Using Soil Science Principles for Wetland Mitigation, Voluntary Restoration and Creation

W. Lee Daniels and many, many more

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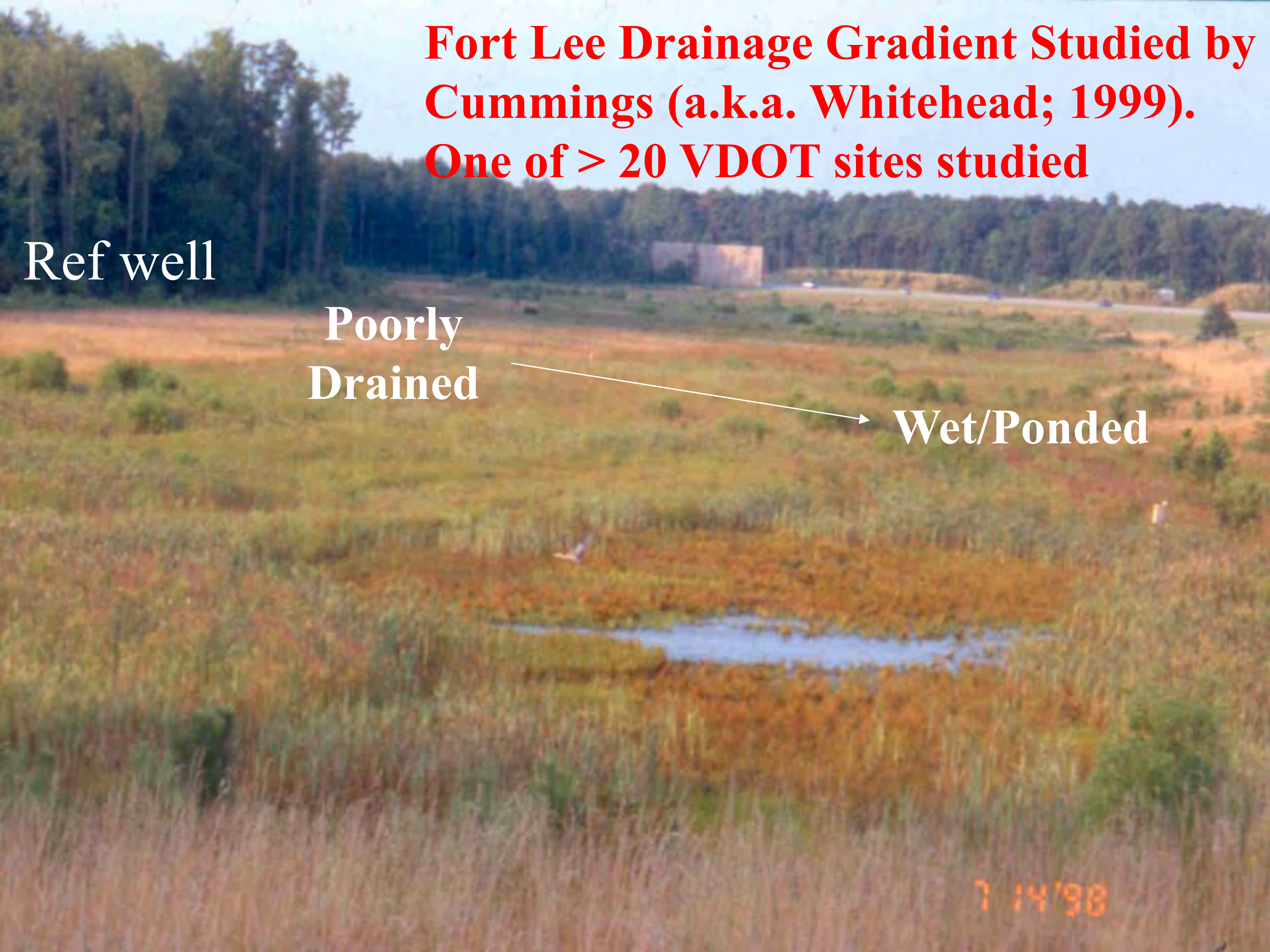
http://www.landrehab.org

