Susquehanna Shale Hills Critical Zone Observatory

All Hands Meeting Agenda and Abstract Volume

The Pennsylvania State University

University Park, PA

May 2019

SSHCZO All Hands 2019 Agenda

Wednesday, May 8th

Arrival of out of town participants – room block at the Atherton Hotel

Ouimet's arrival – Flight UA3959 arrives from Dulles Intl 2:04pm

3:00pm – Roman to meet Ouimet at Atherton lobby and walk to FRB
3:30pm – 4:30pm: meet with soils/ecology/forestry in 217 FRB
5:00pm – 6:00pm: meet with geosciences/engineering/meteorology in 341 Deike
6:30pm – Dinner: Ouimet, Roman, Duncan – Spats at the Grill - confirmed

Thursday, May 9th **ALL HANDS MEETING – Shaver's Creek Environmental Center Hamer Classroom**

8:00am – 8:15am – Welcome and Introductions to SSHCZO. Talks will be grouped, each speaker will have ~ 10 minutes, followed by 10 minute Q/A session to the group.

8:20am – 8:40am – Brantley/DiBiase Synthesis Talk: CZO Research – Future Opportunities

8:45am – 11:00am Research Presentations

8:45am – G1: Measuring and Modelling Forests: Warren Reed, Yuting He

Warren Reed: *Tree-ring derived estimates of forest productivity from north facing mid-slopes within the Shale Hills and Garner Run watersheds*

Yuting He: *What controls the spatial and temporal variability of forest C pools at Shale Hills CZO? An exploration from a model perspective*

Moderator: Margot Kaye = 10 min, 1 min, 10 min + 10 min discussion

9:15am – G2: Measuring and Modelling Roots and Respiration: Ted Primka, Caitlin Hodges

Ted Primka: *Topography and related soil moisture impacts on fine root production within the Susquehanna-Shale Hills Critical Zone Observatory*

Caitlin Hodges: *Soil gas concentrations at Shale Hills and Garner Run indicate anaerobic respiration driven by metal reduction in soil microsites*

Moderator: Jason Kaye = 10 min, 1 min, 10 min + 10 min discussion

9:45am – 10:15am ***Stretch Break and Coffee***

10:15am – G3: Measuring and Modelling Water in Shale Hills and Garner Run: Dacheng Xiao, Qicheng Tang

Dacheng Xiao: *Predominant control of subsurface properties in storage-discharge relationship in catchments derived from contrasting lithology*

Qicheng Tang: *Mesotopography controls on soil moisture and preferential flows*

Moderator: Jon Duncan = 10 min, 1 min, 10 min + 10 min discussion

11:00am – YOU CHOOSE ACTIVITY:

a) Shaver's Creek Outreach and Research Collaborations (Joshua Potter, Justin Raymond, Doug Wentzel, Michael Forgeng) with trail walk around SCEC on "science loop"
b) Shale Hills CZO instrumentation tour with Brandon

12:45pm – 1:15pm – Lunch at Lake Perez – sandwiches, chips, cookies, and beverages

1:30pm – 3:30pm – Field trip – Blue Bird transport from Lake Perez to Cole Farm and back to Shaver's Creek Environmental Center

<u>Discussion Leaders</u>: Roman DiBiase, Perri Silverhart, Jon Duncan, Mike Forgeng, Andrew Shaughnessy, Dacheng Xiao, Yuting He, Caitlin Hodges, and Brandon Forsythe – handouts or poster boards with adviser guidance

4:00pm – 5:00pm – Featured Seminar by Dr. William Ouimet, Associate Professor of Geomorphology at the University of Connecticut, will present "**Quantifying Anthropocene Landscape Change in Southern New England" in the Hamer Classroom at Shaver's Creek Environmental Center**

5:30pm – Dinner – Doan's Bones catered at SCEC

<u>Friday, May 10th</u> **ALL HANDS MEETING – 117 EES Building**

9:00am – 12:30pm <u>Research Presentations</u>

9:00am – G4: Measuring and Modelling Tree Throws: Ben Dillner, Tim White

Ben Dillner: *Plant Resource Availability and Soil Characteristics in a SSHCZO Tree Tip-up Chronosequence*

Tim White: *Sediment flux rates by tree throw in the Shale Hills Critical Zone Observatory and associated satellite sites in the Appalachian Mountains*

Moderator: Brandon Forsythe = 10 min, 1min, 10 min + 10 min discussion

9:30am – G5: Measuring and Modelling Water and Nutrients in Garner Run: Ismaiel Szink, Virginia Marcon, Kristen Brubaker

Ismaiel Szink: *Lithological effects on root distribution and exudate production*

Virginia Marcon: *Where older, slow-eroding soils are more nutrient-rich than younger fast-eroding soils: Landscapes as collectors or losers*

Kristen Brubaker: *Intermediate erosion hypothesis: Does nutrient input rate control vegetation structure and diversity?*

Moderator: David Eissenstat = 10 min, 1 min, 10 min, 1 min, 10 min + 10 min discussion

10:15am – ***Poster Session and coffee***

- EAGER SitS: Emergent Properties during Soil Formation at the Susquehanna Shale Hills Critical Zone Observatory (Brantley et al.)
- TeenShale: Outreach in Science and the Science in Outreach (Williams et al.)
- Deployment of a 3D Seismic Array in the Susquehanna Shale Hills Critical Zone Observatory and Results from a Nearby 400 Meters Line (Ma et al.)
- Using a Near Surface Geophysics and Critical Zone Science Field Experience to Broaden the Participation of Underrepresented Minorities in the Geosciences (Keating et al.)
- Bear Meadows, Pennsylvania: an opportunity for investigating a coupled record of paleoclimate, paleoecology, and paleoerosion processes (DiBiase et al.)
- Historic Indicators of an Anthropogenic Influence on the Critical Zone: Relict Charcoal Hearths within the Context of Shavers Creek (Chester et al.)
- Soil pCO2 and pO2 coupled with geochemistry reveal a strong signal of carbonate weathering and parent lithology at Cole Farm (Hodges et al.)
- Quantifying Hydrologic and Landscape Legacy Controls on Watershed Nitrogen Retention (Kerstetter et al.)
- "Hammond Run": A New Hydrogeomorphic Research Watershed within the Penn State University Experimental Forest (Miller et al.)
- Relic terraces and land use drive hydrologic fluxes in intensively managed critical zones (Mount et al.)
- Sulfate fluxes in mixed lithology watersheds vary with nitrate inputs (Shaughnessy et al.)
- Development of a next generation spatially distributed agroecosystem model (Shi et al.)

11:00am – G6: Measuring and Modelling with Geophysics to See the Subsurface: Xin Gu, Andy Nyblade, Jay Regan

Xin Gu: *Mapping geochemistry onto geophysics to understand the architecture of shale weathering in the shallow subsurface*

Andy Nyblade: *Preliminary Seismic Velocity Models of the Susquehanna Shale Hills Critical Zone Observatory: Is there evidence for deeper weathering under the ridge?*

Jay Regan: *Chronoamperometric Measurement of Redox Reactions in Shale Hills*

Moderator: Sue Brantley = 10 min, 1 min, 10 min, 1 min, 10 min + 10 min discussion

11:45am – G7: Erosion rates, mechanisms, and timescales: Perri Silverhart, Joanmarie Del Vecchio

Perri Silverhart: *The effects of land use on hillslope erosion and valley sedimentation at Cole Farm*

Joanmarie Del Vecchio: *Rates, dates and mechanisms of periglacial landscape change*

Moderator: Roman DiBiase = 10 min, 1 min, 10 min + 10 min discussion

12:15pm – G8: Modelling and Upscaling the Watersheds: Hang Wen

Hang Wen: *Upscaling Hydrological Dynamics at the Catchment Scale*

Moderator: Yuning Shi = 10 min + 5 discussion

12:30pm – 1:55pm – ***Lunch and Discussions and Posters – 2217 EES Building***

2:00pm – 2:55pm – Discussion of collaborations – Next steps

Moderator: Ken Davis

3:00pm – 3:30pm – Feedback from Ouimet – Observations of the SSHCZO

4:00pm – Happy Valley Brewing Company – for Social and Happys

The 9 original hypotheses

H1 - ***Feedbacks among frost shattering, weathering reactions, and the evolution of topography have resulted in an asymmetric distribution of fractures that in turn controls the observed differences in fluid flow in the subsurface between the sun-facing and shaded sides of catchments within Shale Hills and much of the Susquehanna River Basin.*** *(DiBiase, Kirby, Bierman, Singha, Brantley, Lin)*

