Calhoun CZO, a 2nd generation CZ observatory

the Southern Piedmont, home to some of the most agriculturally degraded landscapes in America

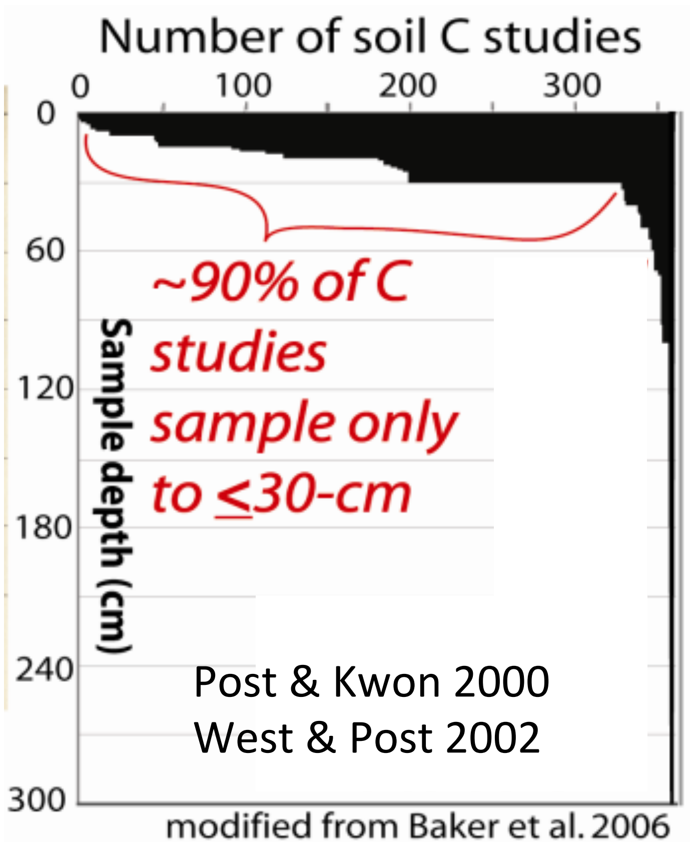
1948

Photo: USDA Forest Service

2006

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



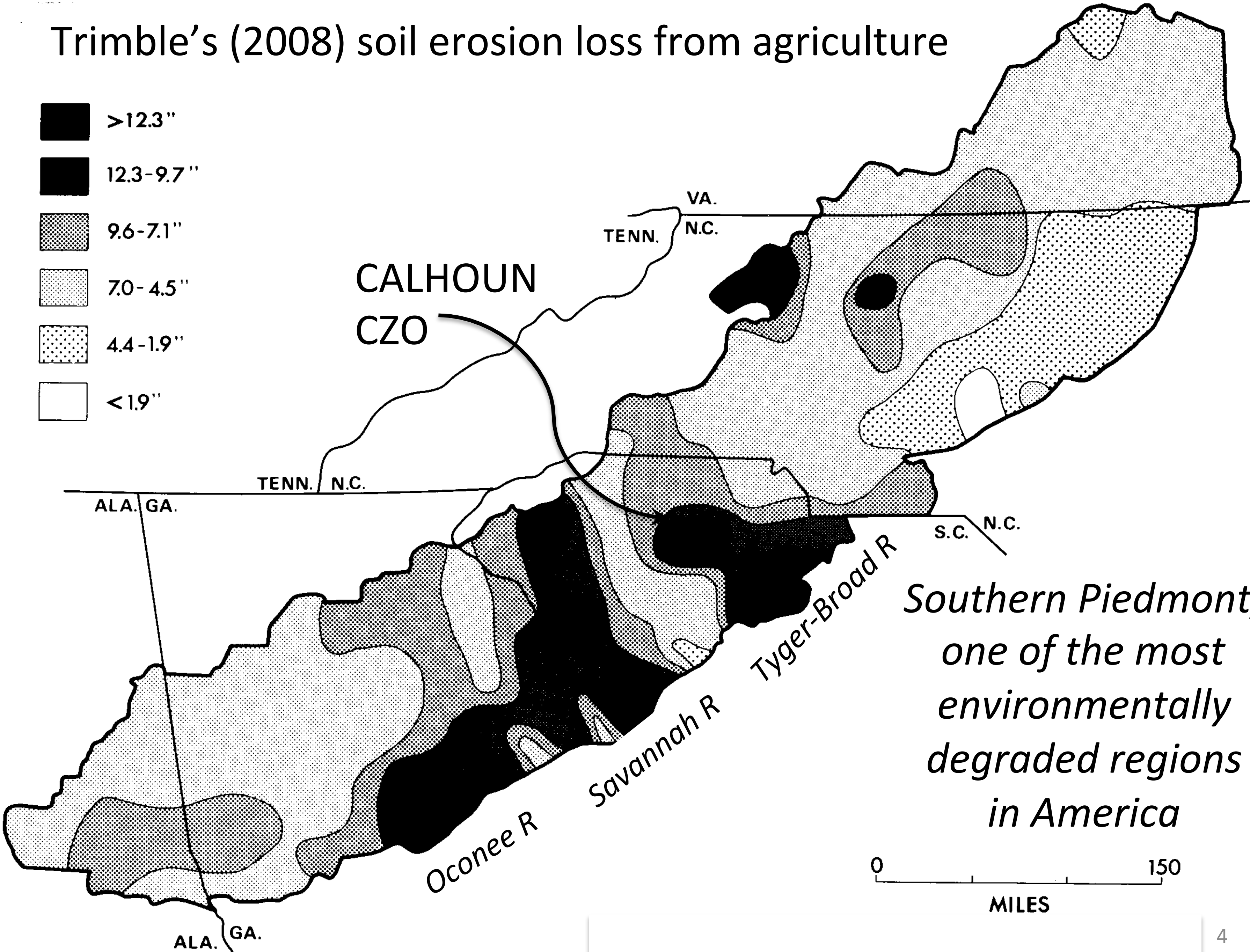
The Southern landscape less than a century ago…