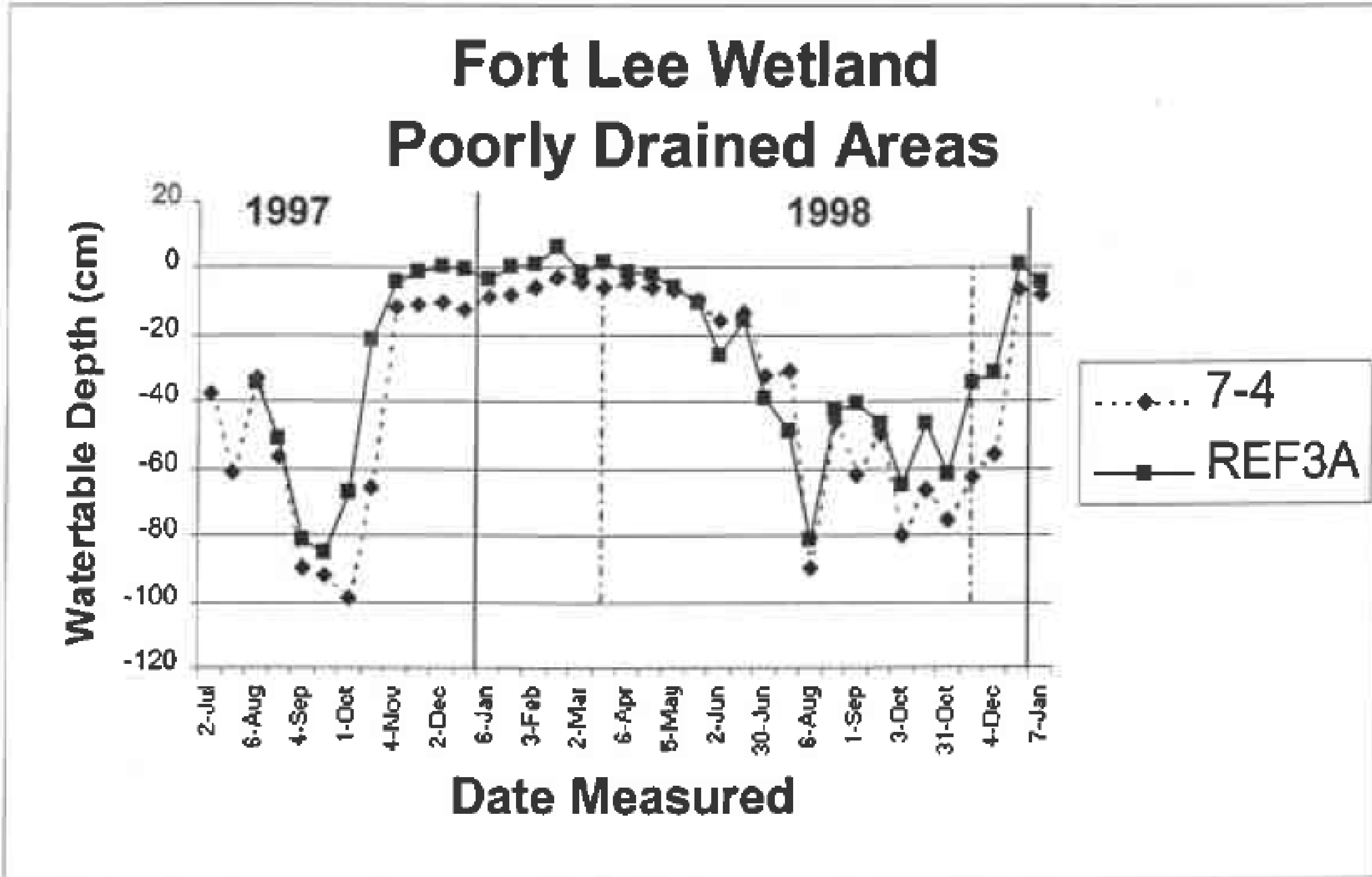
Objectives

- **Describe common created wetland soil limitations observed over 20 years of collaborative research**
- **Address three commonly held fallacies about wetland creation:**
    1. ***Just make it "wet enough"; soils don't matter.***
    2. ***5% OM is a magic level for wetland creation.***
    3. ***You can't create wetlands in coarse-textured substrates.***
- **Review the development and essential components of created wetland soil reconstruction guidance protocols**


