REPORT

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

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Primary PI: Takele M. Dinka

Other PIs: Dr. Cristine Morgan (Major Professor)

Abstract

Understanding the dynamics of cracking and swelling of clayey soils improves the ability to predict the impact of land use on the hydrologic response of watersheds containing shrink-swell soils. The objective of this research was to characterize the impact of land use on spatial and temporal shrink-swell dynamics of a Vertisol. The hypothesis of this research is there is a variation in soil shrinkage on different land uses. This is because variations of soil properties, topography, and land use modify local infiltration, runoff, and storage in cracking and swelling soil. Cracking and swelling, in turn, influence infiltration, runoff, and storage, creating a feedback loop. In situ measurements of vertical soil movement and soil water content along with analysis of soil properties were made on fields under three land uses. The land uses were grazing land (GL), native prairie (NP), and cropland (CL). The research was conducted at the USDA-ARS Grassland, Soil and Water Research Laboratory near Riesel TX. The soil at the site was Houston Black (Fine, smectitic, thermic Udic Haplustert). To monitor vertical soil movements, five measurement sites on a GL and NP and four measurement sites on a CL (corn) were selected. Bi-weekly measurements of soil subsidence and soil water were made beginning in June 2008. The change in absolute heights of rods anchored at 0, 30, 60 and 90 cm was used to track the temporal trends in thickness of soil layers. Near each set of rods, soil water content was measured using a neutron moisture meter. The study showed that maximum soil subsidence and the time of its occurrence varied with land use. The maximum soil subsidence ranged from 91 to 112 mm in the sites of GL; from 70 to 75 mm in the sites of NP, and from 67 to 76 mm in the sites of CL. The maximum soil subsidence in the cornfield (CL) was within the same range as that of the prairie (NP), but the maximum occurred in mid July of 2008 in the prairie whereas maximum shrinkage did not occur until mid August of 2009 in the cornfield. In addition, there were differences in relative subsidence of soil layers within and among land use. Grass roots, size, and shape of gilgai likely influence the observed variation and further studies are underway. Knowledge gained in these studies may be used to modify and refine hydrology models that simulate runoff, infiltration and solute transport across different land uses in a Vertisol landscape.

Problem and Research Objectives

Seasonal cracking of shrink-swell 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 assumed to affect crack opening and closure. This indicates that shrink-swell behavior of soil may change depending on land use system and vegetation cover.

Several methods, including field and laboratory have been applied to understand the shrink-swell behavior of soil. Some of these are measuring the Coefficient of Linear Extensibility (COLE) in the laboratory (e.g; Vaught et al., 2006; Grossman et al., 1968) , measuring height change of a soil in the field as a result of shrink-swell (e.g; Arnold et al., 2005; Bronswijk et al., 1991), and direct measurement of cracks in the field (Kishne et al., 2008). However, little has been done to characterize and quantify the spatial and temporal variation of soils shrink-swell activities under different land use systems. Understanding the impact of land use on soil shrink-swell activities help improve the knowledge of shrink-swell dynamics and in turn the study of hydrology in shrink-swell landscapes. The overall objective of this research is to determine if there is any difference in a Vertisol subsidence under different land use systems and to quantify the spatial and temporal shrink-swell activities under different land use systems.

Materials/Methodology

The research was conducted at the USDA-ARS Grassland, Soil and Water Research Laboratory near Riesel TX. In situ measurements of vertical soil movement and soil water content along with analysis of soil properties were made on fields under three land uses. The land uses are grazing land (GL), native prairie (NP), and cropland (CL). The soil at the site was Houston Black (Fine, smectitic, thermic Udic Haplustert). To monitor vertical soil movements, five measurement sites on a GL and NP and four measurement sites on a CL (corn) were selected based on topographic information and apparent soil electrical conductivity. At each site, soil from cores was described, and soil texture and inorganic carbon were analyzed. Bi-weekly measurements of soil subsidence and soil water were made beginning in June 2008. Particle size analysis, inorganic carbon and total carbon analysis were done. Measurements of soil subsidence and soil water were done to characterize the shrink-swell activities of Vertisols. The soil subsidence is estimated by taking the difference between the maximum soil height and the current soil height. Soil water loss from a soil layer was also estimated to study its relationship with soil subsidence. Soil water loss is estimated by taking the difference between the maximum soil water in the layer and the current soil water.

Principal Findings

- The study showed that maximum soil subsidence and the time of its occurrence varied with land use.
- The maximum soil subsidence ranged from 91 to 112 mm in the sites of GL; from 70 to 75 mm in the sites of NP, and from 67 to 76 mm in the sites of CL. The graph of soil subsidence of one site for each land use in shown in figure 1.
- The maximum soil subsidence in the cornfield (CL) was within the same range as that of the prairie (NP), but the maximum occurred in mid July of 2008 in the prairie whereas maximum shrinkage did not occur until mid August of 2009 in the cornfield.
- In addition, there were differences in relative subsidence of soil layers within and among land use.
- Soil subsidence varies yearly, spatially and with a landuse.
- Grass roots and gilgai presence and shape could be a reason for variation in soil subsidence within and among landuse.

