Temporal Effects of Subsoiling on the Soil Hydraulic Conductivity and Water Retention of Reconstructed Soils

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Background

- Anthropogenic disturbances, such as open-pit mining and subsequent reclamation, cause significant alterations to soil properties by inducing a high degree of soil compaction.
- Compaction negatively affects pore volume, connectivity and distribution which influences soil water processes including infiltration, percolation (i.e., hydraulic conductivity), drainage and evapotranspiration.
- A heavy duty rip-plough has been shown to ameliorate compaction by breaking up large compacted layers, into smaller aggregates and clods.

Figure 1. A McNabb Winged Subsoiler D7R XR Caterpillar used for sub-soil ripping of compacted soils in the fall of 2010 at Genesee Prairie Mine, AB. Sub-soil ripping was completed to a 60 cm depth.

Objectives

- To assess the medium-term effect of subsoiling on a reconstructed soil
- To compare the soil-water characteristics between the ripped and un-ripped plots at different depths by deriving soil moisture retention curves fitted to the van Genuchten model
- To assess the variability of saturated and un-saturated hydraulic conductivity between ripped and non-ripped soils at varying depths

Experimental Design

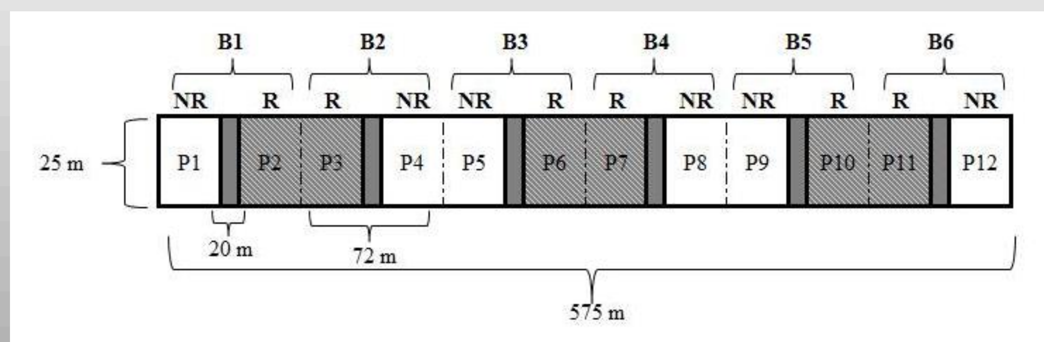


Figure 2. Experimental design layout of the study site showing ripped (R) and non-ripped (NR) soil plots. B is block and P is plot. Solid gray blocks represent buffer areas between ripped and non-ripped treatments.

Methods

Evaporation Method: measures the change in evaporation rate (water flux) and tension (hPa) at two depths under natural drying conditions to measure the moisture retention curve and un-saturated hydraulic conductivity for tensions > -1000 hPa

- Cores were manually weighed 3-4 times daily
- Tensions were automatically recorded by the TensioView Software
- Moisture retention curve derived from the change in mass of water loss (g) and mean tension (hPa) of the two tensiometers

Figure 3. HYPROP unit, showing tensiometers and sensor (www.ums-muc.de).

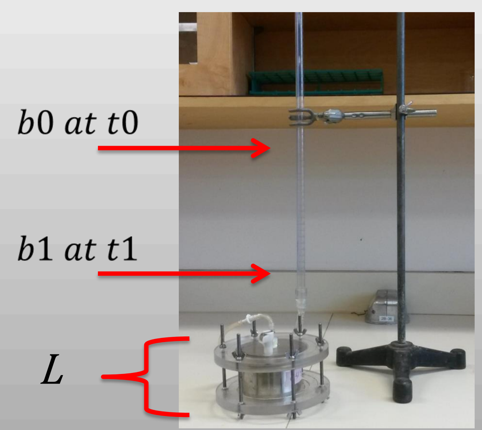
Figure 4. Hyprop campaign measuring the water loss and water tension due to evaporation.

Pressure Plate Extractor Method: Uses applied gas pressure to push water from soil cores to quantify points on the moisture retention curve < -1000 hPa

- Cores were equilibrated to pressures of 1000, 5000 and 15,000 hPa

Falling Head Method: measures the un-steady state flow of water through a soil column to determine the saturated hydraulic conductivity.

