WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Fragipan influence on hillslope hydrology and solute transport.

Focus Categories: HYDROL, ST, NPP

Keywords: perched water table, saturated flow, contaminant transport, soil-water relationships, land-water interactions, nitrogen

Duration of Project: March 1, 2000 - February 28, 2001

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Non-federal funds Pledged: $15500.00

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Congressional District:

Kentucky 6th District

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(Princeton Research and Education Center)

Significance

In western Kentucky many soils contain fragipans--subsurface soil layers characterized by high density and high mechanical strength relative to overlying soil layers. The presence of a fragipan in a soil landscape controls water storage and discharge because it restricts downward water movement and promotes the development of perched water tables above the fragipan. In sloping landscapes, the fragipan encourages lateral subsurface water flow. The movement of dissolved and suspended species (e.g., carbon, nutrients, fertilizers, pesticides) to surface water and groundwater is enhanced through this lateral downslope flow above the fragipan. For example, a common practice for disposal of animal wastes is land application to agricultural land. Once applied to the soil, many factors control the fate of inorganic or organic nitrogen in the animal waste. The widespread occurrence of fragipans may affect the fate and transport of nitrogen and other dissolved or suspended species. To fully understand the effects of different surface management operations on surface water and groundwater systems, especially in complex soil landscapes found in western Kentucky, it is necessary to examine the hydrological processes within the soil.

Results & Benefits of Proposed Research

Because of the physical, hydrological, and biogeochemical importance of fragipans, knowledge of their affects on soil hydrology, and the subsequent biochemical processes that occur in this environment is essential for understanding the use and limitations of fragipan soils in western Kentucky. Data generated through the proposed research will provide for characterization of (i) the depth to, duration of, and frequency of perched saturated conditions above a fragipan at different landscape positions within the landscape, and (ii) the direction and magnitude of lateral flow above the fragipan. The results of the proposed research will answer questions important to soil and water management in fragipan landscapes: Where are perched zones of soil saturation above the fragipan developing, for how long, and how often? How is the direction and magnitude of subsurface flow affected by the presence of the fragipan? Because of the potential for transport of contaminants above the fragipan to surface water or groundwater systems, the outcomes of this research will provide information on the management of soils in fragipan landscapes.

Nature and Scope

Fragipans are important soil features that affect (i) the productivity of agricultural land, (ii) the development potential of non-agricultural land, (iii) biogeochemical processes within the soil, and (iv) the quantity and quality of water entering surface and subsurface water systems that drain fragipan soils. There are approximately 9,500 km^2 of fragipan soils mapped in Kentucky, representing 14% of the Commonwealth. In western Kentucky, fragipan soils are common in areas where Wisconsinan loess overlies less permeable pre-Wisconsinan materials (bedrock or paleosols formed in bedrock residuum). The objectives of the proposed research are to characterize the depth to, duration of, and frequency of saturated conditions perched above the fragipan at different landscape positions, and elucidate flow patterns in these perched zones of soil saturation. Of particular importance is the direction of the lateral subsurface flow. The perched water does not necessarily flow perpendicular to surface elevation contours because the topography of the fragipan surface is not parallel to the topography of the soil surface.

This is one aspect of a larger project designed to examine how the presence of these perched zones of soil saturation influence soil biogeochemical processes above the fragipan. Whether saturated conditions develop above the fragipan, and how long they persist, controls the development of anaerobic conditions and the occurrence of biochernical processes, like nitrate reduction. The goal is to develop an increased understanding of pedological, hydrological, and biogeochemical processes in fragipan landscapes. Future objectives will include studying the effects of surface management (e.g., fertilizer application, animal waste application, cropping systems) on nitrate transformations above the fragipan.

Research Plan

This study will be conducted in western Kentucky at the Princeton Research and Education Center. A field site (100 m x 100 m) has been identified that shows a range of fragipan expression along topographic (and hydrologic) gradient. The soils within this site are deep, moderately well drained soils formed in loess over bedrock. A relatively impermeable fragipan is present in the upper meter. Slope gradients range from 2 to 6%. This land is currently under grass cover that is periodically mowed.

We have constructed a preliminary map of the depth to the fragipan across the catena using a tile probe. This initial mapping was used to establish locations for field plots and permanently installed field-monitoring equipment.

<u>Current Methods:</u> We have installed piezometers, constructed from 2.5-cm polyvinyl chloride (PVC) pipe, directly above the fragipan at 25 locations (5 x 5) within a regular grid (20 m x 20 m) of sample points across a single hillslope. They are being used to measure the depth to the perched water table above the fragipan at each location (when present). Saturated soil conditions are indicated when water is present in the piezometer. All piezometers will be monitored manually on a biweekly basis. In addition to manual monitoring, continuous water table monitoring systems, each consisting of a pressure transducer and digital data logger in one unit, have been installed in nine piezometers across the study site, but concentrated in the lower landscape positions where ephemeral perched water tables are more likely to develop. These data will allow for the detection of short-duration saturated conditions that may develop in response to individual storm events.