"… 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

Eroded old cotton fields, Calhoun, SC
Photos: Allan et al. 2006, USFS ~1950

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

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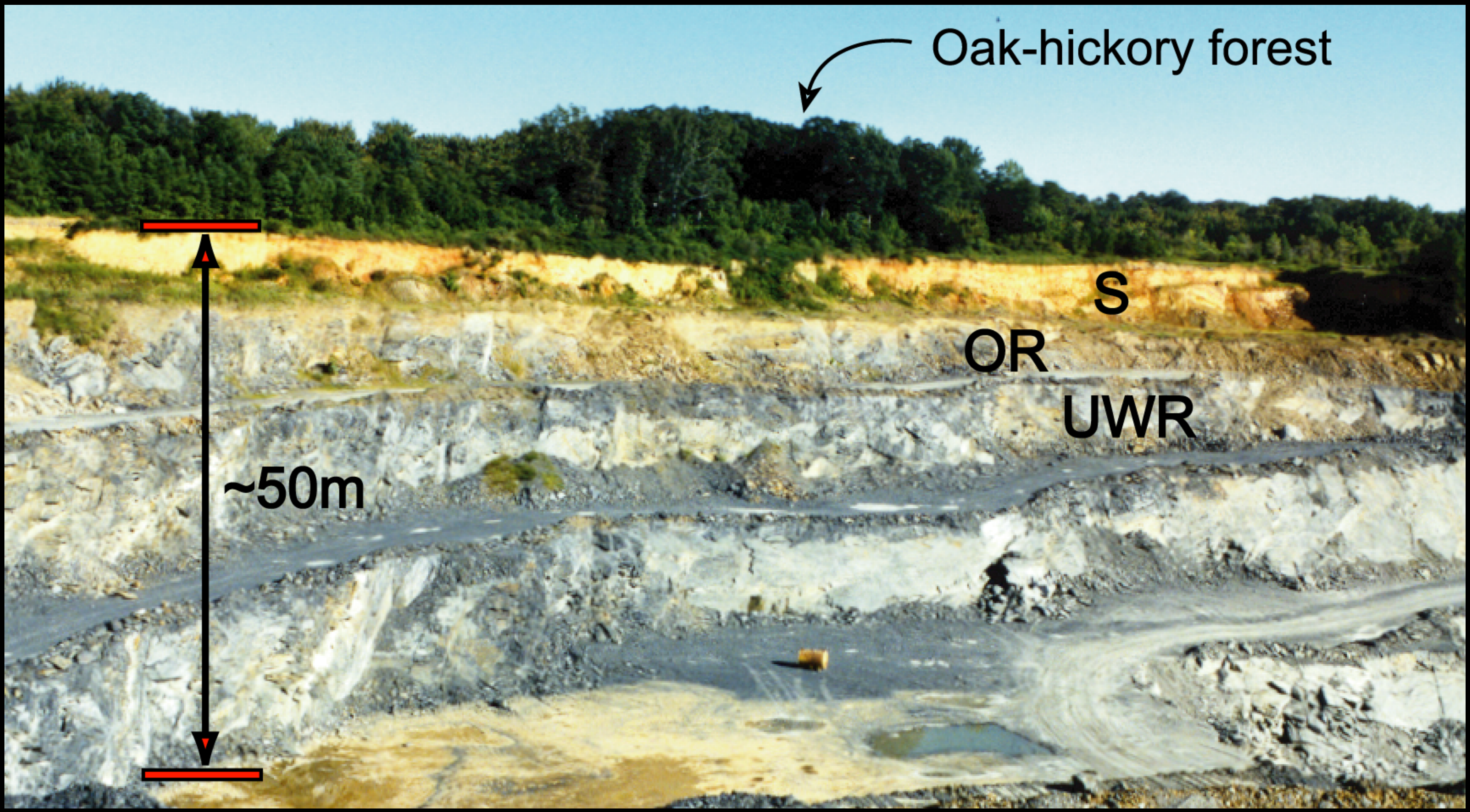
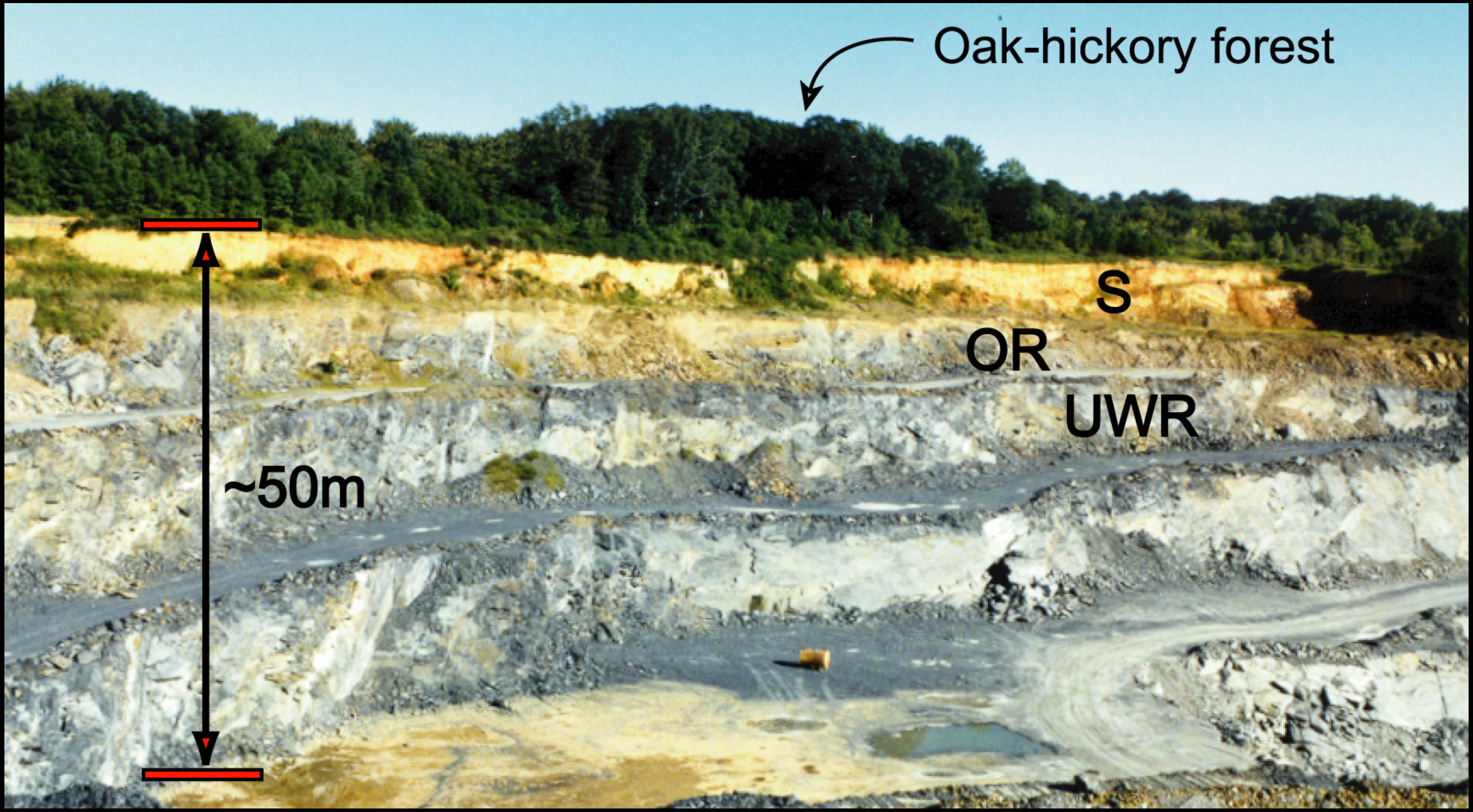
CCZO Conceptual model - NRC definition … *but also*