- Hydraulic conductivity is measured by the rate of water fall in a burette which is attached to the top of a sample.
- 3 undisturbed cores were measured at 5-10, 15-20 and 30-35 cm depths.
- K_s was determined from an equation adapted from Darcy's Law (Klute and Dirkesen 1986):



$$k_s = \frac{aL}{A(t1-t0)} \cdot ln\left(\frac{b0+L}{b1+L}\right)$$

Figure 5. Falling head method setup; where ks is the saturated hydraulic conductivity, a is the cross sectional area of the burette, A is the sample cross sectional area, L is the sample length, b0 is the height of water at time zero and b1 is the height of water at time two.

Results

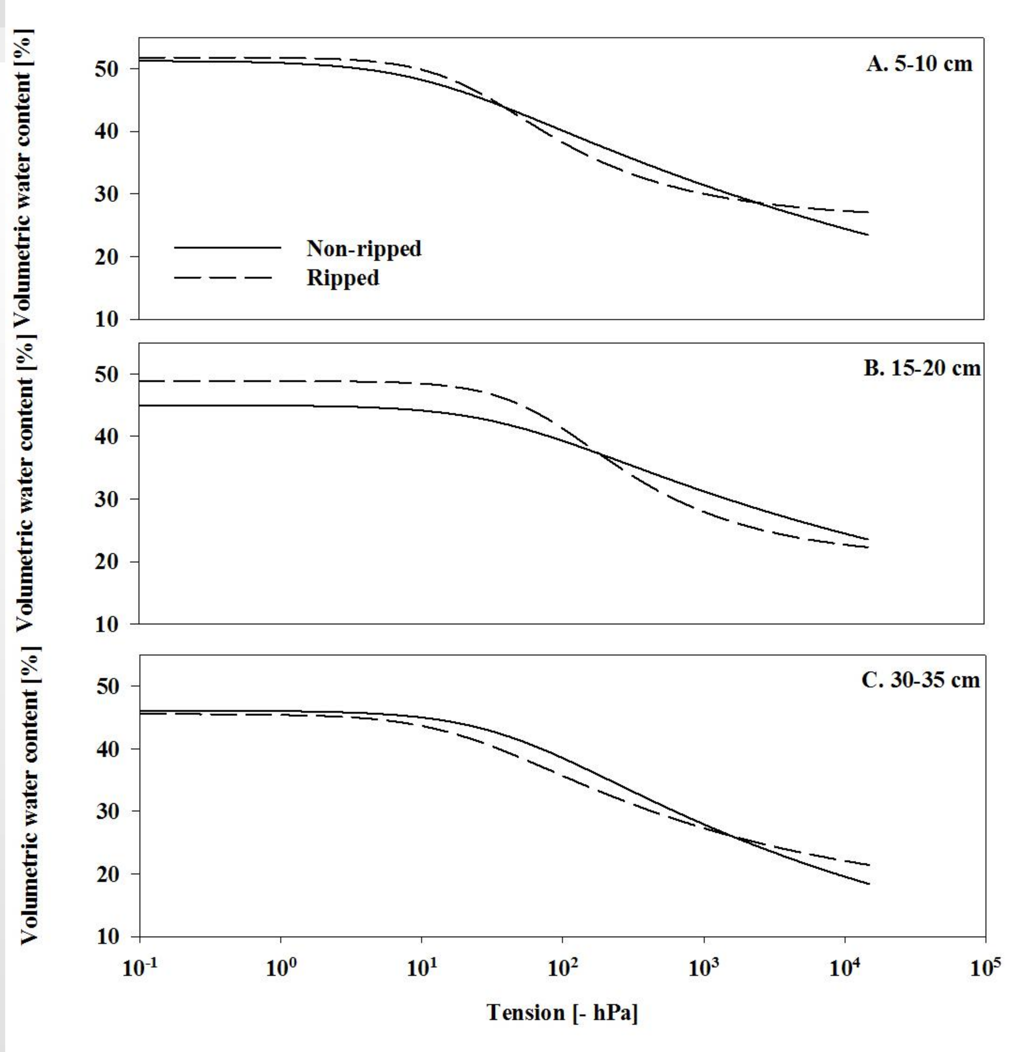


Figure 6. Soil moisture retention curves for ripped and non-ripped soils at 3 depths (A. 5-10, B. 15-20, and C. 30-35cm) fitted to the van Genuchten model for moisture.

