ECOLOGICAL ENGINEERING 35 (2009) 723–734

available at www.sciencedirect.com

ScienceDirect

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

The effects of vegetation on restoration of physical stability of a severely degraded soil in China

Shuihong Yao[a,b], *Jiangtao Qin*[a], *Xinhua Peng*[a], *Bin Zhang*[a,*]

[a] *State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, P.O. Box 821, Nanjing 210008, China*

[b] *Graduate University of Chinese Academy of Sciences, Beijing 100049, China*

ARTICLE INFO

Article history:
Received 17 July 2008
Received in revised form
31 October 2008
Accepted 23 November 2008

Keywords:
Aggregate stability
Tensile strength
Hydrophobic DOC
Soil restoration
Soil water repellency

ABSTRACT

Vegetative restoration may increase stability of degraded soil through enrichment of soil organic carbon (SOC). It is not clear whether hydrophobic fractions of dissolved organic carbon (DOC) function, although soil water repellency is generally linked to soil stability. The objectives of this study were to determine the effects of vegetative restoration and hydrophobic DOC fractions on soil hydrological and mechanical stability. Five investigated plots included eroded bare soil as a control, restored eroded soils planted either with Camphor tree (*Cinnamomum camphora*) or Lespedeza shrub (*Lespedeza bicolor*) since 1987, and two undisturbed soils with the same vegetation types. Water stability (WS), tensile strength (TS), and soil water repellency (SWR) of soil aggregates were measured at three water potentials, i.e., −6, −60 hPa and oven drying at 40 °C and at three depths (0–5, 5–10 and 10–20 cm). Reforestation of Lespedeza and Camphor trees for over 15 years increased SOC, hydrophobic DOC (H-DOC) and hydrophobic acid DOC (HA-DOC), WS and TS of the restored soils compared with the eroded bare soil, with more profound effects under Lespedeza shrubs than under Camphor trees, especially for TS. No significant differences were found between the restored and undisturbed soil under the same vegetation type. SOC was significantly correlated to total porosity, hydrological and mechanical stability and soil water repellency, suggesting the significant effect of SOC on soil restoration. SWR was more closely correlated to SOC and to H-DOC concentration than to total DOC and HA-DOC in the top soil. The humification and aromaticity indices of DOC indicated that greater SWR in the soils under Lespedeza than under Camphor trees can be attributed to greater amount of litter fall and more active microbial decomposition. Although WS and TS varied with soil water potentials, TS was strongly correlated to SWR, but no link was found with WS. This study suggests that the combined influences of soil organic compounds binding and coating soil particles, retarding water wettability and modifying soil porosity are probably extremely important mechanisms of mechanical stabilization in soil. Such intricate feedback during vegetation restoration needs further study.

Abbreviations: DOC, dissolved organic carbon; H-DOC, hydrophobic DOC; HA-DOC, hydrophobic acid DOC; SOC, soil organic carbon; SWR, soil water repellency; TS, tensile strength of aggregate; WS, water stability of aggregate.

* *Corresponding author*. Tel.: +86 25 86881198; fax: +86 25 86881000.
E-mail address: bzhang@issas.ac.cn (B. Zhang).

0925-8574/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecoleng.2008.11.008

1. Introduction

Land degradation by soil erosion is a major global environmental problem (Trimble and Crosson, 2000; Vallejo et al., 2006). Land degradation will not only cause a risk of food security by lowering or loss of soil fertility and productivity, but also cause degradation of ecological functions of soil resources such as mitigating global warming by sequestration of soil organic carbon (SOC), improving quantity and quality of freshwater resources, protecting biodiversity, serving as a repository of waste or an archive of human and planetary history, etc. Tackling this problem is often achieved by planting woody vegetation, particularly legumes that can improve soil fertility (Cairns, 2000; Hobbs and Harris, 2001). These plants enrich SOC, subsequently improving soil structure directly (Goebel et al., 2005) by providing the necessary biophysical stimuli to enhance soil aggregation and physical stability (Rogers and Tate, 2001; Buckley and Schmidt, 2001). The processes are crucial to control water-derived soil erosion and sequestrate organic carbon into soils previously depleted of this essential component (Sutherland, 2002; Lal, 2004; Wang et al., 2007).