integrated, long-lived systems, polygenetic & composed of archival products of natural forcings that range widely over the life of most CZs

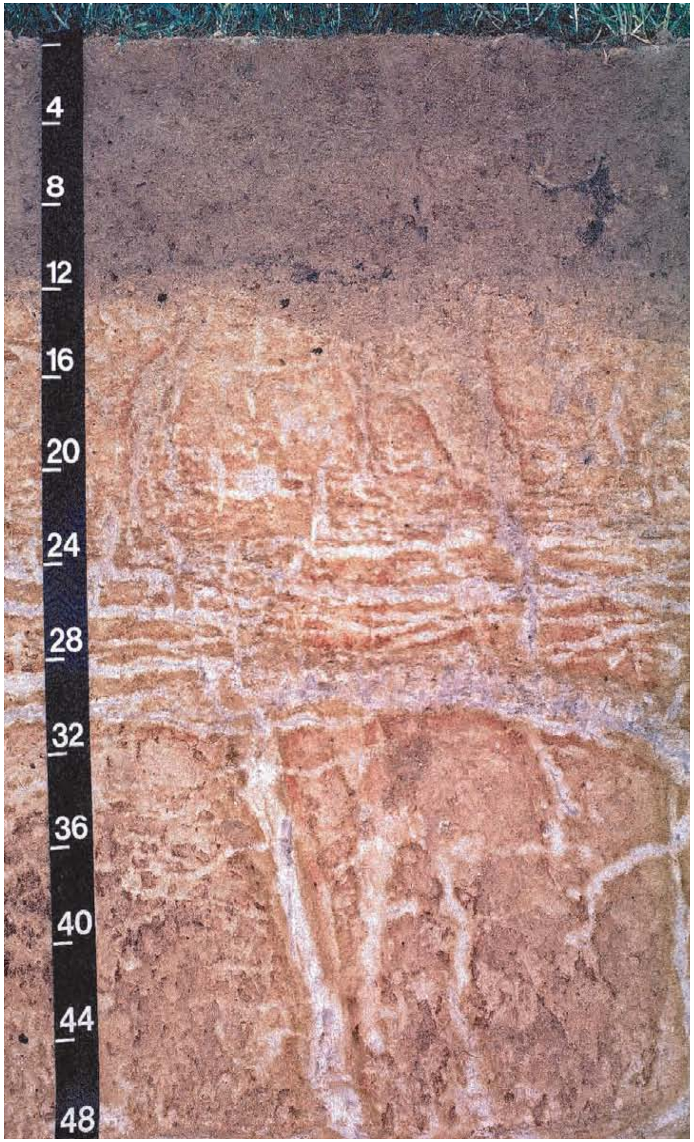


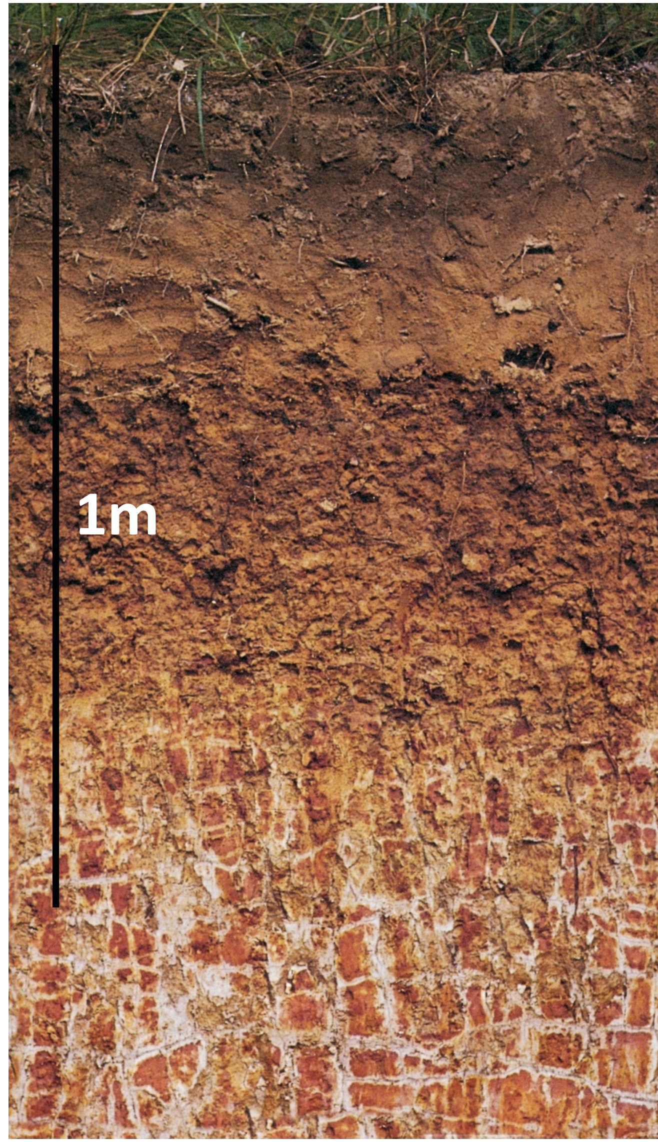
<u>CCZO Conceptual model</u> - NRC definition … *but also*

an open, expanded geo-ecosystem with practically unexplored lower boundary conditions



