Characterizing hydrologic properties of rocky surface soils in Garner Run, Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, USA

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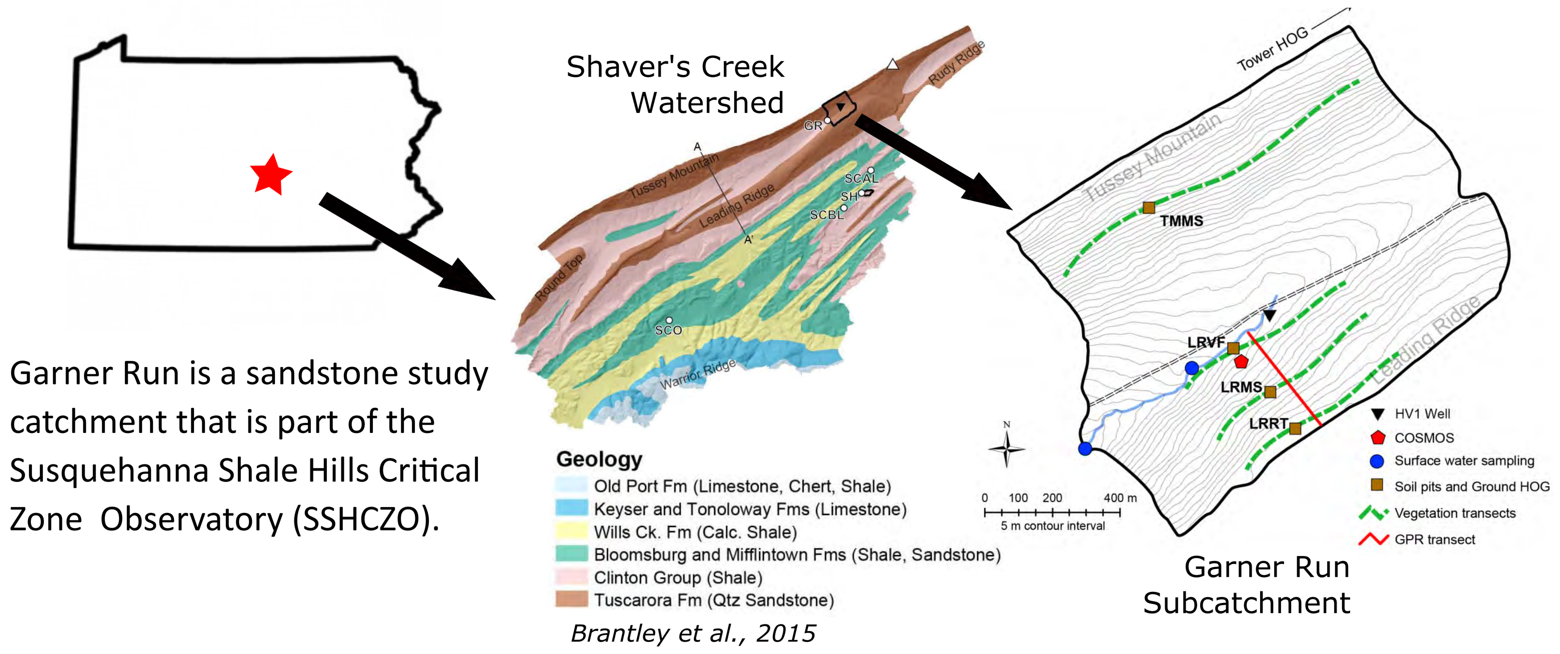
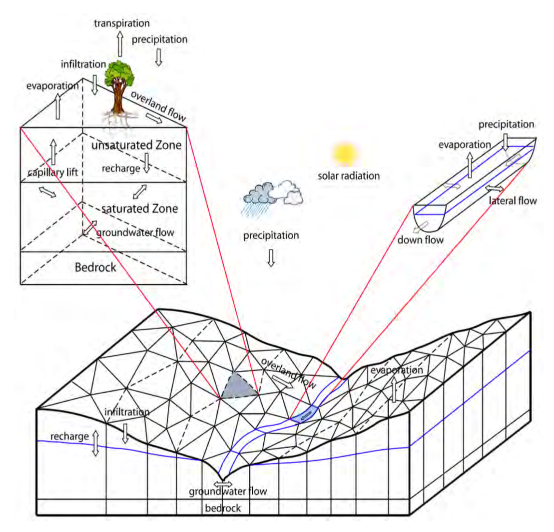
Study Location



Garner Run is a sandstone study catchment that is part of the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO).

