

Rainfall pattern effects on crusting, infiltration and erodibility in some South African soils with various texture and mineralogy

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ABSTRACT

Rainfall characteristics affect crust formation, infiltration rate and erosion depending on intrinsic soil properties such as texture and mineralogy. The current study investigated the effects of rainfall pattern on crust strength, steady state infiltration rate (SSIR) and erosion in soils with various texture and minerals. Soil samples from the top 0.2 m layer were exposed to 60 mm·h⁻¹ simulated rainfall. The rainfall was applied either as an 8-min single rainstorm (SR) or 4 x 2-min intermittent rainstorms (IR) separated by a 48 h drying period. Rainfall pattern significantly ($p < 0.05$) affected crust strength, SSIR and erosion. The IR resulted in higher crust strength and SSIR than SR. The effect of rainfall pattern on SSIR was mostly influenced by the primary minerals, namely, quartz. Therefore, the predicted shift from long duration to short duration rainstorms due to climate change is likely to enhance crust formation and soil loss in semi-arid areas such as the Eastern Cape Province of South Africa.

Keywords: hydrology, penetration resistance, quartz, soil organic matter

INTRODUCTION

Raindrops break down soil aggregates and set off the process of physical crust formation (Assouline, 2004; Carmi and Berliner, 2008; Bu et al., 2013). The ensuing breakdown and consolidation of micro-aggregates and soil particles alter soil surface hydraulic processes such as steady state infiltration rate (SSIR) and runoff (Carmi and Berliner, 2008). Consequently, both soil and rainfall characteristics that determine the nature of crust formation have been extensively investigated in many environments (Stern et al., 1991; Wakindiki and Ben-Hur, 2002; Carmi and Berliner, 2008; Wuddivira et al., 2009; Bu et al., 2013). This widespread and sustained interest in the soil crusting phenomenon signifies both its importance and the lack of a full understanding of its impact on the environment. Among the most investigated soil properties in this regard are texture (Stern et al. 1991; Kay and Angers, 1999; Lado et al., 2004; Wuddivira et al., 2009), soil organic matter (Lado et al., 2004) and mineralogy (Wakindiki and Ben-Hur, 2002; Khun and Bryan 2004; Mamedov et al., 2006; Lado et al., 2007). Wakindiki and Ben-Hur (2002) showed that kaolinitic soils are significantly less susceptible to crust formation than smectitic ones. Similarly, Lado et al. (2007) showed that 2:1 clays are more dispersive than 1:1 clays. Crust formation decreases with increase in clay content because clay particles bind aggregates together contributing to cohesive strength of the aggregates (Boix-Fayos et al., 2001; Chenu et al., 2000; Levy and Mamedov, 2002). Despite acknowledgement that soil mineralogy influences crust formation, only a few studies have dealt with soils dominated by primary minerals. Most likely the low adsorption capacity of quartz (Buhman et al., 2006) makes it less important with regard to plant nutrition. However, the low specific surface area

of quartz promotes rapid soil organic matter (SOM) mineralisation resulting in poor aggregate stability (Buhman et al., 2006). Soils in most parts of the Eastern Cape Province are dominated by primary minerals such as quartz (Mandiringana et al., 2005; Nciizah and Wakindiki, 2012), and are highly susceptible to crust formation (Stern et al., 1991; Mills and Fey, 2004).

On the other hand, effects of rainfall characteristics such as depth (Fan et al., 2008), intensity (Truman et al., 2007) and duration (Augeard et al., 2008) on crust formation are well-known. However, new thinking is being prompted by the current forecasts of climate change's potential effects on soil health and water resources. For example, it is predicted that climate change will alter both rainfall patterns and intensity (Davis 2010; Allen et al., 2011). Rainfall patterns will become more sporadic and the frequency of drought periods will increase in semi-arid regions such as the Eastern Cape Province (Davis, 2010; Financial & Fiscal Commission, 2012). Nevertheless, the exact effects of these climatic changes on surface sealing, crusting and soil erosion are not entirely understood. Kuhn and Bryan (2004) highlighted the existence of soil-climate interactions and stressed the need for the development of a general concept for climate-soil structure interaction. Their study highlighted differences in sensitivity of the soils used to changes in soil condition on drying and subsequent interrill erosion. A 2-fold increase in erosion during dry conditions was observed in clay-textured soils, reinforcing the assertion that crust formation is influenced by rainfall pattern and soil properties. Therefore, there is a need to study the corresponding response of the soil surface to such changes. In so doing, the promotion of environmentally sustainable production systems leading to minimised degradation, as enshrined in the South African Department of Agriculture, Forestry and Fisheries Strategic Plan (DAFF, 2010), may be achieved.

Although the dire impact of climate change on soil structural behaviour is acknowledged (Allen et al., 2011; Kuhn and Bryan, 2004), less effort has been made to offer quantitative investigations in South Africa with regards to the influence of climate change on crust formation. Instead, much research has

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