H2 – ***The distribution of weathering reactions across a landscape can be described as a function of biotic and abiotic production and consumption of acids (CO2, DOC) and O2.*** *(Kaye, Brantley, Eissenstat, Li)*

H3 – ***Trees with deeper roots (oaks) are associated with less frequent tree throw, slower hillslope erosion rates, fewer vertical macropores, faster weathering at depth, and deeper regolith than trees with shallower roots (maples).*** *(Eissenstat, Davis, Kaye, Brantley)*

H4 – ***Macropores are important in controlling fluid flow and chemistry in soils derived from various lithologies, but the nature and effects of these macropores differ significantly among shale, calcareous shale, and sandstone.*** *(Lin, Duffy, Eissenstat, Davis)*

H5 – ***Greater evapotranspiration on the sunny, north side of Shale Hills means that less water recharges to the stream, explaining why Mg and other cations are less depleted in the regolith on the north compared to the south hillslopes.*** *(Li, Brantley, Kaye, Shi)*

H6 - ***Ions that are released quickly from ion exchange sites (Mg, Na, K) throughout the catchment demonstrate chemostatic behavior (~constant concentration in the stream), whereas Fe, Mn, and DOC concentrations vary with changes in watershed-stream connectivity.*** *(Russo, Brantley, Li, Kaye, Shi)*

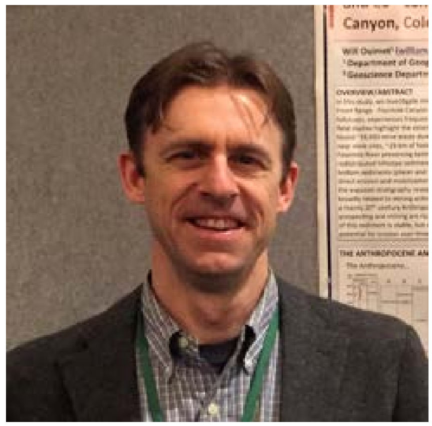
H7 - ***Land-atmosphere fluxes of carbon (C) and water, ground-water hydrology, and ecosystem change are coupled processes at time scales of months to decades. This coupling varies with the lithology and land use and position on the hillslope****. (Davis, Shi, Eissenstat, Duffy, Lin, Kaye)*

H8 - ***Co-located, intensive, relocatable measurements of soil moisture, tree sap flux, sapwood area, LAI, ground water depth, temperature, 18O and D/H along with a 4-component radiometer, laser precipitation monitor and landscape-level soil moisture (COSMOS) can be assimilated within a multi-scale distributed modeling framework to project physical processes from Shale Hills to Shavers Creek to YWC and Snake Creek watersheds.*** *(Shi, Duffy, Davis, Eissenstat, Lin)*

H9 - ***Increasing atmospheric CO2 in the future will cause higher temperatures and faster weathering of clays in the catchment, increasing streamwater solute loads.*** *(Brantley, Godderis, Li, Duffy, Davis)*

The Susquehanna Shale Hills Critical Zone Observatory

hosts Dr. William Ouimet, Associate Professor of Geomorphology, Department of Geosciences and Department of Geography, University of Connecticut, for the 2019 All Hands Meeting

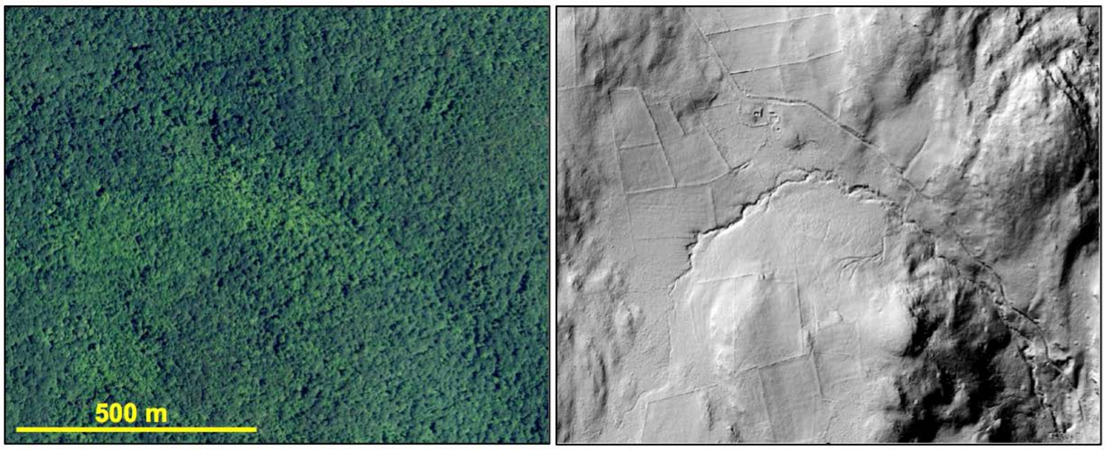


Dr. Ouimet presents ***"Quantifying Anthropocene Landscape Change in Southern New England"*** in the Hamer Classroom at Shaver's Creek Environmental Center @ 4:00pm on Thursday, May 9th

Abstract:

Southern New England and the northeastern US in general preserve a dramatic transformation of widespread 17th to early 20th century deforestation and agriculture followed by abandonment and reforestation. As such, this region provides an important example of rapid Anthropocene landscape change, the production and fate of legacy sediment, and landscape response to anthropogenic vs natural perturbations. High-resolution, publicly available LiDAR point clouds and derivative Digital Elevation Models (DEMs) have transformed our ability to identify and map abandoned land use features below the forest canopy. The extent and intensity of historic land use can be inferred most notably from stone wall lined fields, which indicate areas used for agriculture and pasture for 50-200+ years, and relict charcoal hearths, which signal the production of charcoal from forest hardwoods. Mapping to date, focused in Connecticut and Massachusetts, indicates that the occurrence of intense land use activities such as agriculture/pasture and charcoal production were highly regionally variable. This presentation will summarize ongoing research efforts to address the following Anthropocene research questions: how does the spatial distribution of historic features and inferred land use practices vary across the region?; what controls this distribution?; what are the hillslope and soil impacts of different land use practices?; and how does the type and density of historic features and inferred land use manifest itself in the Anthropocene sedimentary record downstream of affected hillslopes? Overall, this research provides a

unique opportunity to quantify humans' role as geomorphic agents and the drastic changes wrought upon a de-glaciated landscape, and study the direct erosional consequences (gullies) and mobilization of sediment into main waterways. Research emphasis on hillslope modification (i.e., quantifying human imprint, material moved, and erosional gullies) provides a novel complement to the geomorphology community focused on legacy sediment in fluvial networks, river restoration, and the upland sources of flood sediment loads in landscapes with significant historical human impacts.



Caption: An aerial image (LEFT) shows a forested landscape while a hillshaded DEM derived from LiDAR data (RIGHT) for the same area reveals polygons of stone wall lined fields, an old road, circular charcoal hearth platforms (lower right), an old foundation, and gully erosion. Data sources: CTECO and USDA NRCS.

Tree-ring derived estimates of forest productivity from north facing mid-slopes within the Shale Hills watershed

Warren P. Reed[1,2], *Margot W. Kaye*[1]

[1]Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, Pennsylvania, 16802 USA.
[2]Intercollege Graduate Degree Program in Ecology, The Pennsylvania State University, University Park, Pennsylvania, 16802 USA

Forests play a vital role in the global carbon cycle and therefore scientists employ a diverse array of methods to quantify and understand how they change over time. At Shale Hills a forest inventories have been established to track the growth and development of >2,000 individual trees within each watershed. These valuable and intensive forest surveys have illuminated variation in the spatial patterning of forest productivity in oak dominated forests of central Pennsylvania. While the importance of permanent inventories to understanding forest dynamics cannot be overstated, long time scales and many field campaigns are required to develop temporally coarse estimates of forest productivity (for example, 4 year intervals at Shale Hills). To bolster our understanding of the interannual variation in forest productivity at the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO) we established three smaller (314 m^2) fixed area plots within the forested watershed. At each plot, tree cores were extracted from all individuals >5 cm diameter at breast height with the goal of reconstructing decades of annually resolved forest productivity estimates of live aboveground carbon uptake. Results from this study will be useful to 1.) compare other measured and modeled estimates of forest productivity and 2.) described longer term records of forest growth at two intensively sampled study sites.