Fort Lee Drainage Gradient Studied by
Cummings (a.k.a. Whitehead; 1999).
One of > 20 VDOT sites studied
Ref well
Poorly
Drained
Wet/Ponded
7 14'98


Recreated soil in “poorly drained” (?) Position


Native soil ~ 300 feet
away at similar elevation



Hydroperiod of created soil vs native soil at Ft. Lee

Compacted created soil in intermediate drainage (poorly d.) class at Fort Lee. Most of these soils supported facultative upland to upland vegetation and did not support redox feature development.

Why?

Differential Soil Properties at Fort Lee (Cummings, 1999)

0-15 cm	pH	% C	% N
Reference	4.76	2.89	0.18
Mitigation	5.31	0.82	0.07

Differential Soil Properties at Fort Lee (Cummings, 1999)

Bulk Density g/cm^3	Surface (0-15 cm)	Subsurface (70 cm)
Reference	0.71	1.42
Mitigation	1.75	1.71

Similar findings also reported for 10 VDOT sites statewide in 2006 report.

Stolt's Buried Bag Study; follow-up work at Fort Lee

Upland Fe-rich soil plus organic (~2.5% Acer rubrum leaves) amendments wrapped in nylon bag ready to go back into the ground.

Added to created wetland soils at two depths

Stolt's Buried Bag Study

- **Old clod (+ C) removed after several years in the field, with the nylon bag carefully pulled away.**
- **Note: this drove several lab technicians into early retirement!**