Approach



Penn State Integrated Hydrologic Model (PIHM)
Qu, 2004

Penn State Integrated Hydrologic Modeling system (PIHM) is a powerful tool used to predict the hydrologic properties of a watershed.

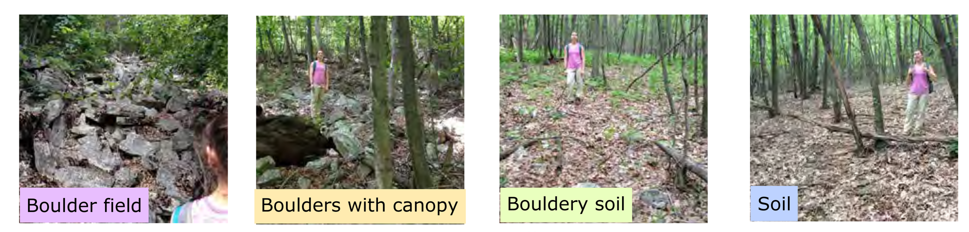
The model requires an understanding of local soil properties, however the input files currently used for Garner Run do not have the spatial resolution to adequately represent the surficial heterogeneity of the subcatchment. Field measurements are necessary to accurately represent this observed heterogeneity.

Motivation

Soil hydrologic properties determine how water, solutes, and sediment move through the near surface environment. While robust methods exist for characterizing the hydrology of homogeneous, fine-grained soils, it is less clear how to incorporate rocky soils into critical zone models.