Improved soil physical stability may result from changes in hydrological and mechanical behaviour (Czarnes et al., 2000). The primary hydrological mechanism contributing to stabilization may be an increase in hydrophobic organic compounds that alter soil wetting properties (Giovanini et al., 1983; le Bissonnais, 1996; Piccolo and Mbagwu, 1999). Soil hydrological stability depends partly upon the release of air-pressure during the rapid wetting of dry soil (Hallett et al., 2001). Reducing the initial rate of wetting should diminish the build-up of air-pressure in soil pores, thereby enhancing its structural stability. Evidence that hydrophobic compounds influence soil wetting will be reflected in its water repellency. Wallis et al. (1991) and Hallett and Young (1999) have shown that most soils have a low level of repellency, and that the level is influenced by soil management (Hallett et al., 2001) and biological processes (White et al., 2000). We showed previously that the restoration of severely degraded soil by planting vegetation enhances soil water repellency (SWR) and soil porosity (Peng et al., 2003). SWR was found to be enhanced on aggregate surfaces because of the accumulation of dissolved organic carbon (DOC) due to eluviations under cycles of wetting and drying (Zhang et al., 2004; Jasinska et al., 2006). However, whether soil water repellency depends directly on hydrophobic DOC and this contributes to soil hydrological stability is unclear.

Mechanical processes can also enhance soil stability, with various studies indicating this process to be far more significant than hydrological processes (de Gryze et al., 2007). Mechanical stabilization may result from soil aggregation due to SOC cementing, encrusting or coating, enmeshing and infilling (Tisdall and Oades, 1982; Soane, 1990). It protects against destruction such as rainfall drop impact, as well as rapid wetting. Soil organic carbon binds soil particles and provides a ‘spring’ against mechanical deformation within and between soil aggregates (Gupta et al., 1987; Dexter, 1988; Zhang et al., 2005) and a matrix for higher water absorption, which increases soil shear strength at a given soil water potential (Zhang and Hartge, 1995). Hydrophobic dissolved organic carbon (DOC) on soil aggregate surfaces such as by wetting and drying cycles (Zhang et al., 2004) can alter not only soil wettability and water adsorption (le Bissonnais, 1996; Piccolo and Mbagwu, 1999), but also interfacial energy between solid and liquid due to wettability-induced changes in microscopic water distribution on soil aggregate surfaces (Goebel et al., 2005, 2007) The changes in interfacial properties may also alter soil mechanical strength as it may diminish capillary cohesion and increase effective stress at a give soil water regime. However, the information on the interaction of hydrophobic DOC or soil water repellency and soil mechanical stability is limited.

In this study, physical stability of soil aggregates is defined as water stability (WS) against fast wetting and tensile strength (TS) against mechanical destruction. These two processes simulate the hydrological and mechanical destruction during heavy rainfall. We hypothesized that increases in soil organic matter improve soil physical stability after vegetation restoration, partly due to presence of hydrophobic DOC that coat pore walls and aggregate surfaces. The effect may vary with vegetation type due to the difference in hydrophobicity of litters. Both soil water repellency (de Jonge et al., 1999; Doerr and Thomas, 2000) and soil tensile strength (Ibarra et al., 2005.) vary with initial soil water content so tests were conducted at multiple water potentials. Moreover, soil organic matter generally decreases with soil depth, so the effect of soil depth was also considered for the determination. The objectives of this study were to determine the effects of vegetative restoration vegetation type on hydrological and mechanical stability and the effects of hydrophobicity of organic carbon and SWR.

2. Materials and methods

2.1. Study site

The research was carried out on plots for a long-term experiment established in 1987 at the Ecological Experimental Station of Red Soil, Chinese Academy of Sciences in Yingtan, Jiangxi Province, China (116°5′30″E and 28°5′30″N). This experiment evaluates the restorative effect of different types of vegetation on water erosion of a severely eroded soil with an exposed plinthic layer (Zhang et al., 2001; Peng et al., 2003). Five treatments were investigated: (1) bare eroded land with an exposed plinthic layer (EB); (2) restored bared land planted with *Lespedeza bicolor* (RL); (3) undisturbed land planted with *Lespedeza* shrub (UL); (4) restored bare land planted with *Camphor* tree (RC); (5) undisturbed land planted with *Cinnamomum camphora* tree (UC). Soils were sampled at 0–5, 5–10, and 10–20 cm depths from each of triplicate plots in 2007.

2.2. Soil chemical and physical properties

Soil samples were taken with a shovel from 0 to 5, 5 to 10, and 10 to 20 cm in depth at five points in each plot, and then mixed to form a composite sample for each plot. The soils were partially air-dried at room temperature until at a water content where they were easily friable and then separated into 10 mm aggregates by hand along natural failure surfaces, which were used to measure WS, TS, SOC and DOC. An intact sample was ground to pass a 2-mm sieve for particle size analysis and a 0.25-mm sieve for chemical analysis using routine methods