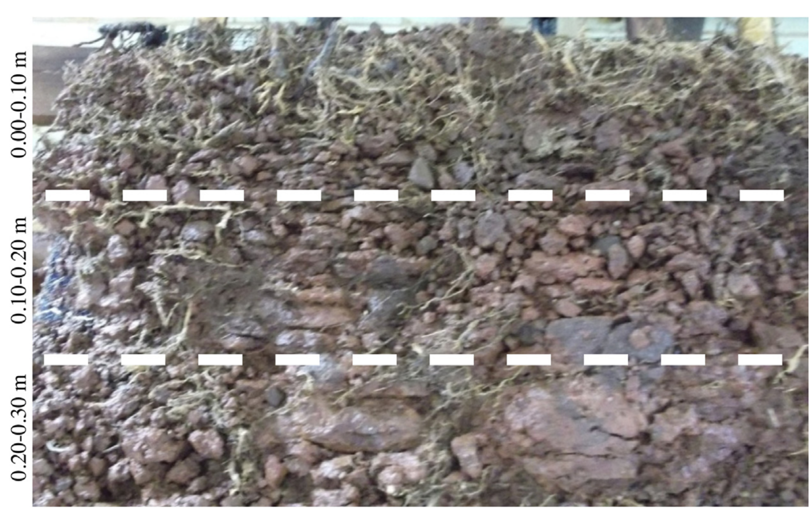

Fig. 1. Soil monolith taken at a depth of 0.30 m, with aggregates caused by compression below the 0.00–0.10 m layer.