Estimating Crack Volume in Two Shrink-Swell Soils

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INTRODUCTION

High shrink-swell soils are associated with high clay content and predominantly smectitic clays; soils reported with other minerals such as kaolinite have also been observed to have high shrink-swell potential. When these soils are subject to periods of wetting and drying, the formation of cracks in the soil leading up to the surface can drastically alter the landscape hydrology (Wilding and Puentes, 1988). The ability to predict the opening, closing, and extent of these cracks in the field is important for simulating and understanding hydrology on these shrink-swell landscapes. To measure soil cracking in the field, a few methods are available in the literature, but little is understood about how these methods compare. One method is to directly measure the cracking; however, this method is incredibly time consuming and little is known about the accuracy (Kishne et al, in review). Another method is to measure the vertical subsidence in situ as the soil dries. Combining subsidence and assuming equidimensional shrinkage, the crack or void volume can be calculated (Bronswijk 1991; Bauer et al. 1993). Lastly the soil moisture can be measured in situ and combined with measured or estimated values of the Coefficient of Linear Extensibility (COLE), to calculate crack volume. All three methods have strengths and weaknesses. Particularly, a method that is rapid so that many sites on a landscape can be measured in one day is preferred. Another unknown in estimating soil cracking of natural soils is how mineralogy interacts with crack formation. Most Vertic soils are associated with smectitic clays, however, in central Texas Vertisols with mixed mineralogy are present.

The *overall objective* of this research was to compare the difference between these three methods of estimating soil cracking and compare the cracking behavior of the two Vertisols one smectitic and one with mixed mineralology.

METHODS

In August 2006, two sites, a Burleson Clay (Fine, smectitic, thermic Udic Haplusterts) and a Ships Clay (Very-fine, mixed, thermic Chromic Hapluderts), were located. At each site (1 and 2), one reference monument and three replicates (a, b, and c) of a set of soil-anchored rods to measure vertical movement and a neutron probe access tube were installed. The set of soil–anchored, iron rods included 4 rods, each anchored at different depths of 20, 40, 80, and 120 cm. The depths were chosen to show the different vertical shrinkage at various depth increments. The monument at each site was an iron rod anchored at 3-m deep, the estimated depth where no significant shrinkage would occur. An aluminum neutron moisture meter access tube was installed within each set of soil anchored-rods (Fig. 1).

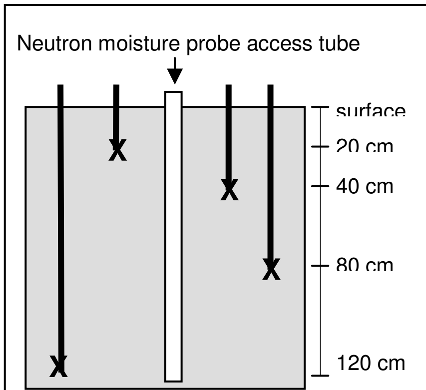

Figure. 1 Schematic of field instrumentation

Measurements were made at both sites from August 2006 to December 2007. Approximately every 2-3 weeks (depending on weather); moisture and leveling measurements were made on the same day. Moisture measurements were made in 20-cm depth increments to 130 cm deep using a Campbell Pacific 501DR neutron moisture meter. The neutron probe was calibrated at each site with a RMSD of 0.04 $m^3\ m^{-3}$. Vertical changes

in the soil-anchored rods were made by comparing the rod height to the fixed monument using a Sokia SDL50 Laser level (Japan), with accuracy of 2 mm. The equation used to estimate crack volume using soil height measurements was from Bronswijk (1991).

Hand measurements of the geometrical crack dimensions were made at the same time as the leveling measurements whenever cracks were at least 2 cm deep or 1 cm wide - if it did not meet these criteria it was considered surface crusting and was not measured. Crack depth was measured to the nearest mm with a set of steel straps, 6.35-cm wide by 0.79-cm cut to various lengths. The crack depth was measured relative to the surface by placing the steep tape it into the crack until it touched the bottom. Crack length and width were measured with a flexible retracting tape measure. A measurement of the length, width, and depth of a crack were taken approximately every 10 cm. Crack measurements are conducted over a 1 by 1-m area at four different areas within each site near the soil-anchored rods. The crack volume was calculated assuming triangular geometry.

In December 2007, the sites were destructively sampled. Three cores from each of the replication locations were pulled and COLE was measured for each horizon at each of the replication sites (a, b, and c) in triplicate and averaged (NRCS, 1996). The COLE values were used along with the moisture measurements to estimate crack volume. Assuming equi-dimensional shrinkage, vertical shrinkage of each soil layer was estimated. Crack Volume was predicted using these values for one-dimensional shrinkage were used with the formulas from Bronswijk (1991). With the remaining cores, bulk samples were collect for analysis of particle size, salinity, organic carbon, and total carbon (NRCS, 1996).

