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Landscape Whole System Sensitivity to Land Use Influences, Kentucky River, Ky.

Palisade inner bend walls, Bowman's Bend area

Overview

The Kentucky River downcuts some 100 meters into the Bluegrass limestones, opening up karst dissolution features to surface view. In the 1800's, the Bowman's Bend area along the river was cleared for crops and pasture, leaving hardwood forests edging the river escarpment. These land use patterns have remained relatively consistent since then. Changes in water pathways evolving in upland soils under long-term pasture/grassland cover now appear to be initiating increased sediment movements.

In recent years, a pattern of increasing erosion has become apparent in which shallow surface incisions and gully heads have formed at geomorphically sensitive locales along the grassland/forest boundary. At these locations, field survey indicates that gullying most likely results from a spatially nonuniform distribution of changes in soil water pathways in the upland grassed slopes. Runoff increases related to recent conversions from fescue to native tufted grass species may interact with a much more slowly evolving tendency for soil moisture to perch at the soil/bedrock interface. Under long-term grass cover, gradual changes in soil properties in the upland areas now appear to be changing slope hydraulics, shifting increasing amounts of water into subsurface lateral flow paths. This moisture increase is likely caused by loss of tree root penetration of bedrock layers.

(A and B) Tree roots tap into cutters and bedrock bedding planes, carrying preferential flow into epikarstal storage.

(C) Stems of tufted Indian Grass are shown following a January 2004 prescribed burn. Replacement of fescue with tufted species in 1998-1999 has exposed more soil to direct rainfall.

Environmental Issue: Long-term Land Use Impacts

Land use practices involving changes in vegetation cover are known to set up conditions that alter hydraulic flux patterns in underlying soils. The differences in runoff, infiltration, and translocation dynamics created by differing land covers are fairly well known, but the ways in which soil changes propagate effects throughout landscape systems over long periods of time are poorly understood. This project assesses the changes in vertical and lateral flows that have evolved in the soils of a fluviokarst terrain since conversion from hardwood forest to grassland in the early 1800's, and then correlates them with current management practices. Erosion patterns observed in the study area are seen as emergent forms developing in sensitive locales under comprehensive short and long-term grassland cover effects. This project thus describes human land use impact from within a whole-system perspective that incorporates both spatial and temporal landscape dimensions. Results should provide important data concerning land management practices in karst terrain, as well as insight into system evolution over time.

Hypothesized Soil Changes

Clay builds up under grass cover above the soil/bedrock interface in locations where tree roots do not penetrate fissures in the bedrock. Water drains laterally above the clay. Where converging lateral water flows intersect the forest, preferential flow at the rooting depth creates gullies. Temporally emergent subsurface pathways in slopes interact with runoff patterns created by current management practices, exacerbating erosion. Differences evolving between grassland and forest flowpaths should be measureable through determination of soil texture, infiltration capacity, and pathway traces.

Methodology

Synthesis of Approaches:

Part 1
- Intensive survey and mapping of karst and erosion features along 1.5 km of the river escarpment *
- GIS analysis of soil, geology, topography
- Land use analysis using aerial photo data (1937 to present)
- Interviews with local landowners and Nature Conservancy personnel

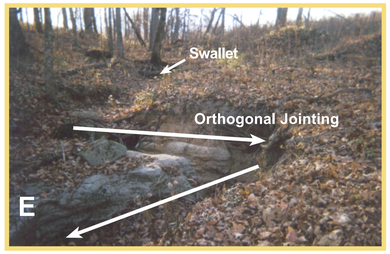
Part 2 (Comparative testing of grassed and forested slopes)
- Indirect measurement of water flux through hydrometer settling soil texture tests
- permeameter measurement of horizon infiltration and hydraulic conductivity rates
- mapping of dye movement through hillslope sections

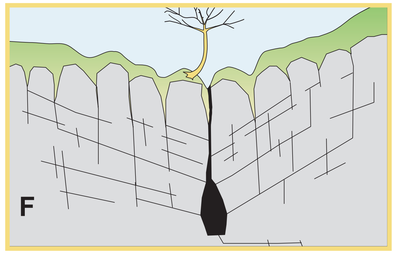
* Partial preliminary data is presented in Phillips, J.D., Martin, L.L., Nordberg, V.G., and Andrews, W.A.Jr., 2004. Divergent evolution in fluviokarst landscapes of central Kentucky. *Earth Surface Processes and Landforms* 29: 799-819.