What controls the spatial and temporal variability of forest C pools at Shale Hills CZO? An exploration from a model perspective

Yuting He, Kenneth Davis, Yuning Shi, David Eissenstat, Warren Reed, Margot Kaye, Jason Kaye

Abstract

The terrestrial carbon (C) cycle remains the least constrained component in the global C cycle, partly due to the difficulty of quantifying C sources and sinks in complex terrain. We used observations at the Shale Hills Critical Zone Observatory and a biogeochemistry model, Biome-BGC, to study the spatial and temporal variability of C stocks in a first-order watershed. The model simulated the average C pools and fluxes in the watershed after constraining three model parameters with observations. The model was also able to generate the observed spatial patterns of C pools in the watershed, with higher biomass and soil C in the valley and lower values on the ridge-top, though the model underestimated the ridge-top to valley differences. Sensitivity analysis of the model Biome-BGC revealed that the spatial variability of the carbon pools is sensitive to a small number of the ecophysiological parameters (e.g. specific leaf area and C allocation ratio between stem C and leaf C).

We hypothesize that spatial structure in model parameters may be needed to fully capture landscape variability in forest C. If true, this requires a new modeling framework that can explain the variability in these parameters across the landscape.

We will also explore the inter-annual variability of forest C stocks and fluxes with three-year simulations (2008-2010), and compare the model results to the 30-40 years of tree ring data collected at Shale Hills.

Topography and related soil moisture impacts on fine root production within the Susquehanna-Shale Hills Critical Zone Observatory

Edward Primka IV[1,2], Tom Adams[2,3], and David Eissenstat[1,2]

[1]Intercollege Graduate Degree Program in Ecology, Pennsylvania State University, University Park, PA

[2]Department of Ecosystem Science and Management, Pennsylvania State University, University Park, PA

[3]Department of Plant Science, Pennsylvania State University, University Park, PA

Abstract Fine root growth and decomposition can influence soil CO_2 efflux levels, but predictive relationships are poorly understood. Many carbon flux models of forested systems rely on linear approximations of fine root dynamics with increasing soil water. However, fine root production and mortality have been shown to vary non-linearly with increases in soil water content over the short term. We hypothesized that topographic effects on soil water content would result in non-linear variation in fine root production across a landscape through time. Fine root production was tracked via bi-weekly minirhizotron sampling in 2016 and 2017 at the Susquehanna-Shale Hills Critical Zone Observatory (CZO). Minirhizotron measurements were paired with time-domain reflectometry (TDR) measurements of soil water content at some of the minirhizotron sampling locations. Here we show trends in fine root production with corresponding soil water content. Results from this and future analyses on fine root production and mortality will be applied to soil CO_2 efflux that was measured at the same sites as the minirhizotrons. Ideally these data will help provide more appropriate approximations of fine root dynamics through time for modeling purposes.

Soil gas concentrations at Shale Hills and Garner Run indicate anaerobic respiration driven by metal reduction in soil microsites

Caitlin Hodges[1], Hyojin Kim[2], Susan Brantley[2], Jason Kaye[1]
[1]Department of Ecosystem Science and Management, Pennsylvania State University
[2]Department of Geosciences, Pennsylvania State University

Soil CO_2 and O_2 cycles are coupled in some processes (e.g. respiration) but uncoupled in others (e.g. silicate weathering), such that simultaneous measurement of these two gases can yield insight into a wide array of biogeochemical processes. We used soil pCO_2 and pO_2 measurements to understand lithologic, hillslope, and seasonal controls on soil gases at the Susquehanna Shale Hills CZO (SSHCZO). We measured soil pCO_2 and pO_2 at three depths from the soil surface to bedrock across hillslopes in one shale and one sandstone watershed over three growing seasons. We found that soil pCO_2 was highest (>5%) and pO_2 was lowest (<16%) in the deep, wet valley floors of both lithologies. However, at any given depth soil CO_2 was higher and O_2 was lower across the hillslope positions in the sandstone watershed. This difference is driven by a greater proportion of roots deeper in the soil profile at Garner Run, driving consumption of soil O_2. Most interestingly, we recorded seasonal variation between coupled and uncoupled CO_2 and O_2 processes. We hypothesize that this seasonal fluctuation arises from anaerobic respiration in reducing microsites during the late growing season when the soils are wet and demand for O_2 is high, followed by oxidation of reduced species in the early growing season when the soils drain and re-oxygenate. We conservatively estimate that this late-growing season anaerobic respiration contributes 36 g C m^{-2} yr^{-1} to the soil CO_2 flux at the SSHCZO. Our results provide evidence for a conceptual model of metal cycling in first-order watersheds and point to the importance of anaerobic respiration to the carbon flux from humid temperate forests.

Predominant control of subsurface properties in storage-discharge relationship in catchments derived from contrasting lithology

Dacheng Xiao[1], Yuning Shi[2], Susan Brantley[3,4], Brandon Forsythe[4], Roman DiBiase[3], Kenneth Davis[4,5], *Li Li[1]

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[2]Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, PA 16802, USA
[3]Department of Geosciences, The Pennsylvania State University, University Park, PA 16802, USA
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Understanding emergent behavior such as storage (S)-discharge (Q) relationships and threshold connectivity requires large spatial datasets and is often limited by convoluted effects of multiple variables. Here we circumvent such limitation using data-informed physics-based hydrological modeling (Flux-PIHM) in catchments with similar vegetation and climate but different topography and soils derived from gray shale (Shale Hills, SH, 0.08 km2) and sandstone (Garner Run, GR, 1.34 km2). Using three lines of analysis, we test the hypothesis that flatter slope and a large riparian zone at GR override the effects of soil properties, leading to dampened streamflow response and linear Q-S relationship compared to SH. Transferring calibration coefficients from previously-modeled SH to GR reproduces trends but not magnitude of monthly discharge until after incorporating measured boulder distribution at GR. Model calibration and sensitivity analysis identify the importance of porosity and van Genuchten parameter n in reproducing daily discharge. Experiments that swap topography, soil properties, and size one at a time so as to disentangle their influence, show that clayey SH soils lead to highly nonlinear Q-S and threshold behavior. With the same SH soil, changing from SH to GR topography and size increase dynamic water storage and decreases nonlinearity. All analysis accentuates predominant control of soil properties in streamflow generation, underscoring the need and challenge for detailed soil characterization as we move toward water Prediction in Ungauged Basins (PUB). This work illustrates the use of physics-based modelling as a learning tool for illuminating mechanisms of emergent behavior.

Mesotopography controls on soil moisture and preferential flows

Qicheng Tang[1], Jonathan Duncan[1], Caitlin Hodges[1], Jonathon Chester[1], and David Eissenstat[1]

1. Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, PA 16802, USA

We expand on our previous results that Shale Hills has a higher preferential flow frequency than Garner Run (averagely 33.5% compared with 21.3%, Tang et al., in prep). This research was based on four Ground HOG locations. Preliminary research assessing how preferential flow differed between two lithologies, shale and sandstone, was answered at point scale. However, differences in mesotopography at the Garner Run site and the Shale Hills site may have also influenced preferential flow. The effect of small-scale local topography on soil moisture and preferential flow remained elusive. This hinders our understanding to link point scale hydrological processes to higher scales and thus parameterize hydrological models more precisely. To answer this, in the summer of 2018, we dug new pits at Shale Hills under a tree throw and at Garner Run under a colluvial bench. Following the soil analysis method developed by Kettler et al. (2001), average clay content for the shale pit is 7.3% compared with 6.0% for the sandstone pit and average sand content for the shale pit is 39.4% compared with 62.1% for the sandstone pit. At Shale Hills, shallow soil moisture content (top 10 cm) was significantly higher under the bench site (27.0%) compared with the slope site (15.0%) in 2019 April. During the same period, however, surface soil moisture did not differ significantly at Garner Run between the bench site (23.1%) and the slope site (25.6%). Preferential flow pathways at the original pits for both Shale Hills and Garner Run were found at the clay horizon (B). The new pits, however, showed surprisingly different preferential flow scenarios. During preferential flow events, Shale Hills new pit responded weakly at 40 cm (< 1% soil moisture increase) while Garner Run new pit responded sharply at the same depth and remained saturated throughout the event. In the end, we leveraged terrestrial structure-from-motion (SfM) to reconstruct the surface texture at these pits in order to provide a better explanation of variation in preferential flow across different mesotopographies and lithologies.