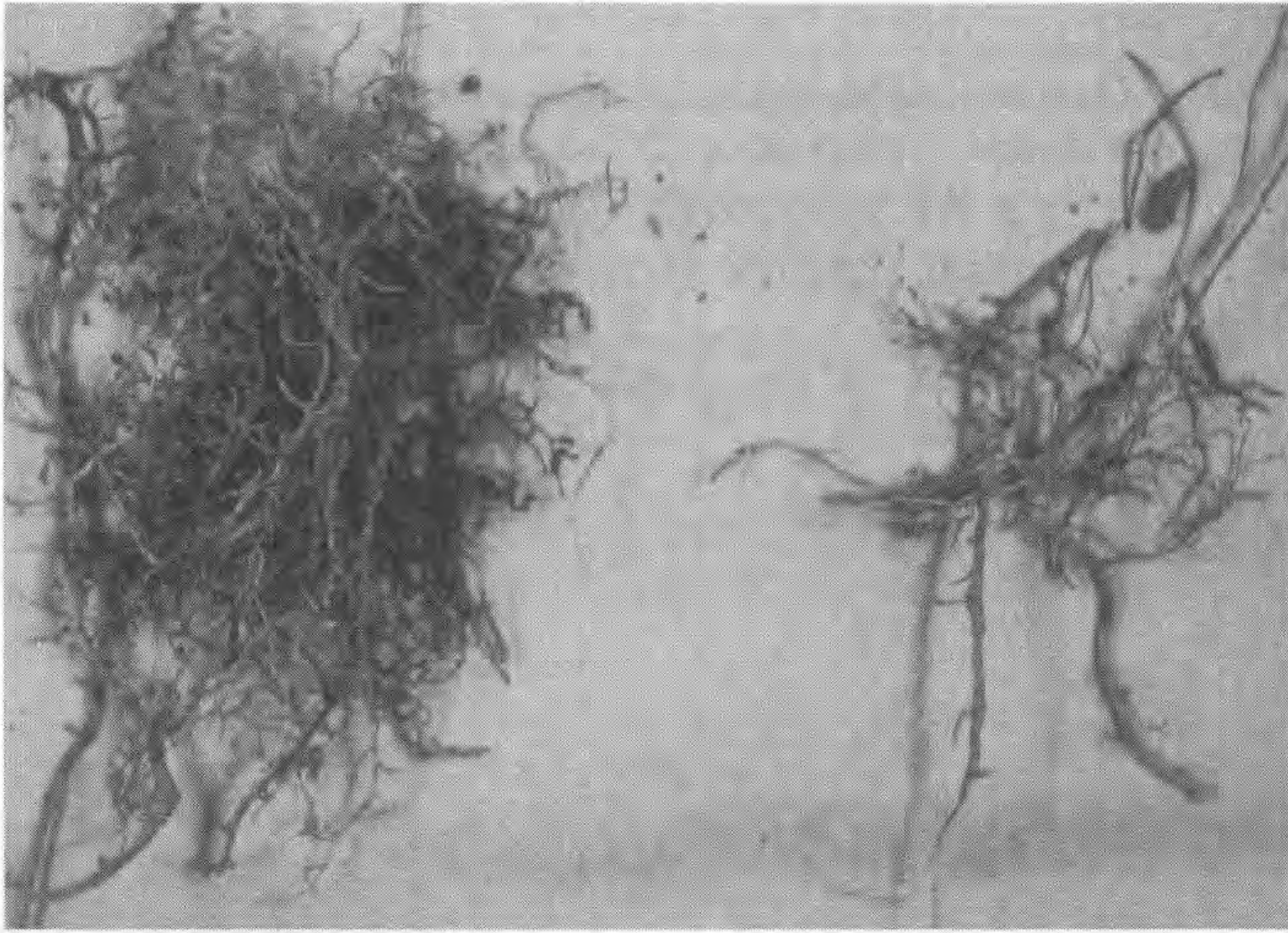


Fig. 2–5. Roots extracted from simulated peds amended with organic matter (*A*) and unamended (*B*) after 2 yr in a forested wetland (frame width is 5 cm).

Stolt et al. (1998) "Buried Bag Study"

- **Peds amended with organic matter lost OM and DCB-extractable Fe at 0.5 to 1.0 g/kg/yr.**
- **Peds that were not amended with organic matter gained Fe at rates up to 2.0 g/kg/yr.**
- **Organic matter coatings, Fe-masses on ped exteriors, iron enriched pore linings, and depletions in ped interiors formed in 2 years**

2

Quantifying Iron, Manganese, and Carbon Fluxes in Near-Surface Horizons of Palustrine Wetlands

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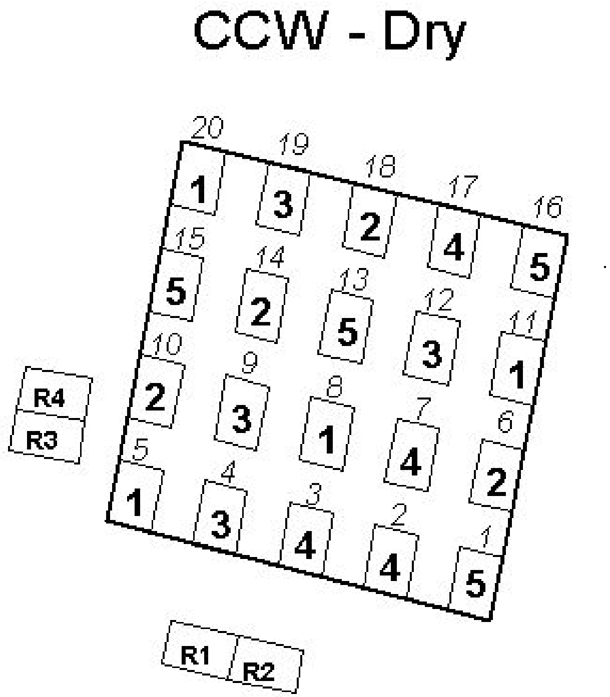
In: *Quantifying Soil Hydromorphology*, SSSA, 1998