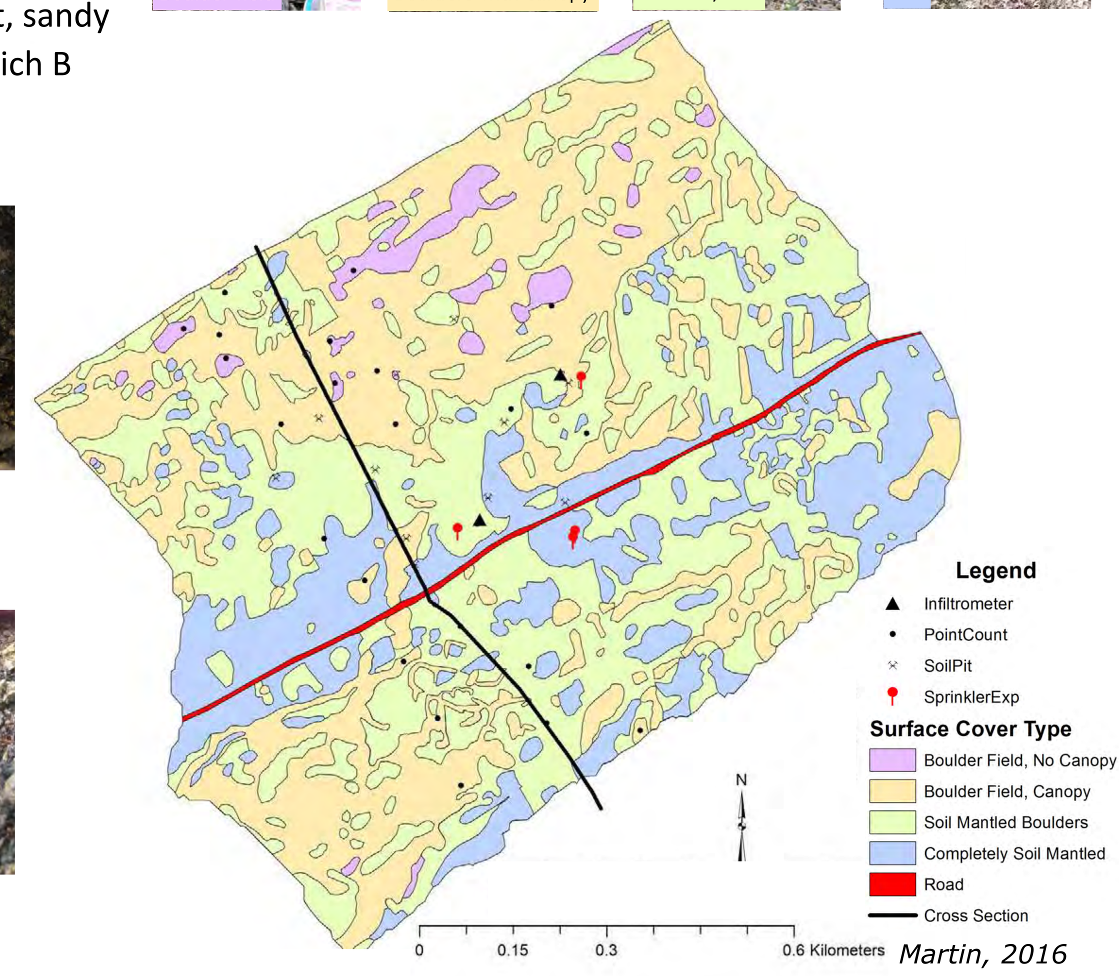
Surface Type

Heterogeneity in surface cover ranges from clay-rich soil to open boulder fields (right). The soil profile includes a thin, organic-rich A horizon and a variably present, sandy E horizon overlaying a clay-rich B horizon (below).



Thick E Horizon

Minimal E Horizon

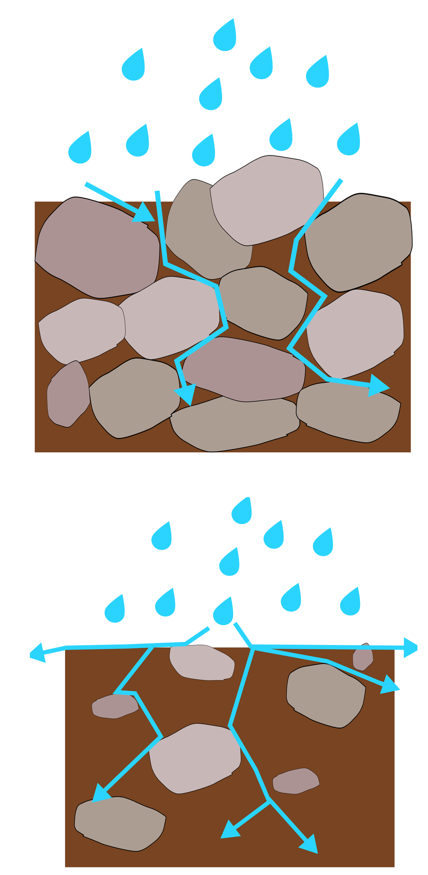


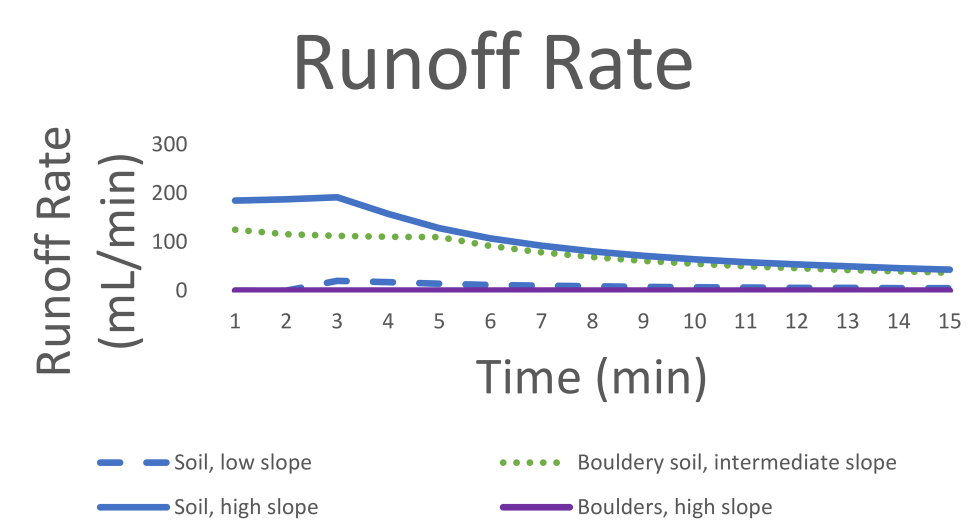
Martin, 2016

Sprinkling Experiments

- Plastic garden edging was used to define an approximately 1 m diameter "watershed"
- A 95 L water tank with a pump attached to a garden hose and showerhead was used to simulate rainfall (see right)
- Runoff was captured and measured whenever possible and qualitative observations were recorded