Plant Resource Availability and Soil Characteristics in a SSHCZO Tree Tip-up Chronosequence

Benjamin Dillner[1], Jason Kaye[1]

[1]Department of Ecosystem Science and Management, Penn State University

Tree uprooting from wind events or tip-up is a major source of forest disturbance in the SSHCZO. During the summer of 2018, soil sampling surveys were conducted on tree tip-up pits and mounds of varying ages in the Shale Hills catchment. Comparisons were made between the pits / mounds and undisturbed forest floor (controls) to determine how nutrient availability, moisture / sunlight, and soil profile characteristics changed over time. In general, mounds had low soil moisture whereas pits had increasing moisture with heavy accumulation of leaf litter. New tip-ups had high light availability and an early season flush of ammonium. Older tip-ups had eroded mounds that when cored revealed original forest floor O horizons between 30cm and 50cm down. Due to differences observed between tip-ups and the controls, it takes much longer than 30 to 50 years (age of oldest tip-ups) for disturbed tip-up soils to become equivalent to the undisturbed forest floor.

Sediment flux rates by tree throw in the Shale Hills Critical Zone Observatory and associated satellite sites in the Appalachian Mountains

Tim White[1], Ashlee Dere[2], and Sarah Sharkey[1]

[1] Earth and Environmental Systems Institute, The Pennsylvania State University; [2] Department of Geography & Geology, University of Nebraska Omaha

Tree throw, the upheaval of soil and bedrock in the root mass of a fallen tree, is a major process in the overturn and downslope transport of soil and shallow bedrock in mountains. We report on measurements of tree throw at the Shale Hills Critical Zone Observatory (SSHO) and associated satellite sites in the central and southern Appalachian Mountains spanning from Alabama to New York. In our study, slope and prevailing wind direction, while important in places, did not control the majority of tree throw events. The depth to a root limiting layer and the distance from the center of a root wad to the center of an excavated pit increased from north to south – suggesting that deeper roots excavate more soil and deeper soils generally exist in warmer climates.

The basin-wide average sediment flux rate by tree throw determined from 479 tree throw measurements in the SSHO, an 8-hectare headwater catchment, is 2.8 x 10^{-3} m^3 m^{-1} y^{-1}. That rate is greater than the range of 8 x 10^{-5} m^3 m^{-1} y^{-1} to 3.9 x 10^{-4} m^3 m^{-1} y^{-1} determined from similar measurements from the five satellite sites in the Appalachian Mountains. While our observations double in number and verify formulations of sediment flux due to tree throw cited in the literature, the values exceed by several orders of magnitude values for sediment flux rate by soil creep on slopes.

Similar measurements made from a large tree blow down event that occurred adjacent to the SSHO in late summer 2017 help elucidate the disparity in values between the SSHO basin-wide average flux rate and the range of values determined from the satellite sites. Assuming a storm event duration ranging from hours to one day, we calculate instantaneous sediment flux rates by tree throw from the storm of 1.3 to 1.3 x 10^4 m^3 m^{-1} y^{-1}. The SSHO basin-wide data set can be binned by age of tree throw (determined in the field by assessing tree decay state) and is found to include a record of a time period in which sediment flux rate by tree throw reached 1.1 x 10^{-3} m^3 m^{-1} $y^{-1,}$ exceeding other time bins by an order of magnitude. Therefore we suggest that the SSHO basin-wide average tree throw fluxes are skewed because data from a catastrophic event resides within the greater data set, and that a lesser value on the order of 10^{-4} m^3 m^{-1} y^{-1} is most representative of stochastic sediment flux rates by tree throw in the temperate climate of the Appalachian Mountains.

Lithological effects on root distribution and exudate production

Ismaiel Szink[1,2], Susan L. Brantley[3], David M. Eissenstat[1,2]

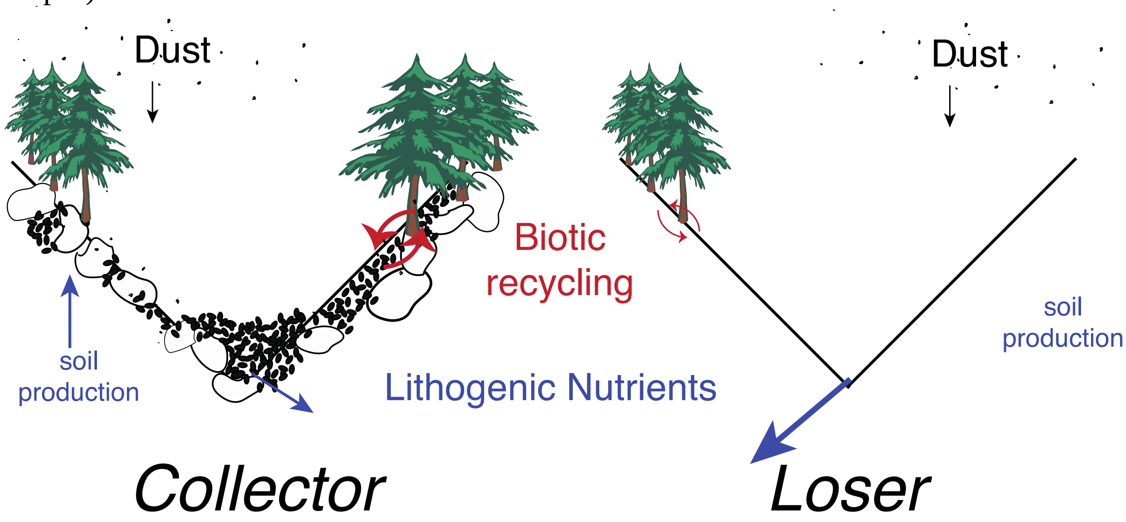
[1]Department of Ecosystem Science and Management, Pennsylvania State University, University Park, PA, USA
[2]Incollege Graduate Degree Program in Ecology, Pennsylvania State University, University Park, PA, USA
[3]Department of Geosciences, Pennsylvania State University, University Park, PA, USA

Roots drastically alter their environment in both short- and long-term timescales by weathering rocks, stabilizing soil particles, and mobilizing nutrients. Understanding the effects of lithology on root distribution and exudate production is an important preliminary step in modelling water and nutrient movement. We examined how soil parent material affects vertical rooting distribution by contrasting shale- and sandstone-derived soils in central Pennsylvania. Despite comparable aboveground biomass and nutrient concentration, shale sites had ~60% greater root length density than sandstone sites.We attribute these differences to the chemical and physical properties found between the two soil types. To determine how roots are responding to lithological differences, we will attempt to measure the rate of root exudation within shale- and sandstone-derived soils, with an emphasis placed on compounds that might help plants recycle and forage for the specific nutrients, such as nitrogen and phosphorus, they need on these two soil types. These results will highlight the role of biotic controls on soil solution concentration and nutrient availability as well as plant-soil interactions on mineral weathering.

Where older, slow-eroding soils are more nutrient-rich than younger fast-eroding soils: Landscapes as collectors or losers

Virginia Marcon, Beth Hoagland, Wenjing Liu, Xin Gu, Jason Kaye, Susan L. Brantley

Decline in ecosystem productivity occurs on slow-eroding lithologies because nutrients derived from the underlying bedrock, referred to here as lithogenic nutrients, are depleted over soil residence time. In other watersheds with faster erosion rates, ecosystems are maintained by weathering of bedrock that provides lithogenic nutrients. Contradicting this paradigm, we observed similar above-ground biomass and soil phosphorus concentrations on two neighbouring watersheds with vastly different erosion rates and soil residence times: one ecosystem is developed over a sandstone with long soil residence times (~100 ka) and the other has developed over shale with shorter soil residence times (~20 ka). The similarity in biomass and soil P content is surprising considering bulk P concentration in the sandstone bedrock is ~3x lower than in the shale. Despite the chemical and physical resistance of the sandstone bedrock, it is mantled by ~1 m thick soil that is enriched in Al, K, Fe, P, Mg, and clay. These components were determined to be largely derived from dust and/or residuum of stratigraphically younger strata. Thus the rigid, durable sandstone acts as a collector of fine particles retaining more material than is lost to the stream and groundwater. In contrast, the net retention and loss of fine particles by the shale is inferred to be more balanced over the soil residence time. Foliar P and bioavailable soil P are also higher on the sandstone as compared to the shale, which is not easily explained by dust deposition. A better explanation for these differences is tighter biotic recycling of P on the sandstone, as observed on other low-nutrient substrates. We conclude that ecosystem maintenance depends on both nutrient content of the lithology and whether the rock is largely an accumulator of nutrients from residua/dust (*collector* landscapes), or an exporter (*loser* landscapes).



