Calhoun CZO, a 2nd generation CZ observatory
the Southern Piedmont, home to some of the most agriculturally degraded landscapes in America

Photo: USDA Forest Service

Photo: Allan et al. *Catena*
The need for CZ science of a tree-top to bedrock science *amply demonstrated by the maximum depth of sampling* of 360 studies of how land use alters organic carbon.
The Southern landscape less than a century ago...

“... a miserable panorama of unpainted shacks, rain-gullied fields, straggling fences, rattletrap Fords, dirt, poverty, disease, drudgery, and monotony that stretches for a thousand miles across the cotton belt.”

UNC Prof. C. S. Johnson (1935)

Walker Evans, *Spring Plowing near Tupelo*
Trimble’s (2008) soil erosion loss from agriculture

Southern Piedmont, one of the most environmentally degraded regions in America
Calhoun CZO

15 investigators: 6 universities & colleges, & USFS
Duke, UGA, GaTech, Kansas, Miss State, & Roanoke
D. Richter, A.Porporato, B. McGlynn, M. Kumar, S. Palmroth, J. Wang, R. Bras,
D. Markewitz, A. Thompson, P. Schroeder, A. Cherkinsky, D. Nelson,
S. Billings, J. Giessen, K. O’Neill

All together pulling on CZ questions...
hydrology, biogeo- & geochemistry, pedology,
ecophysiology, forestry, environmental history, &
anthropology

4-5 Oct 2013: First all-hands meeting at the Calhoun
in rural South Carolina
CCZO science focus ---
aims to integrate sciences of water, mineral, & carbon cycling associated with CZ evolution, specifically land degradation & recovery
20th c. Piedmont farmland widely abandoned & with much regrown in secondary forest, motivating many to equate ecologists’ old-field succession with ecological restoration

Our CZO team has a more critical perspective, in fact that reforestation *more masks than restores* fundamental alterations in CZ hydrology, geomorphology, biology, and biogeochemistry
CCZO Conceptual model - NRC definition ... but also integrated, long-lived systems, polygenetic & composed of archival products of natural forcings that range widely over the life of most CZs
CCZO Conceptual model - NRC definition ... *but also*

an open, expanded geo-ecosystem with practically unexplored lower boundary conditions
CCZO conceptual model belowground: two networked subsystems that contrast in structure & function

**Upper system:**
Well mixed, Don Johnson “biomantle,” physically & chemically weathered

**Lower system:**
More sedentary & heterogeneous, chemically weathered with bio-hydro hotspots networks
Three Calhoun-CZO field facilities
a) Plot studies (others across region)
   Permanent LTSEs (P2, Pine reforestation)
   Space-time substitutions (H2, Old hardwoods; P3, Pine; C1, Cultivated)
b) Erosion-carbon studies:
   Holcombe’s Branch
c) Experimental catchments
Building on previous Calhoun research

a) Expanding 60-y studies of *whole ecosystems*: 16 0.1-ha plots in old cotton fields resampled every 5 y, 0 to 0.6-m mineral soil
Large $^{14}$C enrichments indicate rapid turnover of fresh organic matter throughout 60-cm profile.
Calhoun’s record of acidification in reforested soils

from Richter 2006 et al. Oecologia
Building on previous Calhoun research

b) deep coring across catenas, from recent 70-m core on an Interfluve that indicated residence times to be full Pleistocene or older

Bacon et al. 2012 *Geology*

**TABLE 1. Soils on interfluves at the Calhoun Experimental Forest**

<table>
<thead>
<tr>
<th>Hor</th>
<th>Depth (m)</th>
<th>Clay (%)</th>
<th>pH</th>
<th>C (%)</th>
<th>ECEC§ cmol/ kg</th>
<th>EBS§ (%)</th>
<th>totCa</th>
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<tr>
<td>A</td>
<td>0.00–0.07</td>
<td>5.0</td>
<td>3.70</td>
<td>2.33</td>
<td>1.9</td>
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<td>0.07–0.13</td>
<td>6.1</td>
<td>4.05</td>
<td>1.33</td>
<td>1.3</td>
<td>19.2</td>
<td>0.27</td>
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<td>E</td>
<td>0.13–0.32</td>
<td>7.7</td>
<td>4.13</td>
<td>0.54</td>
<td>0.9</td>
<td>19.6</td>
<td>0.20</td>
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<td>Bt</td>
<td>0.32–0.6</td>
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<td>0.24</td>
<td>3.5</td>
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<td>0.6–1.0</td>
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<td>0.13</td>
<td>4.6</td>
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<td>3.98</td>
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<tr>
<td>C</td>
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<td>-</td>
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<td>96.5</td>
<td>7.72</td>
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</table>

§Effective base saturation and cation exchange capacity (EBS and ECEC) estimated with exchangeable base cations and 1M KCl-exchangeable acidity.
Building on previous Calhoun research

c) Expanding previous collections of water and soil gases more deeply into the CZ and across land uses

Richter et al. 2007. Water chemistry & CO$_2$ to 6m
Building on previous Calhoun research

d) Re- and Up-instrument catchment studies aimed at recovery of degraded landscapes

Archived Stripchart data at Coweeta Hydrologic Laboratory
Three Calhoun-CZO field facilities:

- **a)** Plot studies (others across region):
  - Permanent LTSEs (P2, Pine reforestation)
  - Space-time substitutions (H2, Old hardwoods; P3, Pine; C1, Cultivated)

- **b)** Erosion-carbon studies:
  - Holcombe’s Branch

- **c)** Experimental catchments
5.1 Re-instrumenting and Up-instrumenting Calhoun’s Experimental Catchments

5.1.1 Precipitation and Streamflow
Rainfall intensity will be recorded with multiple rainfall gages. In concert with rainfall intensity, streamflow measurements will be used to evaluate catchment hydrologic response and quantify how ongoing responses have changed over the last 50 years.