<u>Proposed Work</u>: The direction and magnitude of lateral flow above the fragipan will be examined using a tracer study. Approximately 1 m upslope of each of the five piezometers in the first row of the grid of piezometers, we will excavate a trench perpendicular to the slope, approximately 2 m long, 0.2 m wide, and 0.2 m deep. A known amount of tracer will be added to each trench, then the trenches will be backfilled with soil to prohibit any movement of tracers in surface flow. Because flow may not be perpendicular to the soil surface, two tracers will be used, Br^- and Cl^-. Different ratios of Br^- to Cl^- in each trench (100/0 %Br^-/%Cl^-, 75/25, 50/50, 25/75, and 0/100) will be used to detect any deflection of flow paths. If flow is perpendicular to topography, the ratio of Br^- to Cl^- downslope of each trench should be approximately equal to the ratio of Br^- to Cl^- in the trench. Conversely, if flow is not perpendicular to topography, there should be changes in the ratio of Br^- to Cl^- downslope of each trench.

We will collect water samples for analysis of tracer concentrations on a biweekly basis. Following measurement of the depth to water in each piezometer, we will evacuate the water using a portable pump. More frequent observations may be made during critical times during the year, e.g., in the fall when perched saturated conditions return above the fragipan. Flow magnitude on a given sample date will be determined by the amount of tracer found in a given piezometer and the distance traveled from the trench. We will determine the percent recovery of the tracers on a given sample date by multiplying the volume of perched water present by the measured tracer concentration.

We will characterize the hydraulic properties of the soil at each piezometer location by extracting an intact soil core down to the top of the fragipan using a hydraulic probe. These cores will be returned to the lab, and a segment of each core from each major genetic soil horizon will be analyzed to determine saturated hydraulic conductivity and bulk density. Using these results and site characteristics, pore water velocity will be calculated.

To examine tracer movement beyond the study site, we will install two additional water table monitoring systems in a stream that flows along to the base of the slope. These will be used to measure the height of water in the stream and to sample water from the stream for water analysis.

Facilities: The Princeton Research and Education Center is located in western Kentucky and encompasses substantial areas of fragipan soils. The Center is staffed with field and laboratory personnel, and houses sufficient laboratory space and equipment, to assist with the management and monitoring of this project. The Department of Agronomy supports a soil and water analysis laboratory with the analytical instrumentation and supplies necessary for routine analysis of the water samples that are taken throughout the year. The College of Agriculture also supports soil analysis laboratories at Princeton and at Lexington for routine soil analysis. Research facilities managed by Dr. Thompson include all field equipment necessary for hydrologic monitoring and soil and water sampling, including a hydraulic probe for extracting soil cores and installing piezometers, a pump for evacuating the piezometers, and a vehicle for travel to the study site in western Kentucky.

Related Research

The amount of water stored above the fragipan can be significant. In western Idaho, McDaniel and Falen (1994) found that 30-60% of the seasonal precipitation was stored above the fragipan during the wet winter months. This water is redistributed across the landscape through lateral flow above the fragipan interface (McDaniel and Falen, 1994; Calmon, 1997; Reuter et al., 1998). McDaniel and Falen (1994) found that the depth to the fragipan surface and the thickness of the zone of soil saturation was greatest in the lower landscape positions. In such fragipan landscapes, the location and thickness of perched zones of soil saturation are determined by (i) the balance between precipitation and evapotranspiration and (ii) the slope of both the land surface and the fragipan surface, plus the relative strength and permeability of the fragipan. Conversely, Jenkinson and Franzmeier (1996) describe areas in Indiana where the fragipan horizons are not continuous across the landscape. On a hillslope in southern Indiana with a discontinuous fragipan, perched zones of soil saturation above the fragipan persisted longer in the upper landscape positions (where there was a continuous fragipan) than in lower landscape positions (where the fragipan was not continuous) (Jenkinson and Franzmeier, 1996). Because the continuity of the fragipan horizon influences the location and timing of perched zones of soil saturation, the location of, depth to, and strength of fragipans within soil landscapes influence the movement and storage of water within the soil profile and will potentially relate to water quality within the watershed. Knowing the topography of the fragipan surface is particularly important for understanding hillslope hydrology when the fragipan surface does not parallel the soil surface (Reuter et al., 1998).

Perched zones of soil saturation are ordinarily only observed seasonally, developing for extended periods in the cooler autumn months and persisting through the winter and into the spring (Pickering and Veneman, 1984; McDaniel and Falen, 1994). This is in response to decreased evapotranspiration rates when air temperatures are lower and plant growth slows or stops. Shorter-duration saturation events occur during the warmer summer months in response to significant precipitation events--when precipitation rates exceed the permeability of the fragipan (Pickering and Veneman, 1984; Calmon, 1997). Recent work by Calmon (1997) in fragipan soils of northeast Pennsylvania found that most occurrences of perched water table events during the summer were of relatively short duration (less than 10 days). However, such short-duration events may be important in the transport of dissolved or suspended species.

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