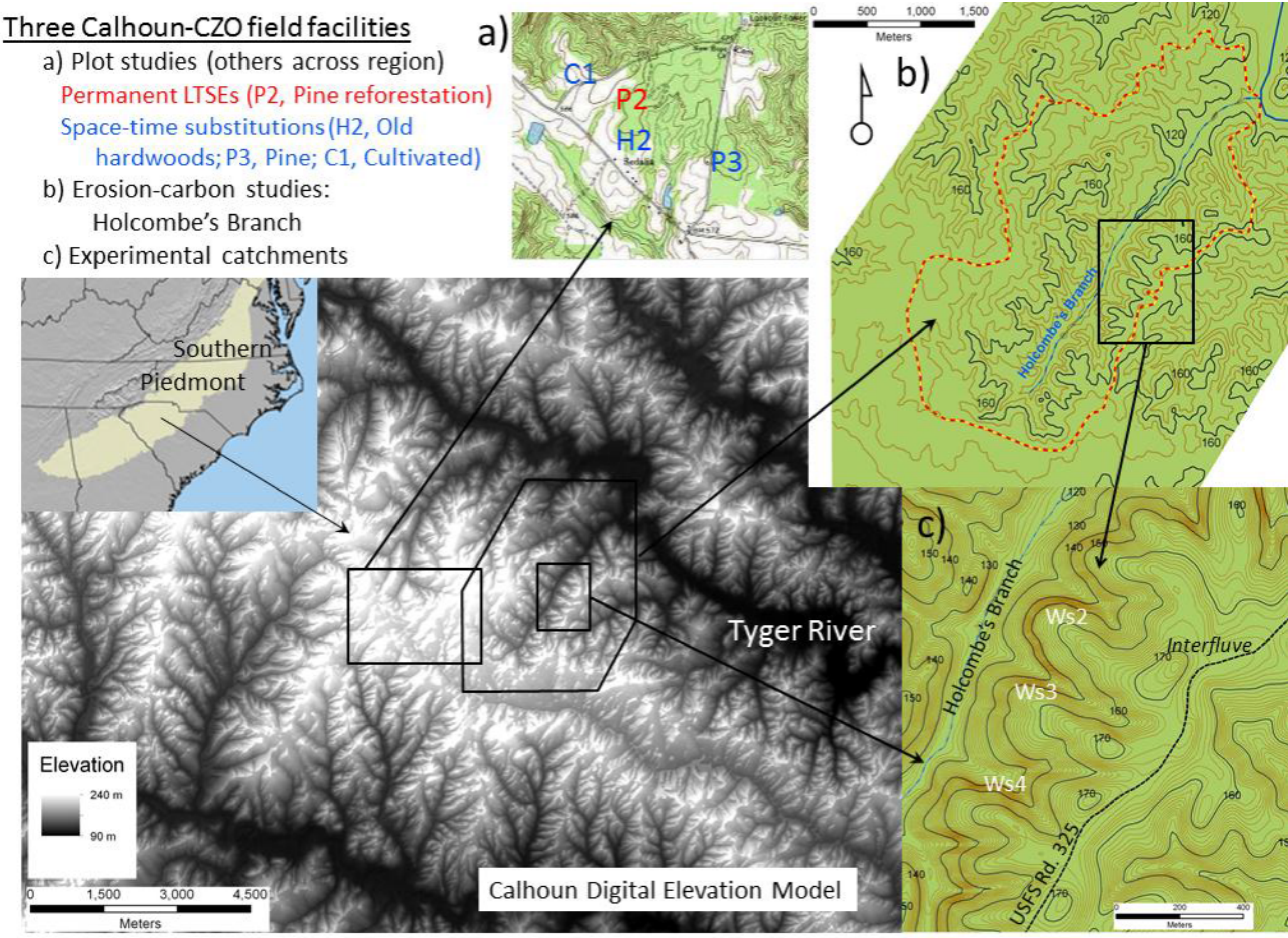
<u>CCZO conceptual model</u> belowground: two networked subsystems that contrast in structure & function





<u>Upper system:</u>
Well mixed,
Don Johnson "biomantle," physically & chemically weathered