Intermediate erosion hypothesis: Does nutrient input rate control vegetation structure and diversity?

Kristen Brubaker[1], David Eissenstat[2,3], and Susan L Brantley[4,5]

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The intermediate disturbance hypothesis in ecology predicts that systems with an intermediate level of disturbance host the greatest amount of biodiversity. We are trying to frame an alternative to this idea that incorporates geologic time scales associated with soil formation. For example, we are working with the hypothesis that differences in ecosystem productivity and diversity can be predicted in part by differences in the residence times of soil materials in shale and sandstone. The faster erosion rate in Shale Hills versus Garner Run corresponds to a smaller residence time for material moving out of bedrock and through the weathering zone, ultimately to be eroded out of the system. In turn, this equates to faster inputs of nutrients through Shale Hills, which could lead to higher productivity and biodiversity. Across the Ridge and Valley province, bedrock and soil type tend to be correlated to landscape position due to differential erosion rates; this makes a direct comparison of productivity difficult. There's also a range of variability of productivity across both bedrock types, particularly due to topographic position and the confounding effect of dust deposition. By using a nutrient input rate framework for modeling ecosystem productivity, we can incorporate all of these variables into one theoretical model of ecosystem structure and function.

This emerging hypothesis might mean that ecosystems with an intermediate denudation rate have a higher annual net primary productivity than ecosystems with a low or a high denudation rate (a 'Goldilocks' erosion rate?). Ecosystems that develop in shale-derived soil tend to have a higher denudation rate, which corresponds to their higher productivity relative to sandstone. Ecosystems that develop in sandstone-derived soils tend to have lower denudation rates, leading to lower overall productivity and biodiversity on average.

Mapping geochemistry onto geophysics to understand the architecture of shale weathering in the shallow subsurface

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The spatial distribution of weathered material across actively eroding landscapes partly determines how water and solutes are routed through the landscape. Generally, geochemical measurements are made on individual specimens and it is hard to upscale from the scale of minerals or clasts to pedons to catchments. In this study, we applied a rock physics model to infer the depths of the subsurface weathering zones and the extents of chemical and physical weathering across landscapes where seismic velocity has been measured in transects at the Shale Hills subcatchment of the Susquehanna Shale Hills Critical Zone Observatory in Pennsylvania, USA.

The rock physics model (modified from Soft Sediment Model) predicts how seismic P- and S-wave velocities and density of shale vary with mineralogy, porosity, pore fluid saturation, and fracturing. The model was calibrated interactively using downhole geophysical logging data and geochemical measurements on core material. The model demonstrates that porosity increases at shallower depths as weathering intensity increases. Under the stream channel near the outlet, where the frequency of carbonate-rich interbeds increases, porosity begins to increase at ~20 m below the land surface. Measurements on the drill cuttings reveals that pyrite oxidation initiates at the same depth, and carbonate dissolution generates porosity. We are working on 1) incorporating the fracture characteristics into the rock physics model; 2) applying the model to a larger area across the catchment where seismic velocity has been measured.

Preliminary Seismic Velocity Models of the Susquehanna Shale Hills Critical Zone Observatory: Is there evidence for deeper weathering under the ridge?

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In June 2018, an active-source seismic survey was conducted over the lower one-third of the Shale Hills watershed. 4,200 vertical component geophones connected to Texan dataloggers were installed with a 2-m spacing. 1,000 sledgehammer and 50 Betsy gun shots were taken in between the geophones, creating a data set containing over 4 million seismograms. P-wave arrival times and being picked on the seismograms and will be inverted to create a 3D P-wave velocity model of the subsurface. Some of the arrival times picked form 2D profiles crossing parts of the watershed. Preliminary models of these 2D profiles will be presented in this talk. The models show little clear evidence for deeper weathering under the ridges compared to under stream valley.

The effects of land use on hillslope erosion and valley sedimentation at Cole farm

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Quaternary climate fluctuations set the pace and pattern of long term erosion in the Shavers Creek Watershed. At Garner Run, erosion rates are ~7 m/my and valley deposits have aggraded since ~340 ka, integrating several Pleistocene climate cycles (Del Vecchio et al., 2018). At the Shale Hills, erosion rates are ~15 m/my and valley sediments have accumulated over the past ~40 ky (West et al., 2013). Based on topography and underlying geology, we infer that Shale Hills and Cole Farm should have similar long-term rates of hillslope erosion and pacing of valley aggradation. However, CF has been under agricultural land use for the past 200 years, with a gradual transition to no till practices beginning in the late 1970's. Here, we evaluate the relative influences of long term (10^3 – 10^5 year) climate fluctuations and recent (200 years) land use on erosion in this farmed upland watershed. Hand augered depth of refusal measurements indicate thin (< 50 cm) midslope soils, thicker toeslope soils, and 4+ m valley fill. Preliminary Cs-137 inventories for samples collected along ridgetop to valley floor hillslope transects extend to a depth of ~25 cm at all hillslope positions, which we infer to be approximately the depth of the plow layer. This also suggests minimal recent (< 60 years) stripping of hillslope soils has occurred. By pairing this data with Cs-137 and radiocarbon dates from several valley axis cores, we will constrain the timing of valley deposition and evaluate the relative influence of Quaternary climate versus anthropogenic land use controls on hillslope erosion and valley sedimentation.

Rates, dates and mechanisms of periglacial landscape change

Joanmarie Del Vecchio[1]
With Roman DiBiase[1,2], Sarah Ivory[1,2], Paul Bierman[3], Lee Corbett[3], and Greg Mount[4]
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We aim to quantify the legacy of past climate boundary conditions on the modern critical zone in order to properly contextualize observations of the current mass and energy fluxes across SSHCZO sites. At these sites, temperature and aridity conditions during the Last Glacial Maximum (LGM) and previous glacial periods promoted bedrock weathering, soil formation and landscape change in ways wholly different than processes occurring in the modern, temperate critical zone. Previous work at Shale Hills and Garner Run quantified regolith residence times and proposed the means by which climate-modulated processes might affect bedrock erosion and sediment transport (West et al., 2014; West et al., 2019; Del Vecchio et al., 2018). However, few studies have analyzed the long-term legacy of periglaciation on landscapes and thus we currently cannot predict the consequences of temperature and aridity changes on glacial timescales for critical zone development. New work at Bear Meadows Bog provides a novel means of connecting paleoclimate and paleoerosion records preserved in the sedimentary record to modern critical zone architecture. Here we show how long-lived sediments on both the hillslopes and the basin can be used to reconstruct both climate and erosion mechanisms during cold-climate phases. We show how paleoecological indicators provide insight into climate-modulated erosion mechanisms at existing CZO sites and that these data can be used to quantify the legacy of periglaciation on the present day critical zone.