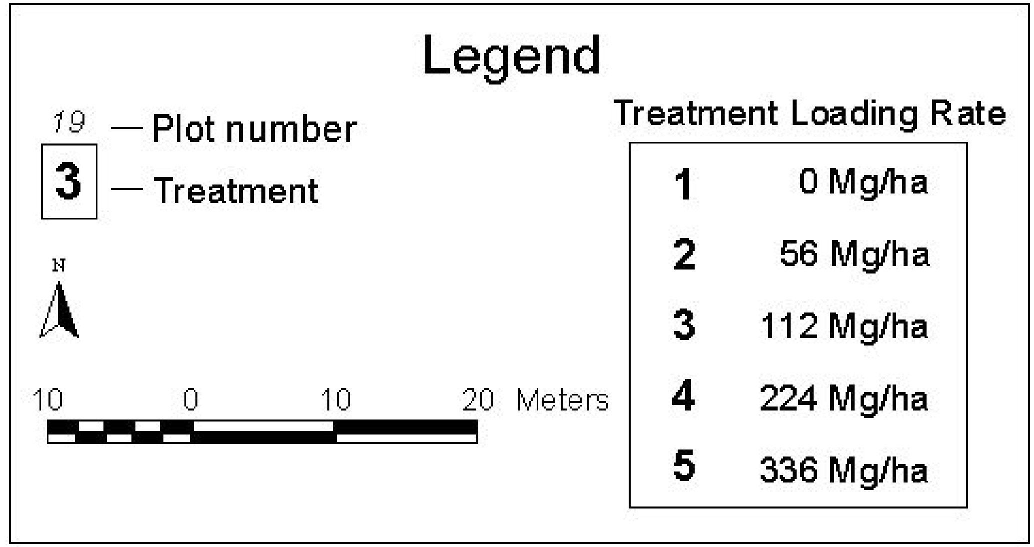
Site for Charles City Wetland (CCW) OM Loading rate experiment, first built in 1997 & 1998; modified by VDOT several times thereafter.

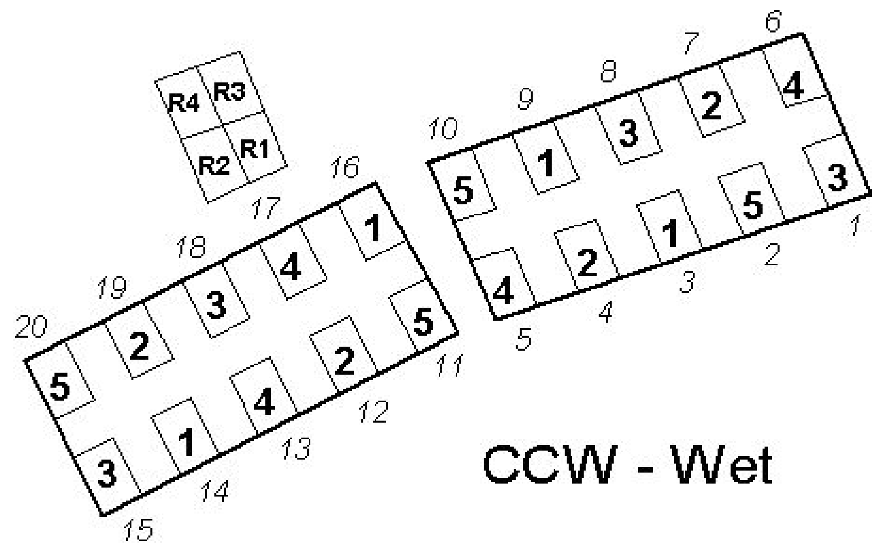
Surface soil at CCW in 2002 after preliminary "remediation efforts"

Note massive structure in surface breaking to firm plates at about 20 cm.