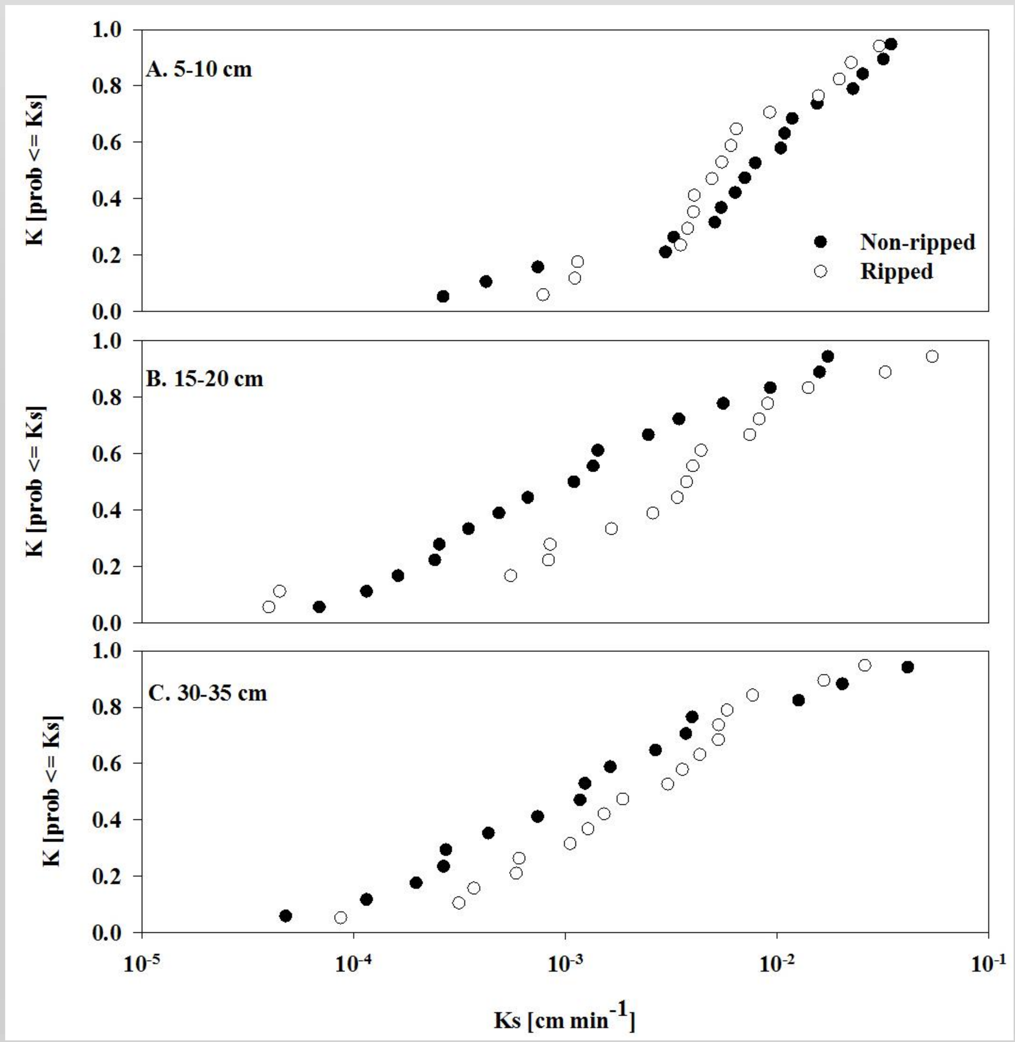


Figure 7. Saturated hydraulic conductivity (cm min-1) for ripped and non-ripped soil treatments at 3 depths (A. 5-10, B. 15-20, and C. 30-35cm) measured with the falling head method.