Upscaling Hydrological Dynamics at the Catchment Scale

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Abstract: Process-based Catchment-Scale Models (CSMs, tens of meters to kilometers) have emphasized the explicit mapping of more and more of the heterogeneities of catchment features (including soil type, depth, topography, and land cover) to understand hydrological and biogeochemical dynamics. However, due to the computational-, labor-, parameter-, and data-intensive limitation, Earth System Models ESMs built on large grid cells (~20-200 km) cannot explicitly include the heterogeneous catchment features. The impacts of these missing features during upscaling from CSMs to ESMs are still poorly understood. In this work, we upscale the hydrological processes in a complex, spatially-explicit model (Flux-PIHM) to a simple, spatially-implicit model with two grid blocks connected by a river channel. The simple model is characterized by average or effective parameters at the catchment scale. We utilize the hydrological data at the Shale Hills in central Pennsylvania and aim to answer two questions: 1) How much details of water dynamics (discharge, evapotranspiration, and water storage) can be captured by the upscaled simple model? 2) What are the key parameters / processes in upscaling? Results show that the simple model captures the daily dynamics of discharge and evapotranspiration at the catchment scale. The effective parameters in the simple model for land cover, soil type, soil depth, and topography that best produce the discharge are within the corresponding ranges from the complex model, except soil porosity. The soil porosity in the simple model that best reproduces discharge is about 60% lower than the average of soil porosity from the complex model. However, the estimated water storage capacity of the simple model (=domain volume × porosity) is close to the effective water body (i.e., storage capacity of hydrologically connected zones) of the complex model. Sensitivity analysis indicates that soil porosity, soil depth, and watershed slope are the most critical features in predicting the catchment-scale water behaviors. The findings suggest the simply averaged approach to parameterize ESMs may potentially lead to erroneous predictions.

TeenShale Network: Outreach in Science and the Science in Outreach

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For seven years, scientists with the Earth and Environmental Systems Institute at Penn State have engaged with earth science students and faculty at State College Area High School on a variety of aspects pertaining to energy exploration in Pennsylvania and shale gas development. Here we present the development of inquiry-driven place-based education and the perceived student impact when classroom lessons are connected to real-world environmental challenges. From observations of well drilling activities and land use changes to the practice of water quality monitoring, data discovery and science communication, each cohort has gained knowledge of what it's like to be a *real* scientist and informed citizen. This practice of authentic scientific discovery has produced interesting data and interpretations and led each student cohort to formulate new hypotheses.

Title: **Deployment of a 3D Seismic Array in the Susquehanna Shale Hills Critical Zone Observatory and Results from a Nearby 400 Meters Line**

Authors: L. Ma, K. Lutz, N.J. Accardo, A. A. Nyblade, X. Gu, G. Mount, S. Brantley

Associated Institutions: Penn State University, Indiana University of Pennsylvania, IRIS, NSF, U.S. DOE

In June of 2018, we deployed a large-scale seismic survey in the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO) located in central Pennsylvania in order to study the critical zone. The critical zone is defined by the layer extending from above fresh bedrock to the tops of trees. In the SSHCZO, the focus is on regolith processes occurring within a shale lithology in a temperate environment. To learn about the subsurface geology over a general area, we deployed 2100 seismic stations twice to create a grid of dimensions 140 meters by 160 meters with two-meter station spacing. A station consisted of a vertical geophone connected to a Texan data logger that recorded seismic energy released from sledge hammers about 1.4 meters away from the nearest receiver. Initial results from 2-D lines crossing through the 3D grid showed P-wave velocities ranging from 300 to 4100 m/s with variable gradient zones thickening and thinning with topography. The goal is to construct a three-dimensional velocity model with seismic refraction data in order to map porosity extending outwards from known values gathered from boreholes after being able to distinguish velocities illustrating the differing lithologies in the subsurface.

Using a Near Surface Geophysics and Critical Zone Science Field Experience to Broaden the Participation of Underrepresented Minorities in the Geosciences

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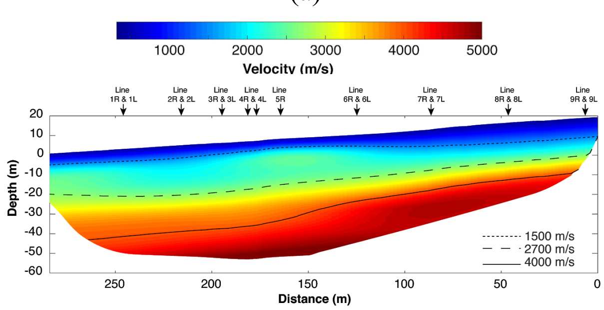
[1]*Rutgers University, Newark,* [2]*Indiana University of Pennsylvania,* [3]*Temple University,* [4]*Dickinson College*, [5]*Penn State University,* [6]*Science Education Resource Center at Carleton College.*

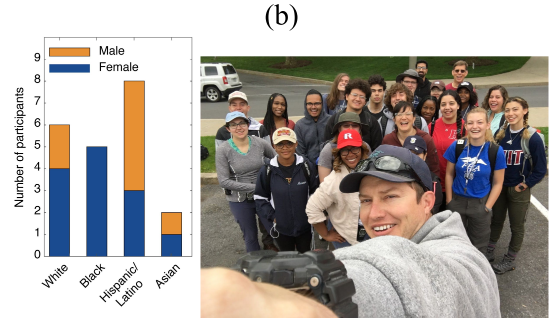
In the United States at the undergraduate level, earth, atmosphere and ocean sciences lag behind other Science, Technology, Engineering and Mathematics (STEM) fields when it comes to the racial and ethnic diversity of students. This deficit is particularly notable for students who are underrepresented minorities (URM) in STEM fields and translates to a lag at the graduate level. Diversity has demonstrated benefits for scientific advancement, including that diverse perspectives provide unique approaches to problem solving, which are needed to solve the complex problems we tackle in the geosciences. Using near-surface geophysics applied to critical zone science as the basis for recruiting and retaining URM students into the geosciences, we have established a program "GEOPATHS Near Surface Geophysics Field Camp Experience".

The first GEOPATHS field experience was held in the Garner Run subcatchment of the Susquehanna Shale Hills Critical Zone Observatory from 19 May to 2 June 2018. The field experience was split into two sections. First, the 17 student participants completed 3 geophysics activities and 1 mapping activity, each led by a peer mentor. In the second section, students designed and implemented a field study using the tools they had learned. Scientific exercises were supplemented by team building activities and talks by professionals to expose students to the range of careers available in the geosciences. Over the next two years of this project, we will assess the impact that the Geopaths Near-Surface Geophysics Field Camp Experience has on broadening the diversity of geoscientists and will create a model that other institutes can use for teaching near surface geophysics to undergraduate students interested in geoscience careers.

(a)



(b)



(A) Seismic refraction tomogram collected by the Geopaths students in May 2018 year; the tomogram was collected parallel to Harry's Valley Road. (B) Demographics and student participants from the 2018 inaugural Geopaths program.

Bear Meadows, Pennsylvania: an opportunity for investigating a coupled record of paleoclimate, paleoecology and paleoerosion processes

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The structure and function of the Earth's Critical Zone depends strongly on the legacy of geologic, climatic, and anthropogenic conditions, which are preserved in topography, soils, and bedrock weathering profiles. Understanding the evolution of Critical Zone processes over geologic time is thus necessary for predicting spatial variations in subsurface architecture and for predicting the response of Earth's Critical Zone to future perturbations from climate and land use change. At the Garner Run subcatchment of the Susquehanna Shale Hills Critical Zone Observatory, prior work indicates slow erosion rates (7 m/Myr), thick soils (2-8 m), and the preservation of relict periglacial landforms. This suggests that sandstone headwater landscapes in the valley and ridge province of central Pennsylvania integrate a long record of past Critical Zone processes across multiple glacial-interglacial climate cycles.

Recently, we have begun investigating the nearby Bear Meadows, a Holocene peat bog surrounded by sandstone hillslopes similar to Garner Run. However, because Bear Meadows is located in a structural trap, it has served as a local sink and is likely to have better preserved a continuous record of past Critical Zone processes. Initial work has focused on analysis of a 20 m deep core through a colluvial toe-slope deposit, 2-4 m cores in the peat bog and underlying sediments, and shallow geophysical surveys (Seismic and GPR) of the hillslope and bog. Cosmogenic $^{26}Al/^{10}Be$ burial dating of the colluvial toe-slope deposits at Bear Meadows suggests a depositional history spanning at least 700 ka – significantly older than burial ages from Garner Run. At shorter timescales, pollen and sedimentological analysis of radiocarbon dated cores from the Bear Meadows bog reveal changes in depositional environment and ecology over the Holocene. Future work is focused on linking these timescales to reconstruct how glacial-interglacial climate cycles influenced the ecology and hillslope erosion processes throughout the Quaternary.

