Can the Cohesive Strength Meter be used to Estimate Critical Shear Stress in an Agricultural and Prairie Soil?

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The cohesive strength meter (CSM, Partrac, Ltd. Glasgow, UK), is a small portable device (Figure 1) that has been used extensively on mud flats and estuaries to measure *in-situ* erosion thresholds of cohesive sediments (Tolhurst et al., 1999). Tolhurst et al. (1999) described the design and function of the device and developed an equation (Equation 1) to relate vertical jet pressures for suspension of grains to equivalent horizontal bed shear stresses (τ_o) in suspension. Equation 1 has been incorporated into a time series plot (Figure 2) creating a data analysis protocol for estimation of a critical shear value (τ_c) (Black, 2007).

$$\tau_0\,(\mathrm{N\,m^{-2}}) = 66.7 * (1 - e^{(-P/310.1)}) - 195.3 * (1 - e^{(-P/1622.6)}) \quad (1)$$

Figure 1. The cohesive strength meter (CSM).

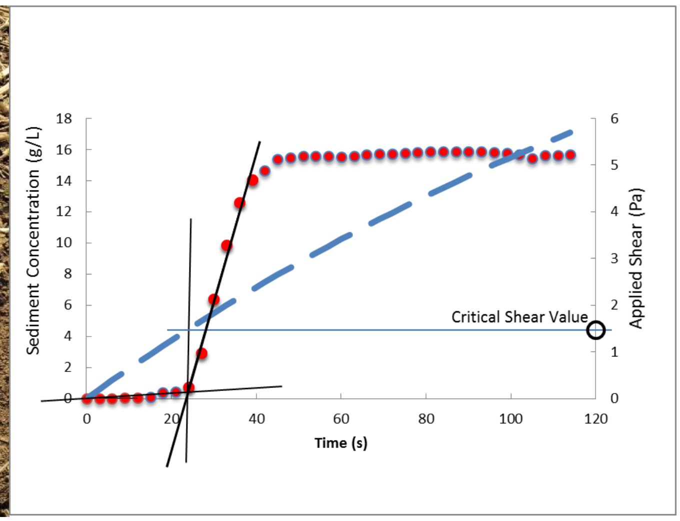

Figure 2. Typical time-series plot.

Both the CSM and the time series plot method of estimating τ_c have been successfully applied to agricultural soils (Singh and Thompson, 2016) and constructed wetland soils (Prellwitz and Thompson, 2014). However, in conditions where the soil surface is stabilized by epibenthic mats (Prellwitz and Thompson, 2014) or prairie vegetation (author's experience) the time series curve and Equation 1 are inadequate in predicting critical shear stress of soil. Current cohesive sediment research has explored new methods to calibrate the CSM internal jet pressure to stagnation pressure (P_{stag}) in order to extend the measurement range of eroding pressures on stable sediments (Vardy et al., 2007). However, these changes do not appear to be represented

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by current time-series protocols. The excess shear equation is primarily used in predicting soil detachment in rills and gullies when the shear stress exerted by flowing water exceeds the critical shear stress of the soil. However, in this research we were interested in the initial particle detachment during sheet or interrill erosion. Therefore, we were interested in using the CSM to estimate particle detachment and the relationship of aggregate stability in this process. This may result in P_{stag} being a more reliable predictor of soil detachment than critical shear stress, and P_{stag} may be a suitable proxy for raindrop impact.

Use of the CSM will be presented in the context of the first author's doctoral work that investigates the effects of increased freeze-thaw cycles on soil aggregation, as stable aggregates offer greater resistance to erosion. Laboratory studies indicate that freeze-thaw cycles generally cause aggregate disruption; however, field studies investigating the mechanisms involved in over-winter aggregate dynamics are lacking. We are testing these relationships in field conditions where it is hypothesized that increased freeze-thaw cycles resulting from reduced snowpack formation will lower aggregate stability. Furthermore, aggregate disruption will leave the soil more susceptible to detachment. This three-year experiment includes replicated treatments of natural snow accumulation, insulated plots to simulate a thick, sustained snow pack, and snow exclusion in an agricultural field and an adjacent restored prairie. This presentation will report data from the first two winter seasons of the study; soil aggregate stability and aggregate mean weight diameter were quantified before and after each winter season, as well as critical shear stress at the time of spring thaw. Changes in soil temperatures, freeze-thaw cycle numbers, and frost depth were achieved between treatments to help explain the response variables.

References

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