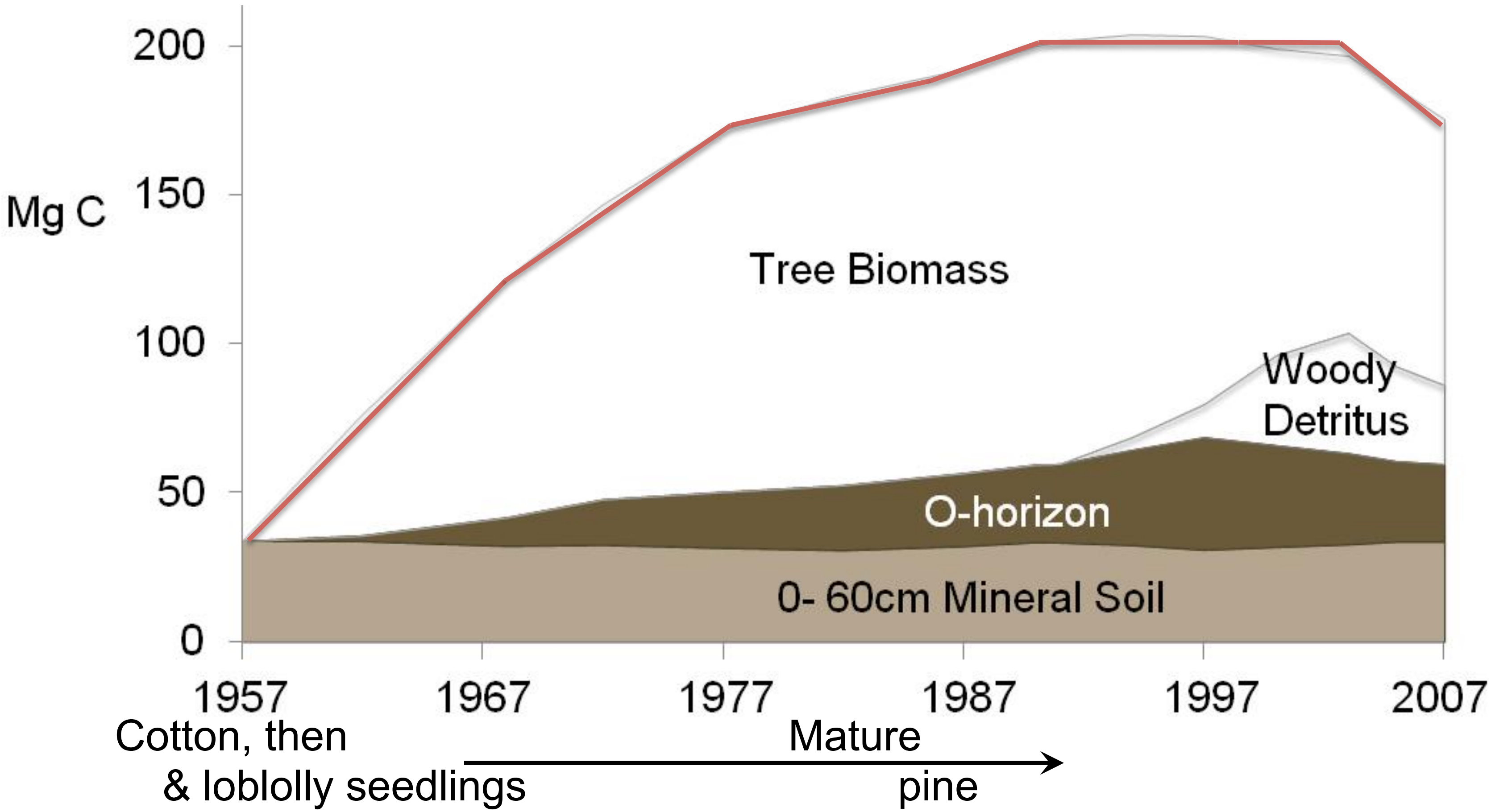
<u>Lower system:</u>
More sedentary & heterogeneous, chemically weathered with bio-hydro hot~~spots~~ networks



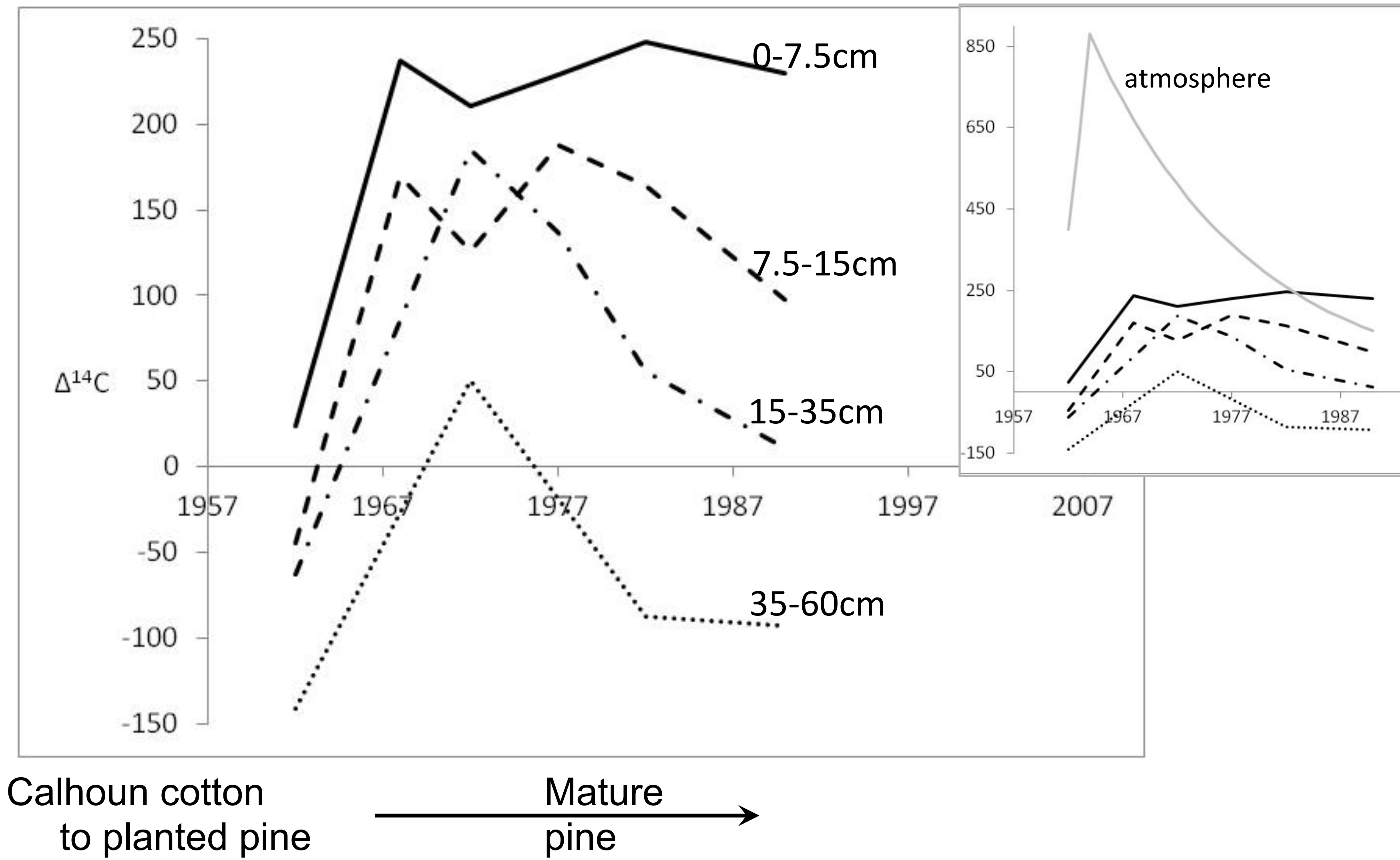
Three Calhoun-CZO field facilities
a) Plot studies (others across region)
Permanent LTSEs (P2, Pine reforestation)
Space-time substitutions (H2, Old hardwoods; P3, Pine; C1, Cultivated)
b) Erosion-carbon studies: Holcombe's Branch
c) Experimental catchments
a)
C1
P2
H2
P3
b)
0 500 1,000 1,500
Meters
Holcombe's Branch
Southern Piedmont
Tyger River
c)
Holcombe's Branch
Ws2
Ws3
Ws4
Interfluve
USFS Rd. 325
Elevation
240 m
90 m
0 1,500 3,000 4,500
Meters
Calhoun Digital Elevation Model