5.1.2 Precipitation and Streamflow Biogeochemistry
Precipitation and streamflows from the three experimental catchments will be sampled with wet-dry collectors and by grab and automated stream sampling for analysis of macro-ion chemistry and various isotopic studies.

5.2 Atmospheric Sampling
Eddy-covariance towers will be installed at the Calhoun LTSE, at a pasture and a hardwood site used for the space-for-time plots, and in a re-instrumented catchment. Each eddy-covariance station will be instrumented with 3-D sonic anemometers, infrared gas analyzers for CO$_2$ and H$_2$O, net radiation sensors, rain gages, as well as low-frequency air temperature and humidity sensors. Depending on the canopy structure, the stations will be built on tripods or towers. Additionally, each transect and cluster of replicate soil profiles will be equipped with rain gage, air humidity and temperature sensors, and soil heat flux plates. PIs Porporato and Richter and Co-PI Wang will collaborate on installation and management of eddy covariance fluxes, based on previous experience in the Duke Forest FACE experiment.

5.3 Vegetation and Soil Sampling
5.3.1 Space for Time Plots: Old Hardwood, Secondary Pine, Grasslands, Cultivated Plots.
We will use a space-for-time substitution to examine the effects of contrasting land use histories on soil properties. The space for time comparison will emphasize old hardwood reference stands but we also include comparisons with soils that have long been cultivated that today have (a) 50-80-year-old secondary forests (mainly pine), (b) 50-80-years of pasture or hayfields, or (c) continuous Calhoun CZO.

Figure 4. Generalized schematic of infrastructure and information flows of the Calhoun-CZO, including connections between empirical and theoretical components of the project.
Questions that organize Calhoun CZO research:

1) Does land degradation decouple upper and lower CZ systems, disrupting macroporosity networks that are conduits for gases and water?

2) How rapidly can re-forestation recover CZ porosity and re-network the CZ into an integrated system?

3) How has historic erosion redistributed and altered organic carbon dynamics on both uplands and in anoxic alluvium filled with historic sediment?

4) Can human-forced CZs enter new steady states, complete with positive feedbacks and attractors that resist recovery of previous states?
Transformative results & special cross-site opportunities

CZ recovery of ecohydrologic and biogeochemistry following land degradation

Lower boundary conditions of CZs & deep belowground CZ structure & process

Interdisciplinarity of CZ science & education - Post-doctoral, graduate, and specifically undergraduate
Some lands were too steep to farm intensively, but flows breached surface soils to expose the highly erodible gully erosion. Gullying developed not only from erosion of and farmed again and generated a later phase of sheet and (32 (Comp32) gully systems (monitoring. This study was conducted on two gully systems transportation routes –

Evidence of on-going gully activity branches of a relatively young age (0.1 ha discontinuous valley side gully over a 9.5-year period storm episodes as evidenced by the 48 tonnes delivered by a gullies contribute runoff and sediment primarily in tropical

Although recent gully studies are rare. Extremely small gullying in the region is no longer a serious problem, adjacent lands, rather than just stabilizing the erosion and restore the function and capability of the affected area and fill and reshape gullies were used in some instances to help
dams, grade-control structures, and gully plugs. Measures to control headcuts and grade changes such as rock check

Landslides (2006), doi:1945, other examples of incised channel and gully research

By the 1930s, land destruction by gully erosion had reached devastating proportions and soil conservation and

By 1939 –

1960s. This period was accompanied by reforestation and

Wehr and Lohr, 1999 involving planting loblolly pine (Pinus taeda)

The potential of ALS technology is promising for many

Jensen, 2000. The ranging unit of an ALS system

McKean and Roering, 2004; Glenn

Jenkins, 1999a characterizing gullies and channels (2005), landslides (2003), and at least one GPS base station to precisely locate the

Ritchie et al., 1994). By 1939, the adjacent county to the north (Hoover (1949)

Happ et al. (1940)). By the 1930s, land destruction by gully erosion had

1974 filled downstream valleys to depths up to 3 m (1930s. The average soil loss from the SNF has been estimated at about 20 to 30 cm of soil, and sediment often

Hansen and Law, 2006). Some abandoned lands were later cleared –

Happ (1945). Mitigation measures on the SNF

1939 –

calls for improved methods of gully –

mechanical devices that

McKean and Roering, 2004; Glenn

Moffiet et al., 2005). The pulsed scanning laser is coupled with a receiver,

Jensen, 2000). The pulsed scanning laser is coupled with a receiver,

2. Technical aspects of laser-scanned topographic data

DEMs, and contour maps. Reduced hydraulic conductivity from clogging of the

surface with buildings and vegetative canopy removed) that converts this time to a distance. The data collected consist of

measures the time (ns) between emission of the laser beam

aircraft (and at least one GPS base station to precisely locate the

an inertial measuring unit that compensates for aircraft

motions, a kinematic Global Positioning System (kGPS),

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