エチオピア Guder 地区の長期耕作土壌の構造安定度：土壌改良剤の効果

Structure Stability of Long-term Cultivated Soils from Guder Watershed, Ethiopia: Effect of Soil Amendments

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Introduction

Land degradation and erosion is the essential agricultural challenges in highland of Ethiopia. Long-term soil management practices, nearly without conservation, intensely reduced soil organic matter and quality, and deteriorated soil structure and drainage capacity (Mengistu et al., 2016). Using proper conservation practices may steadily restore soil physical quality, and hydrological and biological characteristics; however, it may take several years. Thus along with conventional conservation measures, using additional or alternative conservation practices, such as application of easily available soil amendments with a specific chemical complexes (e.g. anionic polyacrylamide [PAM], lime, gypsum) one can improve the structure stability and drainage capacity of surface layer of soils. Under high-kinetic energy raindrop impact, soil crusting and sealing, and resistance to alterations in the physical conditions (e.g. breakdown of aggregates, a physico–chemical clay dispersion, that lodge and clog the conducting pores) of the tilled layer depends on soil type and associated properties (Kutılek, 2004). Water retention curve at low (0-50 cm H_2O) suction (e.g. macropores) can be linked to measured soil properties, and hence soil drainable porosity and structure stability can be derived from easily determined field soil characteristics (Mamedov and Levy, 2013). This study presents results (i) obtained from structure stability studies of four cultivated soils from Guder watershed, Ethiopia (> 2000 m), using the High Energy Moisture Characteristics (HEMC) method, and (ii) that link soil type (clay mineralogy), and contribution of wetting, PAM and lime application to pore size distribution for the development of effective management and conservation practices.

Material and Methods

Samples of four acidic soil types from tilled layer of intensely cultivated Guder watershed with various clay mineralogy (Vertisols, Regosol, Luvisols, Leptosol) and clayey texture was used. Experiments was conducted to evaluate the effect of soil type, wetting rate, lime (1.6 g L^{-1}) and PAM (200 mg L^{-1}) application on soil structural stability, using the HEMC method (Mamedov and Levy, 2013). In this method, (i) energy of hydration and entrapped air are the main forces responsible for breaking down of aggregates, and (ii) water retention and structure stability parameters are inferred from changes in the pore size distribution following controlled wetting. The water retention curves of samples were characterized by a modified VG model that provides (i) model parameters α and n, which represent the location of the inflection point and the steepness of curves, and (ii) a soil structure stability index (SI =VDP/MS; VDP-volume of drainable pores, MS-modal suction). Deionized water (DW) and ethanol were used for wetting of aggregates. Nonpolar liquid-ethanol eliminate aggregate slaking and could be reference for treatments.

Results and discussion

The studied treatments had, generally, considerable effects on the shape of the water retention curves (Fig. 1) : soil type, wetting rate, PAM and lime had mostly significantly effect on the stability indices (SI, VDP and MS) and the model parameters (α and n). The SI and α increased, and MS and n decreased significantly with PAM and Lime application and the decrease in wetting rate; however the shape of curves were soil type dependent, since the changes were observed in the various size of the macropores (> 60-125; 125-250 & >0.250 μm) and hence apparent macroagregates. Changes in soil structure following aggregate breakdown, resulted in the formation of a larger number of aggregates/particles of smaller sizes, producing

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the inter-aggregate or particle pore size distribution to shift toward a greater number of smaller pores, and thus to a decrease in the VDP, and to a higher value for the MS. Most of soils (3 of 4) with low organic matter, and mixed and/or predominant smectite clay mineralogy, higher clay activity and dispersibility (Vertisol, Luvisol, Leptosol) had very low structural stability (SI=0.010-0.013 cm^{-1}) at fast wetting rate (control), and hence susceptibility to sealing, crusting and sheet erosion. The SI of the soils wetted with ethanol showed close values (SI=0.65-0.72 cm^{-1}) and were >5-7 times higher value than controls, indicating higher level of slaking in the latter during wetting. Contribution of lime was smaller, yet notable, particularly in Acrisol. Treating with PAM improved the VDP, and decreased MS, and thus leading to an increase in the SI of soils > 2-3 times (SI=0.026-0.030) relative to control. To compare stability of all soils, the stability ratio ($SR=SI_{Treatments}/SI_{Ethanol}$) was introduced (Fig. 2), showing that generally for all treatments SR of Regosols > Luvisols > Leptosols > Vertisol.

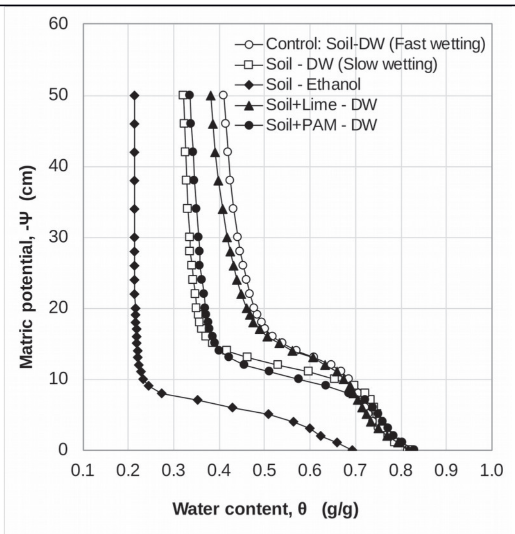

Figure 1. Water retention of Luvisols, non-treated control and treated with PAM (200 mg L^{-1}), and Lime (1.6 g L^{-1}), and wetted with deionized water (DW) or ethanol.

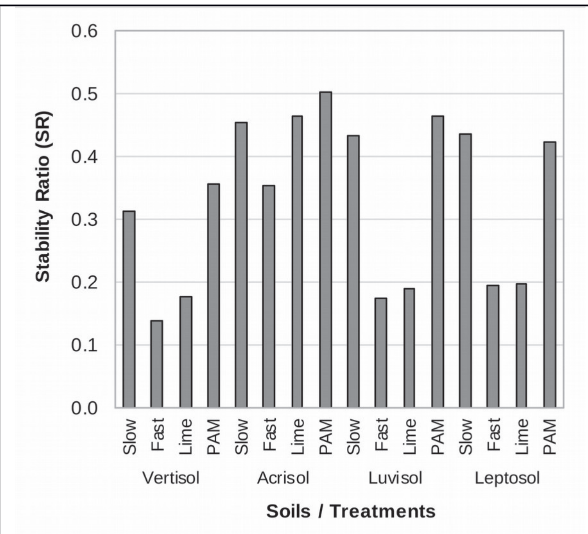

Figure 2. Stability ratio ($SR=SI_{Treatment.}/SI_{Ethanol}$) of four non treated-control (slow and fast wetting), and treated with PAM and Lime (fast wetting rate).

Conclusions

The results indicate that for maintaining soil physical or hydrological properties and erosion control soil type and predominant clay mineralogy, wetting rate (e.g. rain intensity) and cultivation history should be considered before the accurate rate of amendment application. The anionic PAM can be used before heavy rainfall to bind the soil against erosion, particularly in the areas when crops are small to protect soil surface. For effective soil structure and drainage capacity improvement, crusting, and erosion control, PAM application could be associated with other amendments and electrolyte sources such as lime and gypsum (e.g. sol health and physical quality management), which are not part of conservation processes in the studied area.

References

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