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

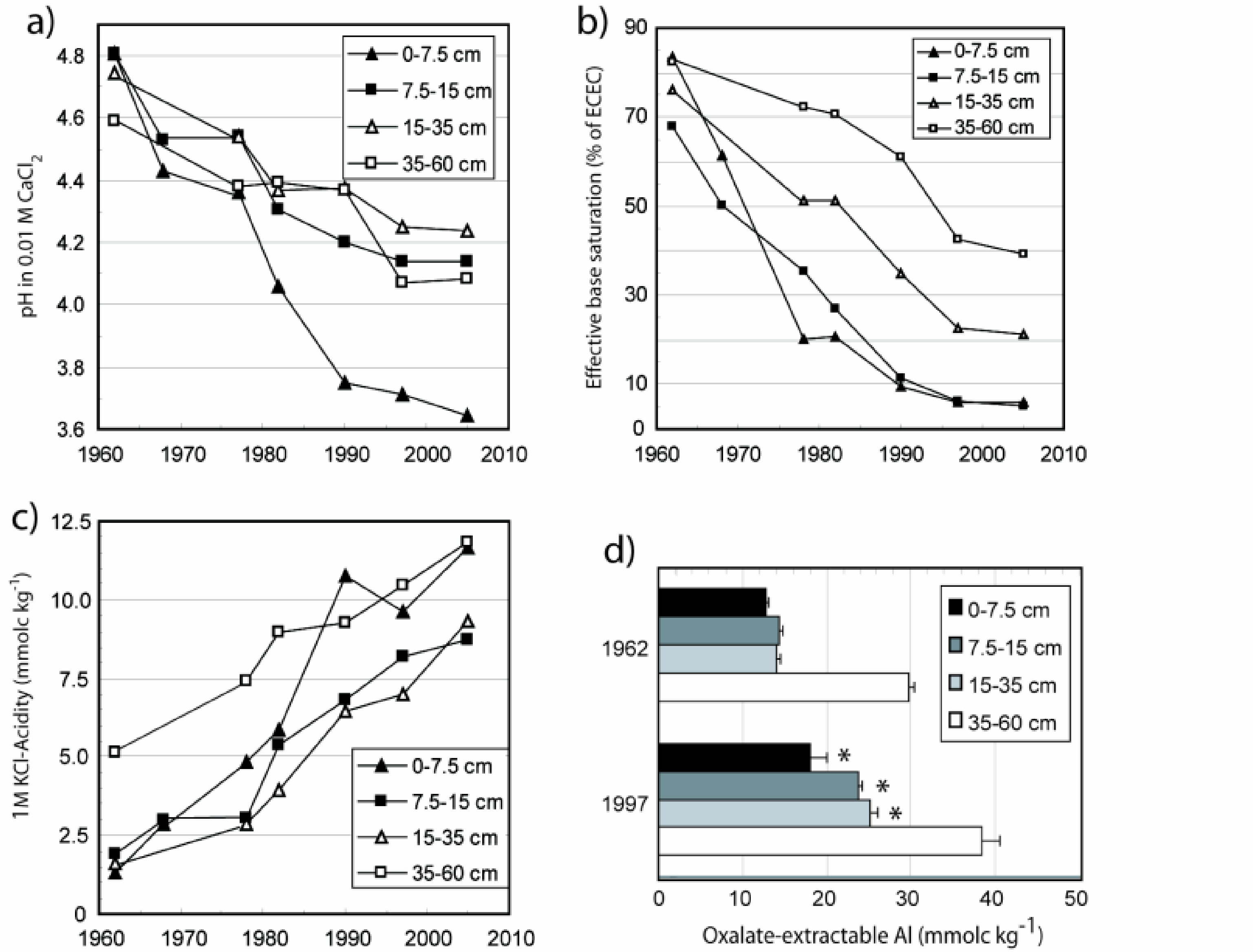


Large ^{14}C enrichments indicate rapid turnover of fresh organic matter throughout 60-cm profile



from Richter et al. 1999 *Nature*

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 are deep, extremely acidic, Ultisols, and in an advanced stage of weathering. Profile from Bacon et al. (2012) from an uncultivated old hardwood stand (H2, see Figure 2).