Historic Indicators of an Anthropogenic Influence on the Critical Zone: Relict Charcoal Hearths Within the Context of Shavers Creek

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Drawing upon the classical geologic paradigm that “the present is the key to the past,” we propose a companion model in which the “past is the key to the present” when studying earth and environmental processes across human time-scales in landscapes altered by anthropogenic activities. The spatiotemporal complexity of coupled human and natural systems thus necessitates an understanding of how characteristic signatures of historic land use and land cover propagate through time to influence contemporary processes. Indeed, considering the implications of past and present human activity compliments our overall understanding of the critical zone. To help illustrate these themes, we present a preliminary review of land use history within the context of Shavers Creek. Specifically, we focus on emerging research questions related to watershed-scale impacts associated with the region’s once-booming 18th- and 19th-century iron production industry. About 3.5 kilometers north of the Susquehanna Shale Hills Critical Zone Observatory stand the remnants of the mid-19th-century Monroe Furnace. Like many other iron furnaces in the eastern United States and elsewhere, Monroe was fueled primarily by charcoal produced in the surrounding forested hillsides. Evidence of this charcoal production is revealed by the thousands of now relict charcoal hearths (up to 15m in diameter) that dot the Shavers Creek landscape. Identifiable on high-resolution (<1m) digital elevation datasets, these landforms of the Anthropocene 1) mark explicit areas of deforestation and 2) preserve layers of biochar within the underlying soil profile. From this realization emerges several questions related to the nature of relict charcoal hearths: How did deforestation associated with charcoal hearth production alter the sediment regime of local watersheds? Can we estimate these erosion rates using spatially explicit models and high-resolution terrain analytics? Are signatures of this historic land use still propagating through the modern landscape? Does the legacy biochar layer contribute to nitrogen sorption? How do hearth soil properties influence local hydrologic pathways and vegetation growth? Given regional and even international occurrence of similar historic charcoal production techniques, these and other questions presented herein converge on an understanding of the environmental implications of this historic land use as it relates to an anthropogenic influence on the critical zone.

Soil pCO_2 and pO_2 coupled with geochemistry reveal a strong signal of carbonate weathering and parent lithology at Cole Farm

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In soils carbonate and silicate mineral weathering is driven by the acidity produced from CO_2 through respiration. When soil pH is neutral, solubility of soil CO_2 in water is high, which increases the importance of soil pCO_2 in controlling mineral reaction fronts. Simultaneous measurements of soil pCO_2 and pO_2 can be used to document these weathering reactions in soils by interpreting the deviation of the slope that defines the relationship of the two gases from -0.76, the slope if aerobic respiration and diffusion dominate the system. Using simultaneous gas measurements, we sought to determine the role of soil CO_2 in controlling mineral weathering in a neutral-pH watershed underlain by calcareous shale at the Shale Hills CZO (Cole Farm).

Over the growing season of 2018 in the Cole Farm watershed we measured soil pCO_2 and pO_2 at three soil depths to the bedrock interface at the eastern midslope, western midslope, and ridgetop hillslope positions every three weeks. Regression slopes of soil gas pO_2 vs. pCO_2 at Cole Farm indicate a strong signature of CO_2 consumption, especially at the midslope positions (east midslope -0.30 ± 0.03 and west midslope -0.48 ± 0.05). At the ridgetop the regression slope (-0.63 ± 0.06) was closer to that defined by aerobic respiration and diffusion. The bulk soil geochemistry, mineralogy, and porewater chemistry indicate greater presence of carbonate minerals at the midslopes (38.2% CaO in the subsurface, 81.5% carbonate minerals, and 120 ppm Ca^{+2} in porewaters) than the ridgetop soil (0.27% CaO in the subsurface and 20 ppm Ca^{+2} in porewaters). Therefore, we hypothesize that the observed consumption of CO_2 in the midslope positions is driven by weathering of carbonate minerals that are not present at the ridgetop. Our results from Cole Farm contrast with measurements at the Shale Hills and Garner Run watersheds which indicate a stronger influence of metal redox cycles on soil gases than carbonate and silicate weathering. Furthermore, these results underline the strong effect of parent material mineralogy on the dominant processes that control soil pCO_2 and pO_2.

Quantifying Hydrologic and Landscape Legacy Controls on Watershed Nitrogen Retention

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Headwater streams are an important feature in the landscape in regard to biogeochemical reactions. Leading Ridge, a 270 ha experimental watershed in Huntingdon County Pennsylvania is underlain by sandstone (56 percent) and shale (44 percent) and has a nitrogen retention rate of 97 percent. The Shale Hills catchment is 8 ha, is completely underlain by shale, and has a nitrogen retention rate of only 53 percent. Part of this drastic difference in nitrogen retention rates between these two watersheds is due to different retention calculations. The Shale Hills estimate includes inputs from geochemical weathering, whereas Leading Ridge did not. However, even applying the Shale Hills retention estimates to the 44 percent of Leading Ridge, there is still a 16 percent difference unexplained by lithology alone. Both watersheds are within the same climate zone and have similar forest composition. One main difference between the two watersheds can be found within the hydrology on the landscape. Leading Ridge is comprised of perennial streams while the Shale Hills Critical Zone Observatory is drained by a single intermittent stream. Streams in Leading Ridge expand and contract through the landscape during the growing season due to precipitation events. Could higher drainage densities and stream network dynamics increase NO_3 retention? Areas in the landscape that wet up and dry down throughout the season could be denitrification hot spots that retain nitrogen in the watershed. While creating hillshade layers of a submeter DEM product for Leading Ridge, 15-meter circle depressions were found in the landscape. With Leading Ridge's history of logging for charcoal as fuel for a nearby iron furnace, the depressions could be explained by relict charcoal hearths. Could landscape legacies from charcoal production retain nitrogen in the landscape? Implications of this study could allow for better representation of how headwaters contribute to nutrient dynamics and how it could affect the waters downstream like the Chesapeake Bay. Modeling the expansion and contraction of streams through GIS methods and testing charcoal nutrient retentions through charcoal hearth cores may have insight on why some forested watersheds are more retentive than others.

“Hammond Run”: A New Hydrogeomorphic Research Watershed within the Penn State University Experimental Forest

Doug Miller[1,2] Jonathon Chester[1,2], Jonathan Duncan[1], Eric Chase[3]

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Penn State University

Small upland catchments throughout the Ridge and Valley Province of Central PA are important contributors to PA’s mapped watersheds and, ultimately, to the Chesapeake Bay. These catchments have generally not been studied extensively and have been overlooked as potential locations for long-term detailed hydrogeomorphic research. An initial project sponsored by the Center for Dirt and Gravel Roads at Penn State to characterize the topography and geomorphology of low stream-order contributing areas and their interaction with forest road drainage systems is evolving into a long-term facility to serve the research, extension, and education missions of the University.

The locally-named “Hammond Run” tributary to Shaver’s Creek forms the outlet for Mothersbaugh Swamp and drains an area of approximately 4.5 square kilometers prior to its discharge into Shaver’s Creek below the Lake Perez dam. Shaver’s Creek Road passes over this high-value eastern brook trout stream. A failing culvert where the stream eroded below the culvert pipe, resulting in a small pool and a large sediment wedge that can’t pass through. Stream elevation downstream of the culvert was at least a meter lower than upstream, resulting in a large scour pool on the downstream side. There are at least three distinct surfaces in the downstream section that could correspond to different channel elevations, potentially resulting from channel incision post culvert placement. This crossing was re-designed and replaced in the Spring of 2019.

Using structure-from-motion terrestrial and sUAS imagery, terrestrial lidar, and conventional total-station tools we have characterized the stream crossing and upstream and downstream sections to create a baseline for long-term tracking of post-build restoration impacts on stream morphology and water and sediment discharge. This work will improve our understanding of the interaction of these headwater contributing areas with forest road placement and built drainage structures and their impact on downstream water quantity, quality, and sediment delivery;

In conjunction with the culvert replacement and research effort described above, we have begun using this small watershed as a laboratory for several resident undergraduate classes including GEOG 315: Landforms and Geomorphic Systems, ERM 448: Rural Road Ecology and Maintenance, and FOR 470: Watershed Hydrology. Several independent student research projects will commence in the Summer and Fall of 2019.

We anticipate growing interest in using the watershed’s high-order survey network and growing hig-resolution geospatial database and have begun to plan additional detailed characterization of vegetation in the riparian corridor as well as a long-term survey of large woody debris in the stream channel. Our poster will outline additional details of these studies and suggest potential future research projects on this unique upland catchment.