(D) Gully head at grassland/ forest boundary line

Emergent Hydraulic Flux Changes in a Complex Fluviokarst Landscape

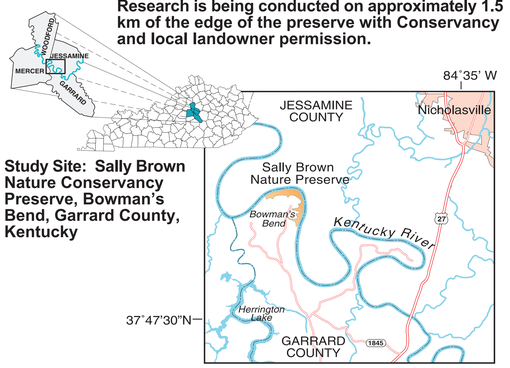
Hydraulic fluxes in hillslope soils develop in relationship to complex integrations of geologic, topographic, vegetative, and climatic factors acting over time. The landscape complexity seen at Sally Brown is additionally affected by karst development, which takes place when naturally acidified water causes dissolution of the underlying limestone bedrock along weakened zones. Karst features develop according to the resistances of varying bedrock layers, and in the study site, vertical shafts are found to develop in the Tyrone Formation of the High Bridge Group. In addition, shallow (2-3 m deep) conduits form in the top portion of the hillslope bedrock, so that a system of both roofed and unroofed shafts and conduits drain the slopes by moving flow within the epikarst, or upper part of the bedrock. Because grassland systems have lower overall evapotranspirative rates and do not support roots capable of wicking preferential flow into epikarstal storage, flow at the soil/bedrock interface appears to increase over time under grass cover, leading to increased conduit flow during storm events. Places at Sally Brown where conduits intersect lateral root systems at the grassland/forest boundary line are prime points of gully head erosion, as shown in photos D and E.



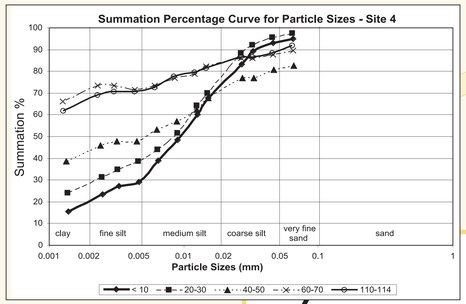


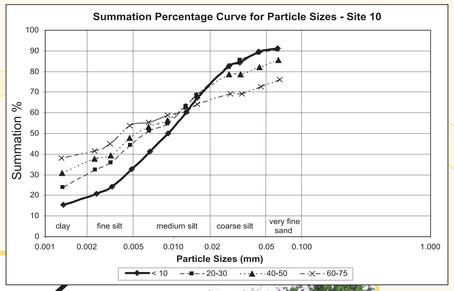
(E) Epikarstal conduit exposed by unroofing. Upslope from this location, an open swallet shows where the conduit is hidden under a soil cap.
(F) Vertical shafts penetrate certain bedrock layers, creating drawdown cones in the surrounding bedrock.

Sally Brown Nature Preserve, owned and maintained for public access by The Nature Conservancy. Research is being conducted on approximately 1.5 km of the edge of the preserve with Conservancy and local landowner permission.



Study Site: Sally Brown Nature Conservancy Preserve, Bowman's Bend, Garrard County, Kentucky



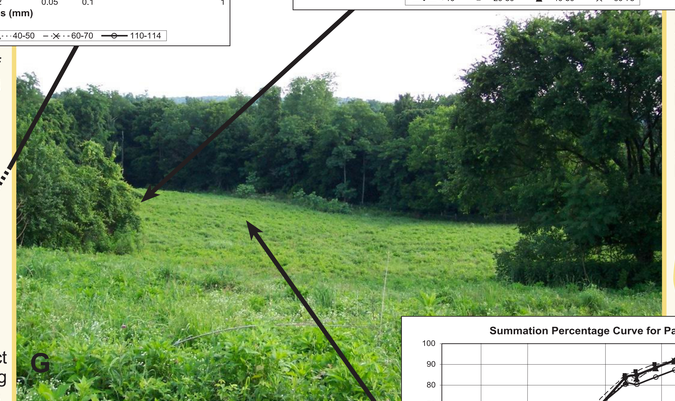


1. Site 4 lies upslope and to the northwest of a grassed sink area. A linear depression leading downslope from the sink marks the presence of a bedrock subsurface conduit. Soils at site 4 are 1.14 m thick and have extremely heavy clay build up in lower horizons and above the soil/bedrock interface.

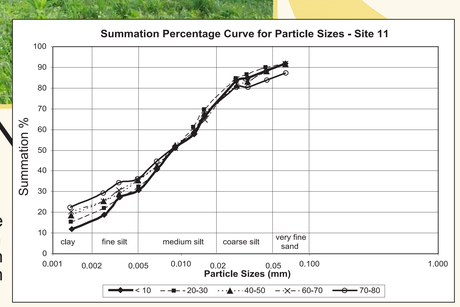
2. Site 10 lies on the hill crest downslope from Site 4 and below the sink. Total profile depth has been lowered from 1.14 m to 75 cm likely because of loss of clays and fine silts from lower horizons.

Preliminary Soil TextureTest Results

(G) In the first stage of Part 2 research, indirect indicators of water pathways in the slopes are being sought through soil texture analysis. Clay layers are often impermeable and cause water to flow laterally within the soil. Early results show that distributions of clay in the lower horizons of the grassed slopes are highly contingent on proximity to linear depressions associated with epikarstal conduits. As sample sites steepen on side slopes edging the depressions, fewer clay and fine silt fractions remain, indicating that they are preferentially being moved from the soil profile base.



3. Site 11 is situated on the slope between the linear depression and Site 10. Clay content is further reduced in lower horizons from what was found in Site 10, even though total profile depth increases slightly.



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