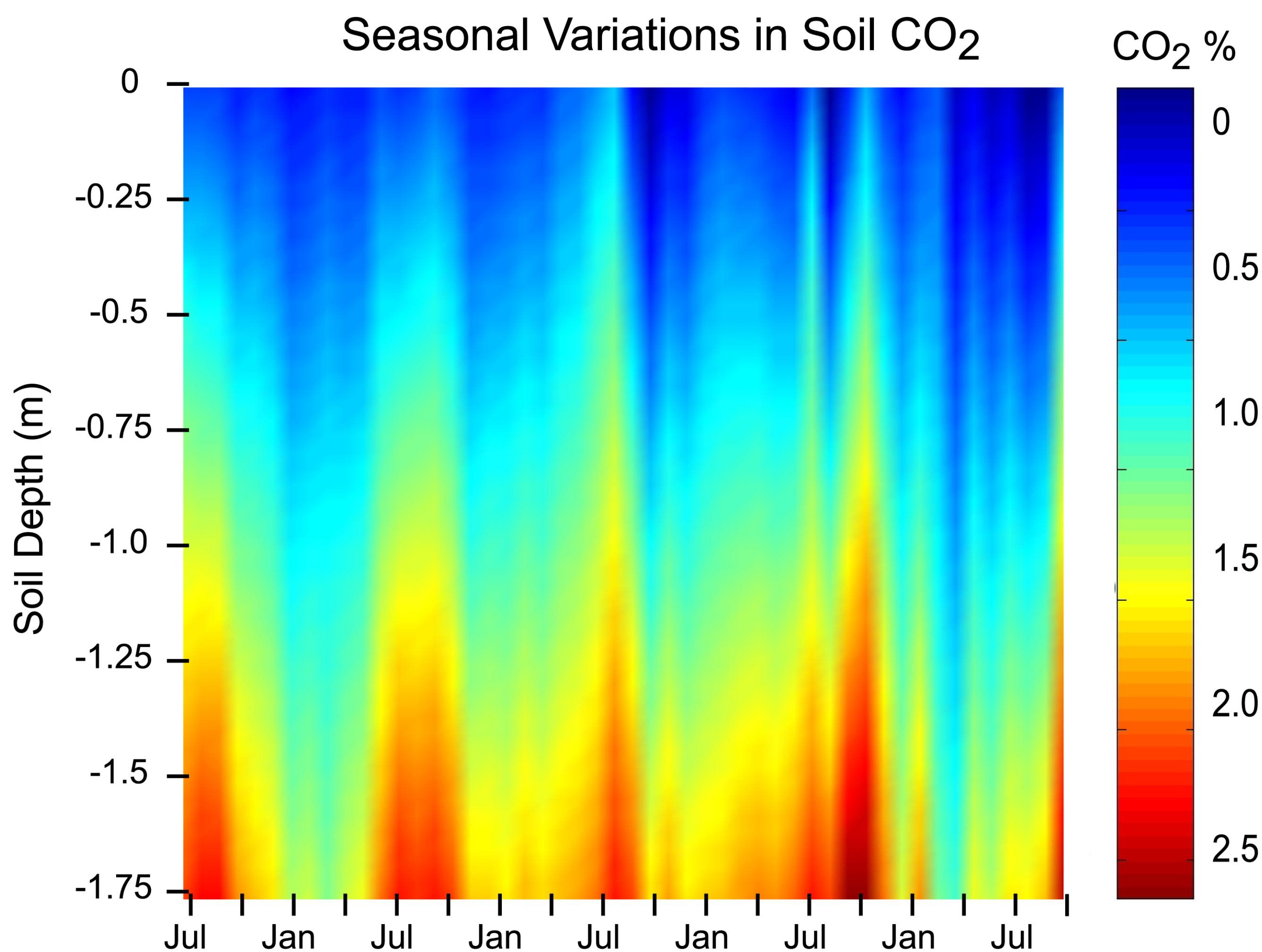
Hor	Depth (m)	Clay (%)	pH	C (%)	ECEC[§] cmol/ kg	EBS[§] (%)	totCa
A	0.00–0.07	5.0	3.70	2.33	1.9	21.9	0.24
AE	0.07–0.13	6.1	4.05	1.33	1.3	19.2	0.27
E	0.13–0.32	7.7	4.13	0.54	0.9	19.6	0.20
Bt	0.32–0.6	41.9	4.03	0.24	3.5	23.8	0.07
Bt	0.6–1.0	52.9	4.06	0.13	4.6	16.1	0.04
Bt	1.0–1.5	40.1	3.98	0.09	4.6	7.9	0.04
BC	1.5–2.0	22.9	3.99	0.04	3.8	5.4	0.04
CB	2.0–2.5	13.6	3.96	0.03	3.7	4.1	0.04
C	3.0–3.5	3.6	3.89	0.01	2.8	4.9	0.06
C	4.0–4.5	4.2	3.88	0.01	4.0	6.5	0.06
C	5.0–5.5	3.3	3.94	0.01	2.7	7.4	0.07
C	6.1–7.6	4.7	4.00	-	2.6	8.8	0.12
C[††]	7.6–9.1	5.9	4.05	-	2.0	20.1	0.22
C	9.1–10.7	5.2	4.17	-	2.1	49.9	0.32
C	10.7–12.2	5.2	4.35	-	2.4	74.8	0.59
C	12.2–13.7	5.9	4.41	-	2.5	79.1	1.13
C[§§]	13.7–16.8	3.7	4.96	-	2.8	87.8	4.43
C	16.8–18.3	1.5	5.51	-	3.1	96.5	7.72

[§]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

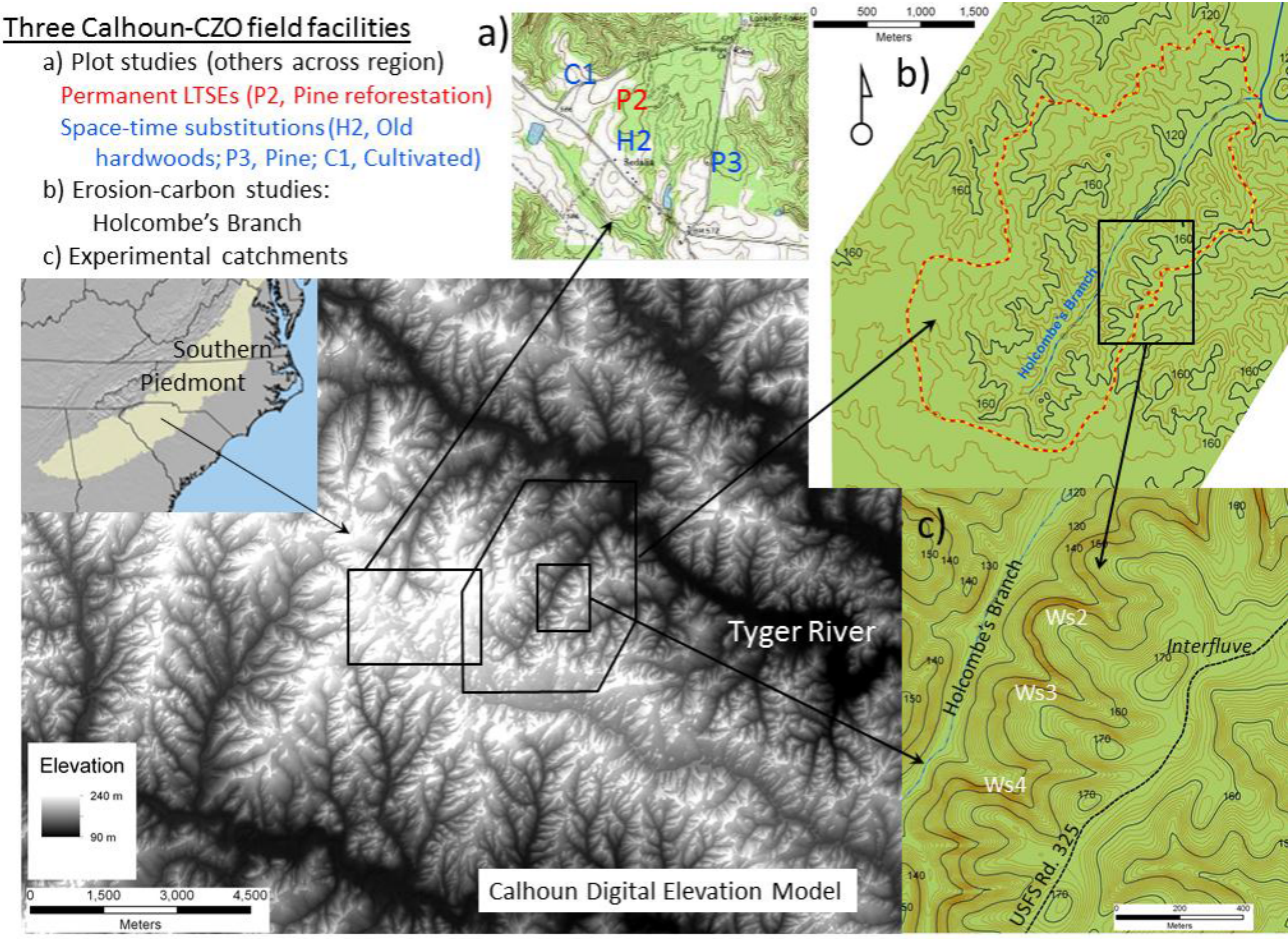
Richter et al. 2007. Water chemistry & CO_2 to 6m