Relic terraces and land use drive hydrologic fluxes in intensively managed critical zones

Greg Mount, Department of Geoscience, Indiana University of Pennsylvania

Ashlee Dere, Department of Geography/Geology, University of Nebraska – Omaha

Tyler Sharretts, Department of Geoscience, Indiana University of Pennsylvania

Agricultural activities have dramatically altered both the vegetation and structure of the land surface but the impacts of such activities may also propagate deeper into the critical zone. To investigate the influence of agricultural activities on deep critical zone hydrology we used near-surface geophysical techniques, including electrical resistivity tomography (ERT) and ground penetrating radar (GPR), to image the subsurface at Glacier Creek Preserve in Eastern Nebraska. The 400 ha watershed has gentle hillslopes (~12°) comprised of last glacial loess overlying till parent material and was used for corn-soybean agriculture until 1959 when the north-facing slope was restored to native tallgrass prairie vegetation. In addition, all hillslopes include constructed terraces, a common feature in intensively managed landscapes in the Midwest. We hypothesize that converting agricultural soils to prairie vegetation restores pore connectivity through the addition of roots and organic matter, thereby allowing water to infiltrate more rapidly and deeply in restored prairie soils. Data were collected across both agriculture and restored prairie ridgetops, as well as a 1 km cross section from ridgetop to ridgetop with 2 m electrode spacing using a Wenner array. ERT data show that resistivity is approximately 2 to 3 times lower (~20 ohm m) up to 5-7 m deep in agricultural ridgetop soils compared to prairie ridgetop soils (40-70 ohm m) that reach nearly 10 m in depth implying slower infiltration in agricultural soils. Furthermore, we observe with ERT data that relic terraces appear to exert a strong control on hillslope hydrology even under restored prairie land use. Specifically, ERT data suggest the presence of perched water and/or slower rates of infiltration under terraces that perhaps temporarily stores water along the hillslope before moving toward the stream. The agricultural terrace exhibits a more consistent range of resistivity values, with no noticeable topographical effect. Thus, not only can surface land use modify hydrologic fluxes within the critical zone, but the legacy of anthropogenic hillslope terracing may persist regardless of surface land use, potentially altering hydrologic fluxes deeper into the critical zone.

Sulfate fluxes in mixed lithology watersheds vary with nitrate inputs

Andrew Shaughnessy, Xin Gu, Tao Wen, Susan Brantley

Pyrite (FeS_2) is a common mineral in the subsurface that is prone to oxidation, which produces sulfuric acid (H_2SO_4). Over short timescales, the coupling of pyrite oxidation to nitrate reduction can attenuate groundwater nitrate concentrations. This is particularly important in watersheds with agricultural land use, such as the Shavers Creek Watershed, which typically features higher groundwater nitrate concentrations due to sustained fertilizer application. In addition to agricultural contaminants, the Shavers Creek Watershed is also impacted by acid rain. We utilize geochemical and hydrologic datasets collected in the Susquehanna Shale Hills Critical Zone Observatory (SHHCZO) to delineate the sulfur budget in several sub-catchments of the Shavers Creek Watershed as well as several reaches along the main stem of Shavers Creek. Selected sites show variability in lithology (e.g., sandstone, shale, limestone) and land-use (e.g., 0-18% agriculture). We use stream water chemistry, multivariate statistics, bedrock chemistry, and mixing models to delineate sulfate derived from precipitation, pyrite oxidation, and fertilizers. Preliminary results on the sulfur budget at the Shale Hills sub-catchment show that pyrite-derived sulfate seasonally ranges from 0.2 to 99.5% of the total sulfate in the stream. The highest proportions of pyrite derived sulfate occurred during the summer months (June, July, August) when the flow was the lowest and the stream is likely sustained by deeper groundwater flow. The annual pyrite-derived sulfate flux for Shale Hills is 3.0-6.2 x 10^{-3} mol m^{-2} yr^{-1}, which is 8.5-17.3% of the total sulfate flux from Shale Hills. Utilizing the results and methodology from this study, we aim to scale up to the Susquehanna River and the Mississippi River Basins to determine pyrite-derived sulfate fluxes for the rivers draining most of the United States. We also aim to determine how land use effects these fluxes.

Development of a next generation spatially distributed agroecosystem model

Yuning Shi, Armen R. Kemanian, Charles White, Felipe Montes
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A spatially distributed agroecosystem biogeochemistry model, C-PIHM, has been developed by coupling a 1-D agroecosystem model Cycles with a spatially distributed land surface hydrologic model, Flux-PIHM. Flux-PIHM is a coupled physically based model, which incorporates a land-surface scheme into the Penn State Integrated Hydrologic Model (PIHM). The land surface scheme is adapted from the Noah land surface model. Flux-PIHM is able to represent the link between groundwater and the surface energy balance, as well as the land surface heterogeneities caused by topography. Cycles is a daily time-step agroecosystem model that simulates the biogeochemical processes and management practices occurring within cropping systems and other land uses. Components of the nutrient cycling algorithms evolved from the CropSyst model, and include a unique non-linear simulation of the carbon-nitrogen cycle that includes saturation theory and a robust radiation and transpiration-based growth engine. Cycles can simulate a wide range of agricultural management practices such as tillage, organic and inorganic nutrient additions, annual and perennial crops, crop harvests as grain or forages, polycultures and relay cropping, grazing, and irrigation.

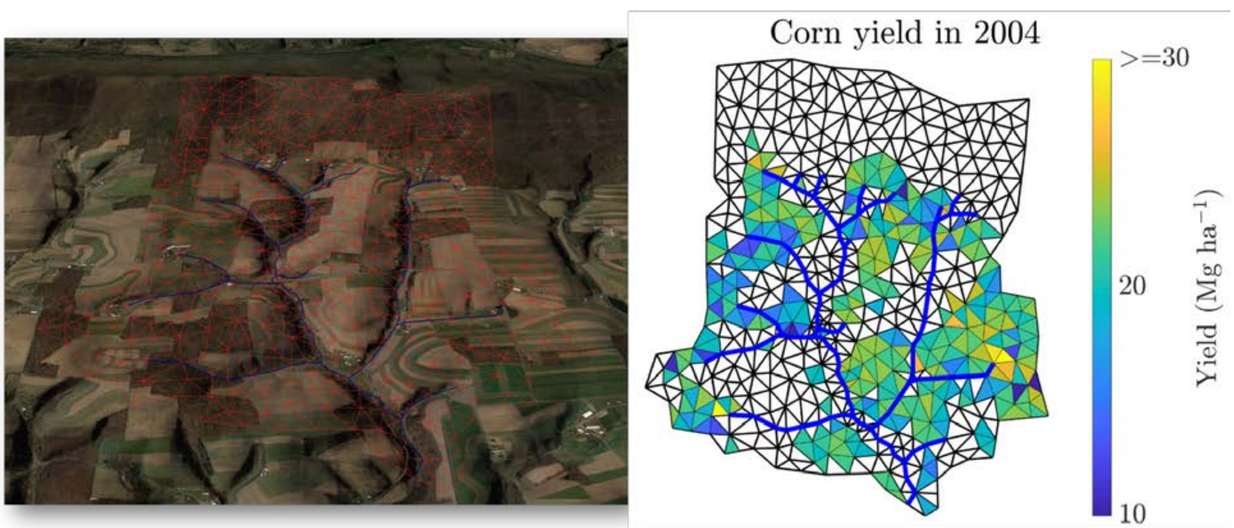

Figure 1 Map of WE38 watershed in Pennsylvania (left) and corn yield in 2004 as predicted by C-PIHM.

In the coupled C-PIHM model, each Flux-PIHM model grid couples a 1-D Cycles model, while soil nitrogen is transported among model grids via subsurface water flow. In each grid, Flux-PIHM provides Cycles with soil moisture, soil temperature, and solar radiation information, while Cycles provides Flux-PIHM with leaf area index. The main advantage is that the transport of nutrients are landscape-driven processes (e.g. denitrification in water accumulation areas, lags in nutrient flow due to dispersion in groundwater), which emerge from the model properties and are not incorporated via calibration. C-PIHM provides a “next generation” tool to study the interaction among water, energy, carbon, and nutrient cycles in different landscape positions, that cannot be achieved without the coupling of these model components.