Experimental Conditions:

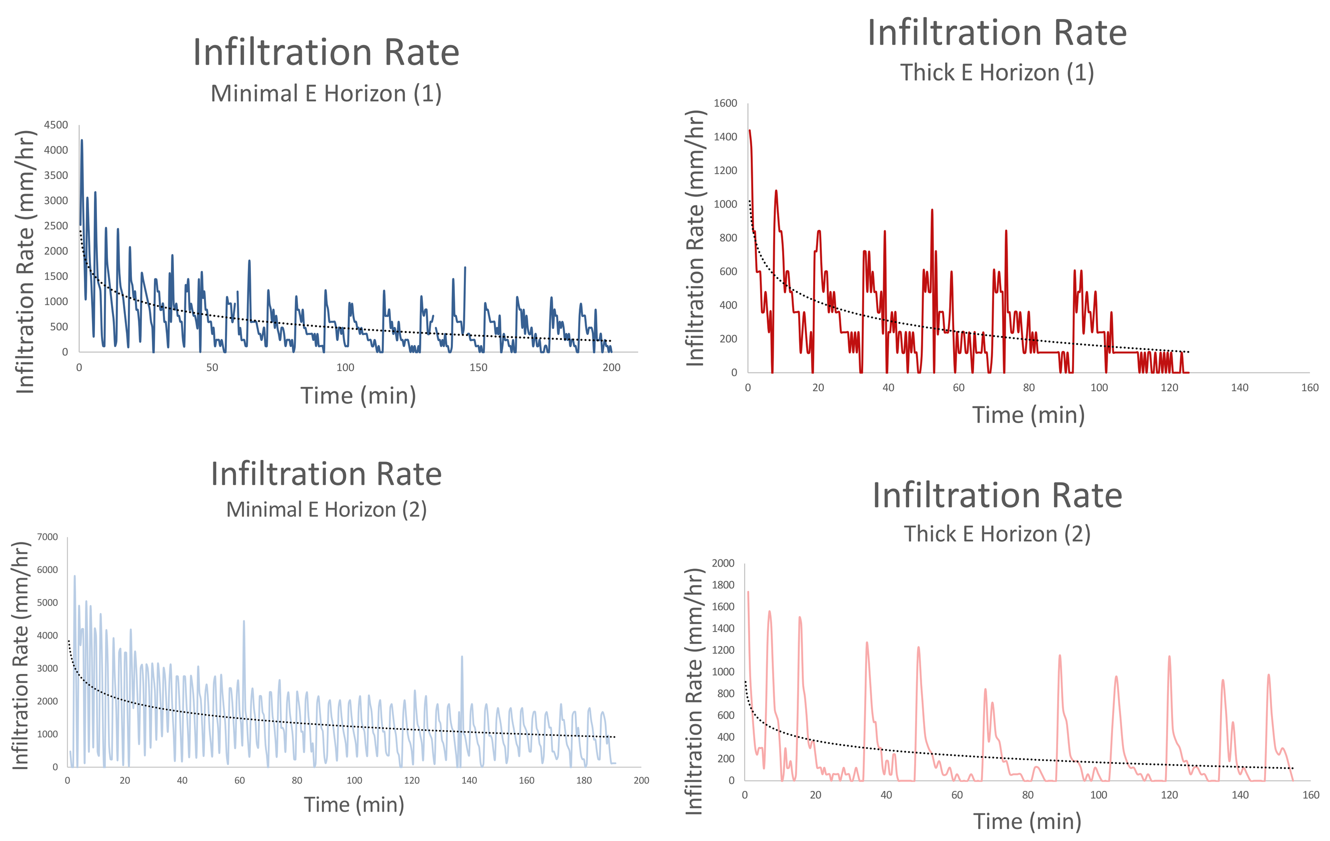


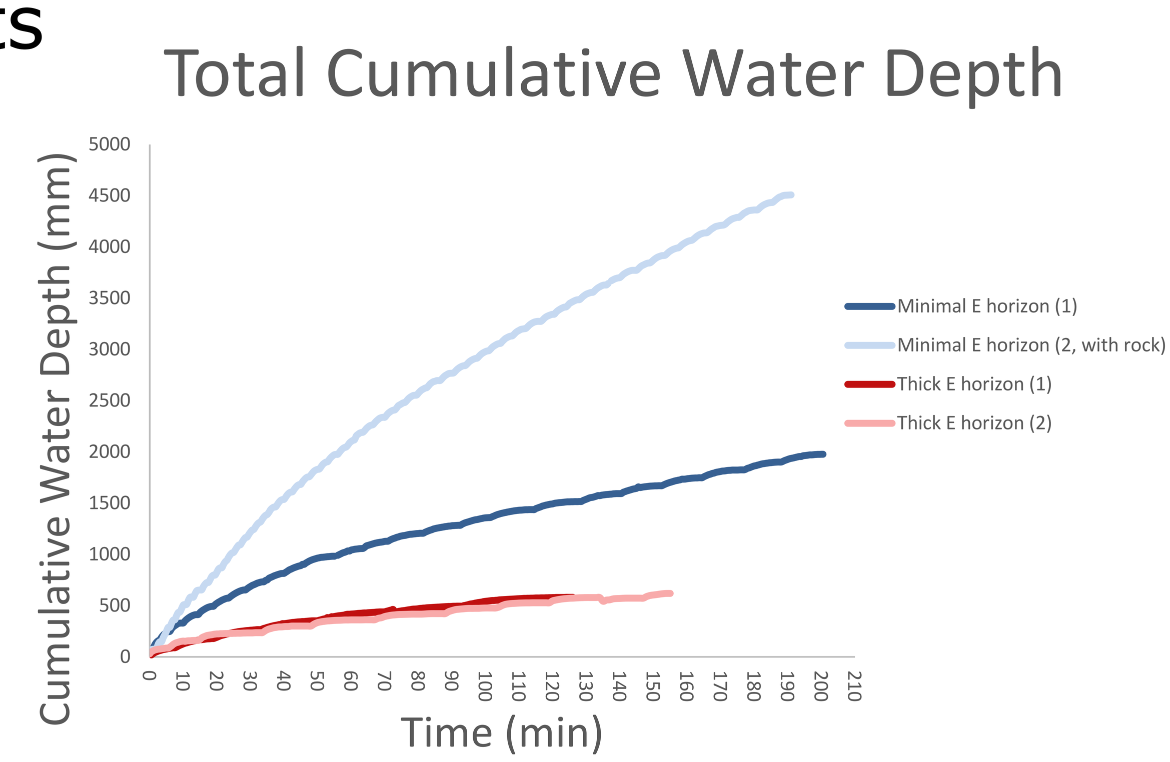


Plot showing differences in runoff rate due to both slope material and gradient (above). For soil-mantled sites, runoff volume increases with slope gradient, while boulders do not yield runoff even on high slopes. (Left) Schematic diagrams showing observed flow paths for both surface cover endmembers.

Ring Infiltrometer Tests

- Turf Tech Double Ring Infiltrometers were used to determine infiltration rates
- Readings were taken every 30 seconds over the course of 120 - 200 minutes
- Two experimental locations were selected on each soil endmember
- Two tests were conducted in each location





As observed by the tapering of the cumulative depth of the wetting front, Thick E horizon (1), Thick E horizon (2), and Minimal E horizon (1) all reached steady state, and when saturated, soil with a thick E horizon absorbs water at a slower rate. Minimal E horizon (2) did not reach steady state. Subsequent excavation of the site revealed the presence of a large cobble directly below the infiltrometer at a depth of 8 cm, indicating that rocks increase the rate at which soil can absorb water.

Conclusions

Potential for runoff during storm events is complex and moderated by many variables, including local surface cover and soil profile, slope grade, and leaf litter cover. Observations based on each of these variables are as follows:

- The presence of a thick E horizon may allow for horizontal flow within the eluviated layer before the wetting of the underlying, clay-rich B horizon
- In locations with soil-dominated surface cover on low, medium and high grade slopes, more runoff was observed on steeper slopes
- On bouldery surface cover, the removal of leaf litter allowed organic-rich mats to absorb some water before infiltrating into macropores, whereas leaf litter left in place acted as a direct pathway to macropores, leaving the underlying organic-rich mat almost completely dry

References

Brantley, Susan L., et al. "Designing a suite of measurements to understand the critical zone." Earth Surface Dynamics 4.1 (2016): 211.

Qu, Yizhong, and Christopher J. Duffy. "A semidiscrete finite volume formulation for multiprocess watershed simulation." Water Resources Research 43.8 (2007).