Title of Proposal: Influence of Land Use and Terrain on Surface Hydrology in Shrink-Swell Soils.

Focus Categories (to be completed by Institution personnel): Hydrology, Surface Water and Non Point Pollution.

Keywords: shrink-swell, crack dynamics, land use, hydrology
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Abstract

Cracking of soils across a watershed reduces the amount of surface runoff and enhances rapid flow of water into the soil and the ground water. However, most hydrological models do not account for cracking dynamics and its spatial extent. Seasonal cracking of soils is mainly driven by the change in soil moisture; however, temporal interactions with antecedent soil moisture and plant roots associated with land use are also suspected to affect crack opening and closure. Therefore, understanding the impact of land use on soil shrink-swell potential is needed to accurately represent hydrology in shrink swell landscapes. The overall objective of this research is to characterize the impact of land use and terrain attributes on spatial and temporal cracking dynamics. Upon completion of this project, we expect to predict when soil cracks open, spatial extent of cracking, volume of cracks, and when they close. The simulation of crack opening and closure will be based on soil physical properties, soil moisture, terrain attributes (contributing area, slope, curvature), and land use. This knowledge will be used to modify and refine soil infiltration and hydrology models that simulate runoff, infiltration and solute transport across watersheds. In addition, we will be partnering with a local high school teacher at Mart ISD to a bring real-world, field-based science problem into to her high school classes and to integrate the honor students' class project in this research.

Statement of Critical Regional Water Problems

Shrink-swell soils occupy about 12 million ha in the United States (Texas has the most acreage), and these soils are extremely important to agricultural production. When shrink-swell soils dry, wide, vertically-oriented cracks facilitate rapid transport of surface water into subsoil through preferential flow. According to Smiels and Raats (2005), water movement in soils that change volume (shrink-swell soils) is not well understood, and management of swelling soils remains problematic. Understanding hydrology on shrink-swell landscapes is needed for improving hydrology models that predict non-point source pollution and flood management in urban areas. In fact, much of the Dallas, Ft. Worth and Houston urban/surburban development is on shrink-swell soils. Present approaches to hydrology of swelling soils are generally based on non-swelling soil theory; they rarely account for crack formation and its consequences. Use of these models results in significant errors in estimations of local water and solute flux, water balance, and aquifer recharge (Smiels and Raats, 2005). Nonetheless, models that can account for crack formation and associated hydrology are rarely used because the phenomena of crack formation and closure are poorly understood.

Simulations of watershed hydrology have shown that the inclusion of simplistic crack models based on shrink-swell potential and soil water content considerably improve predictions of runoff, but large uncertainties are still present because these rudimentary subroutines do not accurately describe the dynamics of crack opening and closing, or the spatial extent of cracks and land use systems (Stolte et al., 1997; Ghidey et al., 1999; Heppell et al., 2000; Morgan, 2003; Simunek et al., 2003; Ruan and Illangasekare 2004; Arnold et al., 2005). Seasonal cracking of a soil matrix can result in poor estimates of runoff and infiltration due to the changing soil storage conditions (Smettem et al., 1991; Stolte et al., 1997; Ruan and Illangasekare, 1998).

Several methods, including field and laboratory have been applied to quantify soil cracking. Some of these are measuring the Coefficient of Linear Extensibility (COLE) in the laboratory, measuring height change of a soil in the field as a result of shrink-swell (Arnold et al., 1973; Bronswijk et al., 1991), and direct measurement of cracks in the field (Kishne et al., 2008). However, little has been done to quantify the spatial and temporal variation of soil's shrink-swell properties across a landscape under different land use systems.

Nature, Scope, and Objectives of the Research

The ***overall objective*** of the research is to study the influence of soil properties, land use, and terrain on surface hydrology in shrink-swell soils by quantifying the temporal and spatial variability of soil cracking. The ***hypothesis*** of this research is that soil properties, terrain, and land use in a given watershed modifies the soil micro-environment. As a result, heat flow from and into the soil, evapotranspiration, and runoff are variable in space and time. The variation of these factors among different land uses results in significant differences in soil development, soil moisture and soil structure, which all influence the shrink-swell behavior. To test this hypothesis *in-situ* measurements of soil shrinking and swelling, soil moisture and soil properties will be made on three land uses (grazing, native prairie, and row crop).

At the completion of the proposed project, we expect to have an ability to quantify the spatial and temporal dynamics of soil cracking which provide the information necessary for understanding watershed hydrology and improving hydrology models applied in watersheds with shrink-swell soils. By including visits by PIs, field trips, and assistance with a class research project, we also expect to extent working knowledge of hydraulic processes into a local, rural high school. An improved understanding of how soil cracking affects watershed hydrology will lead to improved simulation of water, solute and particulate movement in watersheds and to more sound estimates of the effect of land management practices on surface and groundwater quality and quantity.

The research is being conducted near Riesel TX and is located at the USDA-ARS Grassland, Soil and Water Research Laboratory. Across this watershed, the dominant soil is Vertisols. The soil in the catena is mapped as a Houston Black (fine, montmorillonitic, thermic, udic Haplusterts), which is generally around 55% clay.

To study the impact of land uses and terrain on spatial and temporal cracking dynamics, three subwatersheds were selected. These watersheds include grazing land, native prairie and conventional tillage crop land. In each watershed, five sites were selected based on terrain information (slope, curvature) and soil electrical conductivity measurements (depth of soil) to monitor cracking behavior. At each of the sites, soil properties, including COLE will be measured, along with weekly measurements of soil subsidence and soil moisture. To measure subsidence at each site, four metal rods were anchored at depths of 0 (surface), 30, 60, and 90 cm. Additionally, a monument that does not respond to soil shrinkage and swelling was installed within line of sight of all moisture measurements locations at each site. The height of the rods and the monument are measured using a standard surveying equipment (a level mounted on a tripod and a stadia rod) at 0.1 mm vertical precision. The change in rod heights will be used to track the temporal trends in thickness of soil layers between each anchor. Assuming that soil shrinks equi-dimensionally, the volume of soil cracks will be calculated using a simple geometry (Arnold et al., 2005; Bronswijk, 1991). Near each set of rods, a neutron access tube was installed. The tube is used to measure soil moisture using a neutron moisture meter. Field measurements have being taken every two weeks since August 2008. These measurements will continue through 2009.

Results Expected from this Project

1. A mechanistic model of the spatial heterogeneity and temporal dynamics of soil cracking will be created using soil properties and the effect of topographic position. This model will help improve hydrological models (e.g. Lepore et al., 2009) by incorporating the temporal and spatial dynamics of crack opening and closing.
2. The impact of land use on the dynamics of soil cracking will be clearly defined. This will help understand the hydrological behavior of different land use systems in the presence of cracking soils. The output also will help modify hydrological models that are developed based on non-swelling theory.

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