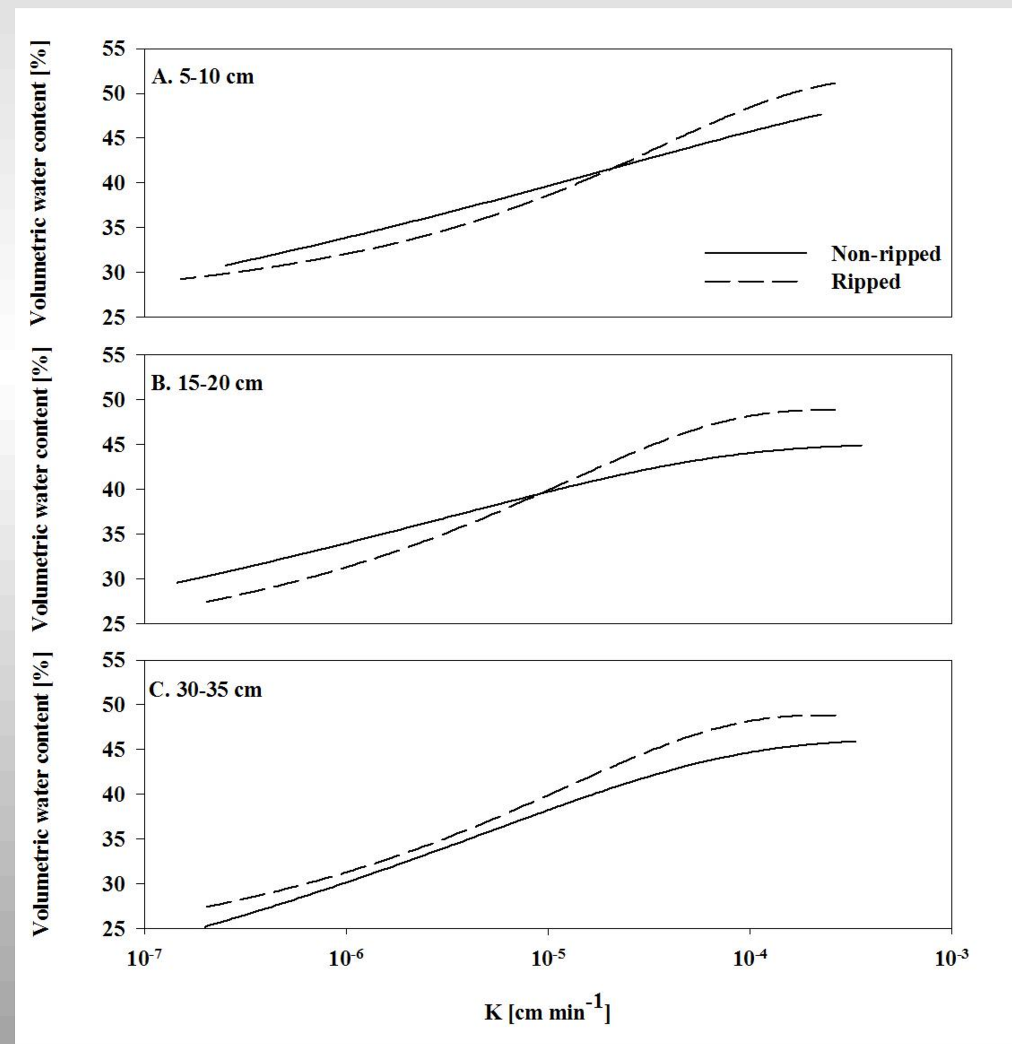


Figure 8. Hydraulic conductivity (cm min^{-1}) as a function of volumetric water content for ripped and non-ripped soils in 3 depths (A. 5-10, B. 15-20, and C. 30-35cm) fitted to the van Genuchten-Mualem Model.

Discussion

- Early structural development indicated by the formation of some discrete pore classes in the range of 2-100 µm in ripped soils as a result of ripper shanks creating cracks and fissures in the soil.
- Higher residual porosity may indicate re-compaction of ripped soils by human activities (i.e., planting and weeding), and natural consolidation.
- Reduced potential for hydraulic barriers and improved percolation and redistribution in ripped soils indicated by a higher K_s.
- Ripping may have changed the volume, size and geometry of pores in the soil, pore necks may have decreased without changing the soil porosity decreasing the unsaturated hydraulic conductivity of ripped soils

Conclusions

- Results indicate some medium term benefits of subsoil ripping. Over all, medium term effects of ripping are most evident in the subsurface layers (15-20 cm) as shown by greater saturated conductivity and saturated volumetric water content.
- Saturated hydraulic conductivities were improved in subsurface layers (15-20 and 30-35 cm) with ripping which is believed to be the result of increased pore continuity, increased pore hydraulic radii and volume or the presence of a few hydraulically important macropores.

References

Klute, A. and Dirksen, C. 1986. Hydraulic conductivity and diffusivity: Laboratory methods. In methods of soil analysis part 1. Physical and mineralogical properties. American Society of Agronomy, Madison, Wisconsin.

Funding Sources