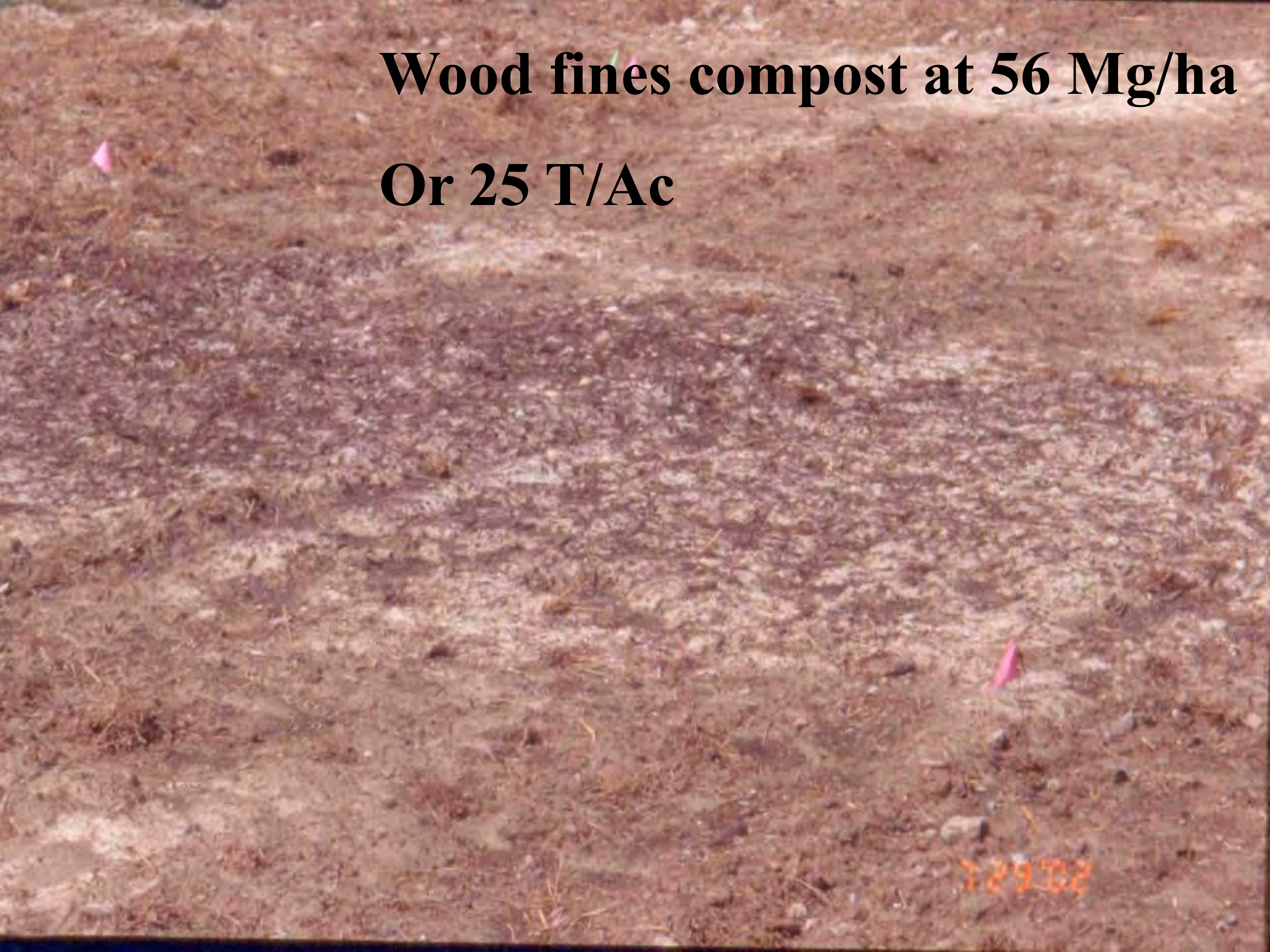
This directly limits rooting, litter to soil incorporation, subsoil microbial biomass, and therefore redox process and associated development of features!