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



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a)
C1
P2
H2
P3
b)
0
500
1,000
1,500
Meters
120
160
Holcombe's Branch
Southern
Piedmont
Tyger River
c)
Holcombe's Branch
Ws2
Ws3
Ws4
Interfluve
USFS Rd. 325
Elevation
240 m
90 m
0
1,500
3,000
4,500
Meters
Calhoun Digital Elevation Model

Calhoun CZO: Overall vision of infrastructure

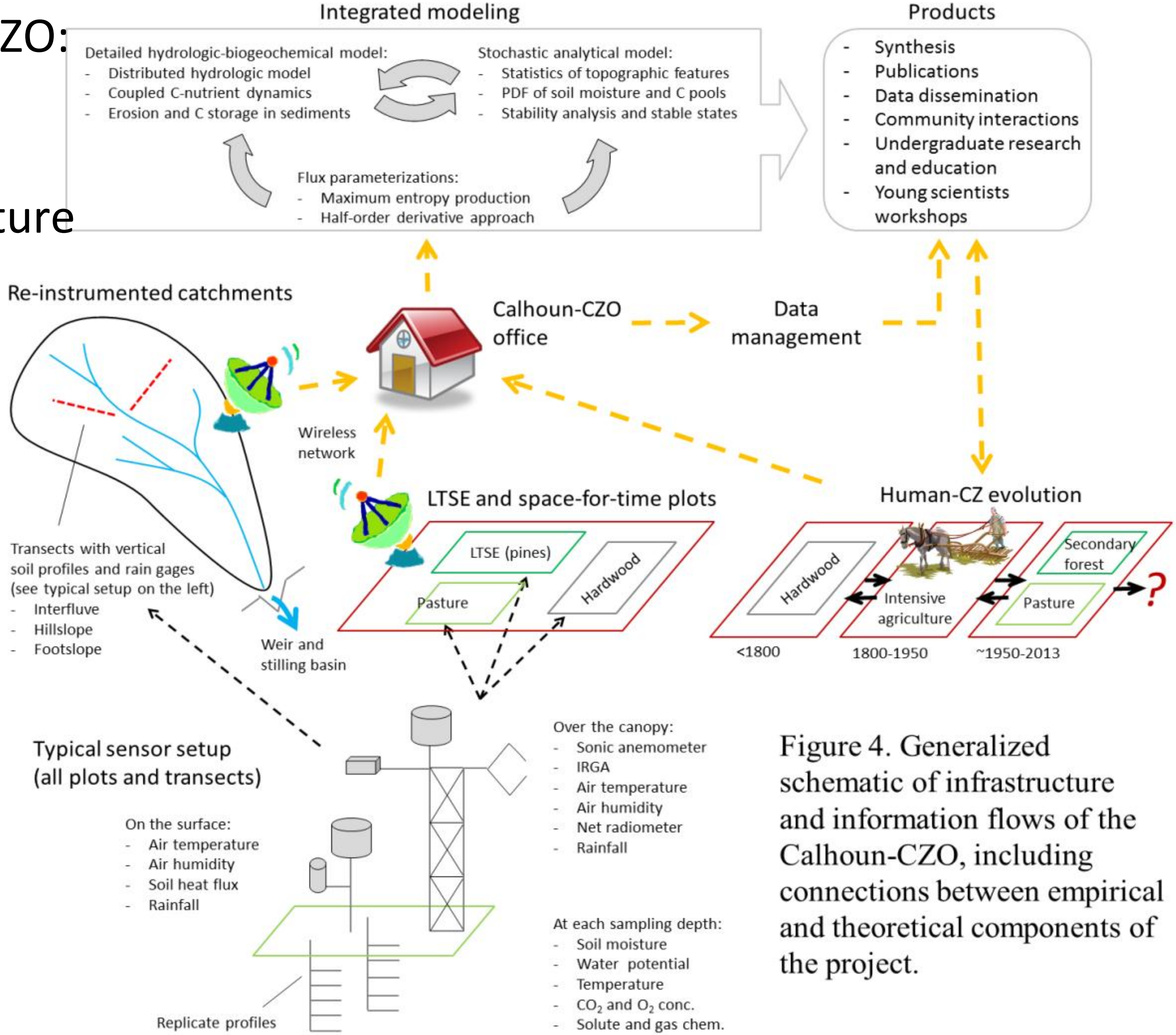

Figure 4. Generalized schematic of infrastructure and information flows of the Calhoun-CZO, including connections between empirical and theoretical components of the project.

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

Photo: Allan et al. *Catena*, 2006