RESULTS

The three methods of estimating crack volume provided a wide range of values for predicted crack volume (Fig. 2).

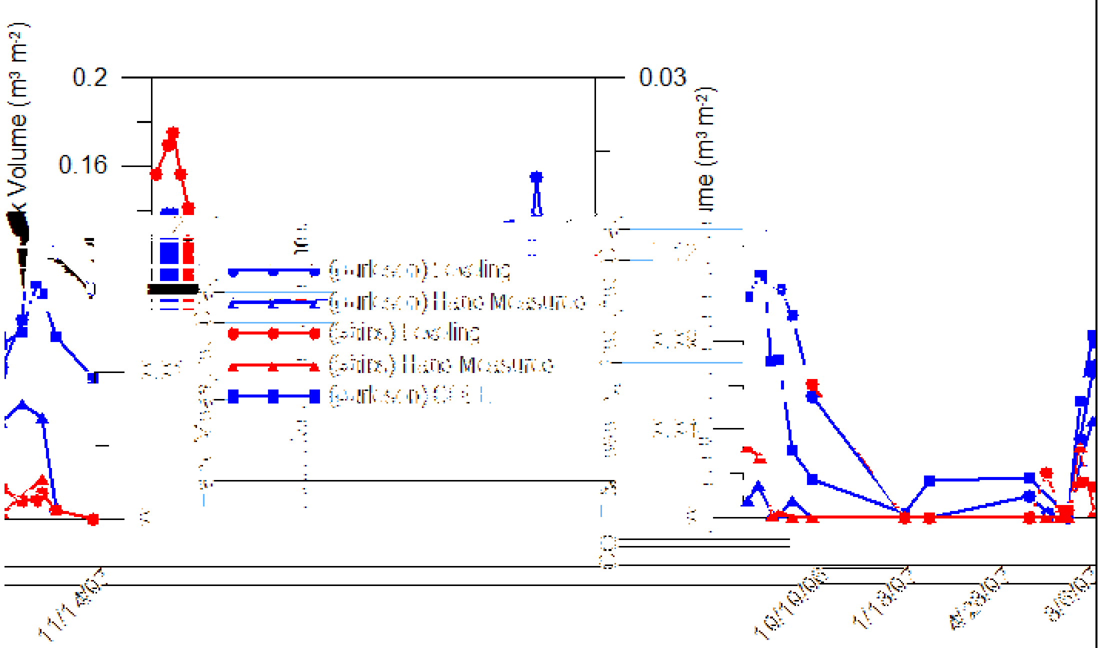

Figure. 2. Predicted crack volume in m^3 of crack volume per m^2 of soil surface from the three different methods.

The leveling-predicted crack volume provided the highest values of estimated crack volume, while the COLE-predicted crack volume for Burleson followed the same trend as the leveling-predicted crack volume and yielded slightly lower values. The hand measured crack volume for the two sites followed the same temporal trend, but yielded values tenfold less than that of the leveling-predicted crack volume. The much lower crack volume for hand measurements is probably because of the unpredictable geometry of the cracks. For example some crack probably did not go straight down, but moved laterally and were not measured. Additionally, there could have been no visible cracking at the surface, while cracks occurred below the surface.

During the first cracking event in 2006 the Burleson and Ships locations leveling-predicted crack volume followed the same trend but the location had higher amounts of cracking. The 2007 cracking event had large cracking values in the Burleson location with little cracking occurring in the Ships location. This cracking difference between the two soils in 2007 can be attributed to landscape position. The summer of 2007 received a lot of rain causing the Ships location to stay wet because of its floodplain position while the Burleson location was located on a terrace.

The lab analysis of the collected samples showed the Burleson and Ships locations had average COLE values of 0.13 m m^{-1} and 0.16 m m^{-1}, respectively. Though the Burleson soil is a smectitic clay, the mixed mineralogy of the Ships soil has a higher shrink swell potential. Lab analysis of total clay content for the two soils has not been completed. Graphs of water content versus shrinkage at both sites agree with the COLE values at the Ships site (data not shown).

SUMMARY

The results of this research have answered some questions and opened the door to further research. The three different methods of estimating crack volume (leveling-predicted, hand-measured, and COLE-predicted) followed the same temporal trend but with values of the hand-measured cracks were much lower. The leveling-predicted crack volume was ten times that of the hand measured crack volume and slightly larger than that of the COLE-predicted crack volume. In conclusion, we would recommend using soil moisture and COLE measurements or leveling to estimate cracking; however, these measurements do not provide any information about the crack geometry or spacing. The measured COLE values were accurate predictors of how the soil would shrink in situ, despite mineralogy.

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