- Maximum subsidence occurred at the same time in grazing land and native prairie, but in a different year in cropland.
- Observations do not always follow the mechanics of equidimensional shrinkage during a normal shrinkage.
- Development of a mechanistic model that relates soil water, antecedent soil moisture and soil subsidence is underway.

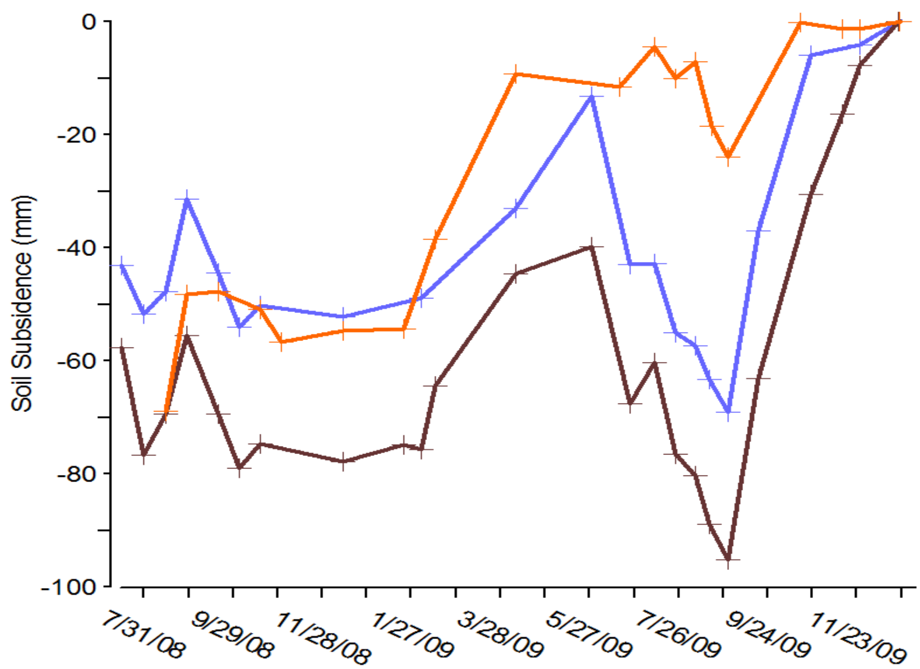

Figure 1. Soil subsidence on each land use, **native prairie**, **corn**, and **grazing land**.

Significance

The result of this study provides the information necessary for understanding watershed hydrology and improving hydrology models applied in watersheds with shrink-swell soils. The graph below is attached to demonstrate how soil subsidence is correlated with runoff at the native prairie land (Figure 2). Assuming equidimensional soil shrinkage, when the maximum soil subsidence measured in the different land use is converted to crack volume, it gives an idea of how much runoff can be trapped by the volume of cracks. In this study, the maximum crack volume estimated during the study period was 114, 98 and 99 mm/m^2 in GL, NP and cornfield. 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 result will also help modify hydrological models that are developed for shrink-swell soils based on theory for non- shrink/swell soils.

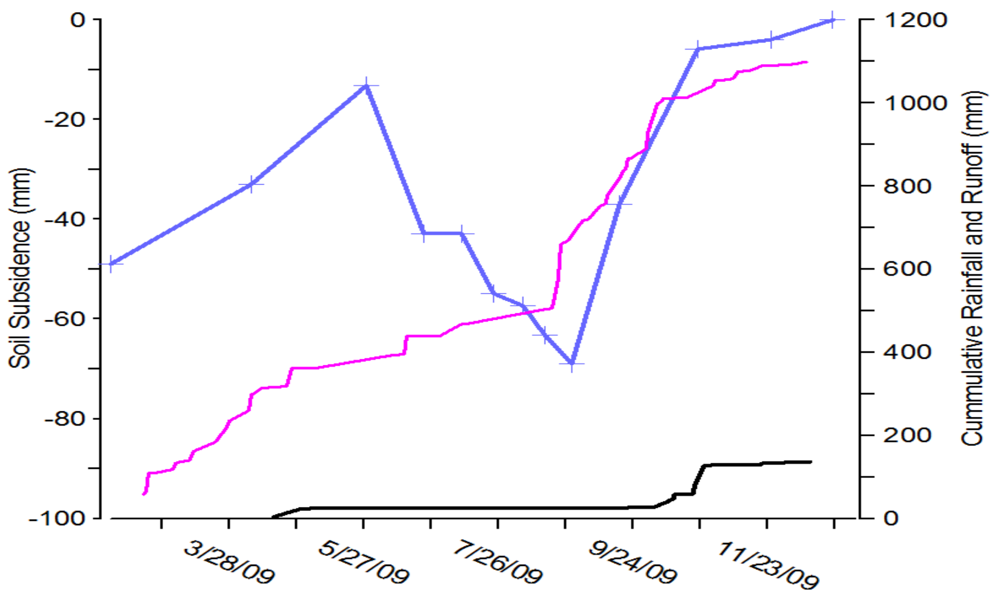

Figure 2. **Soil subsidence**, **cumulative rainfall** and **runoff** at the native prairie.