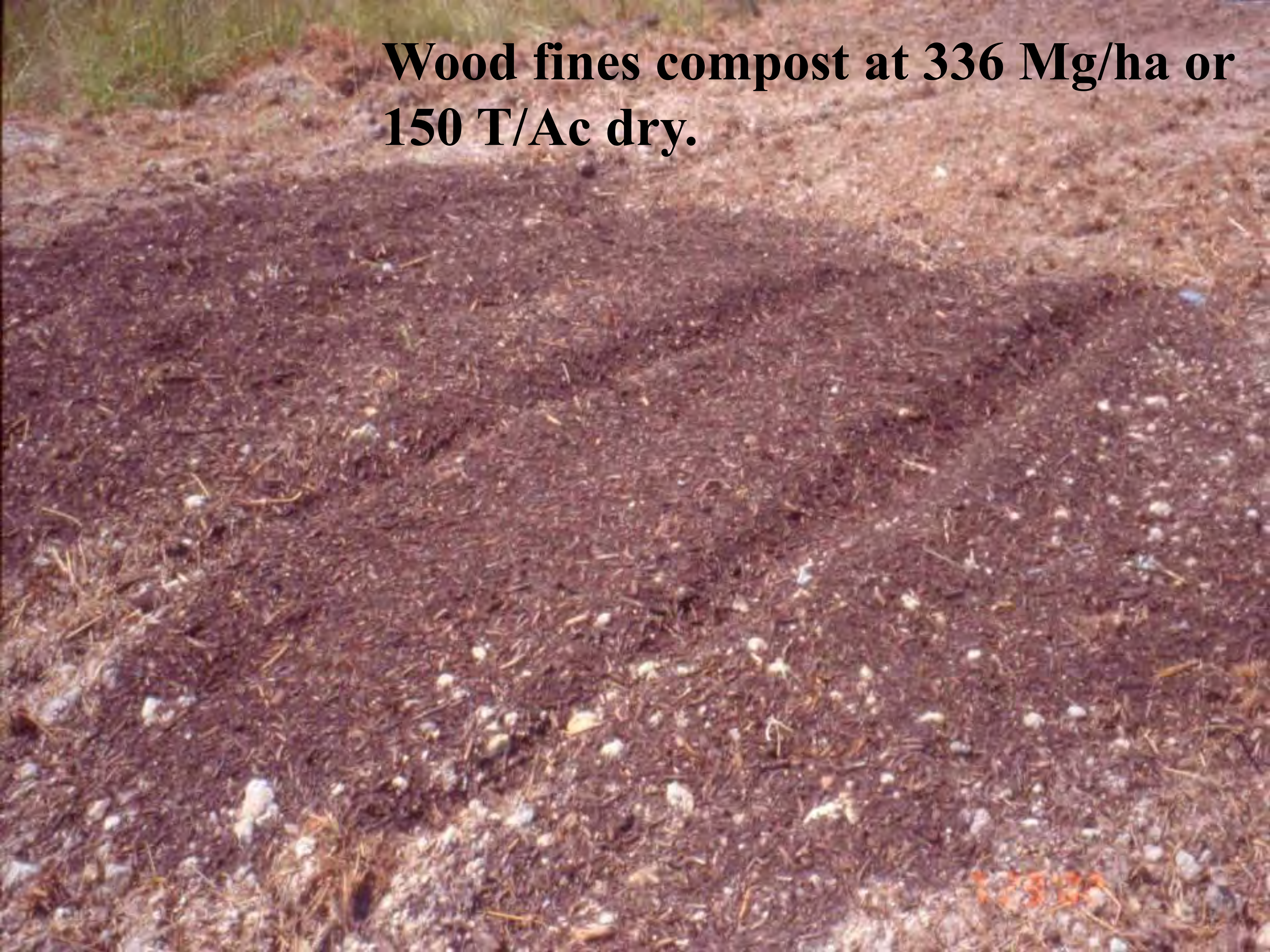






Both experiments combined tillage (disk and roto-tiller) plus wood waste compost amendment at 25, 50, 100 and 150 dry tons per acre.


Wood fines compost at 56 Mg/ha
Or 25 T/Ac


Wood fines compost at 336 Mg/ha or
150 T/Ac dry.

Cara Bergschneider, 2005 MS Thesis

Described soil morphology, soil physical & chemical properties and vegetation response in 2003-2004; two years after treatment application.

Results: Pedogenesis

0 Mg/ha rate

56 Mg/ha (25 T/ac; < 2.5% OM)

Results: Pedogenesis

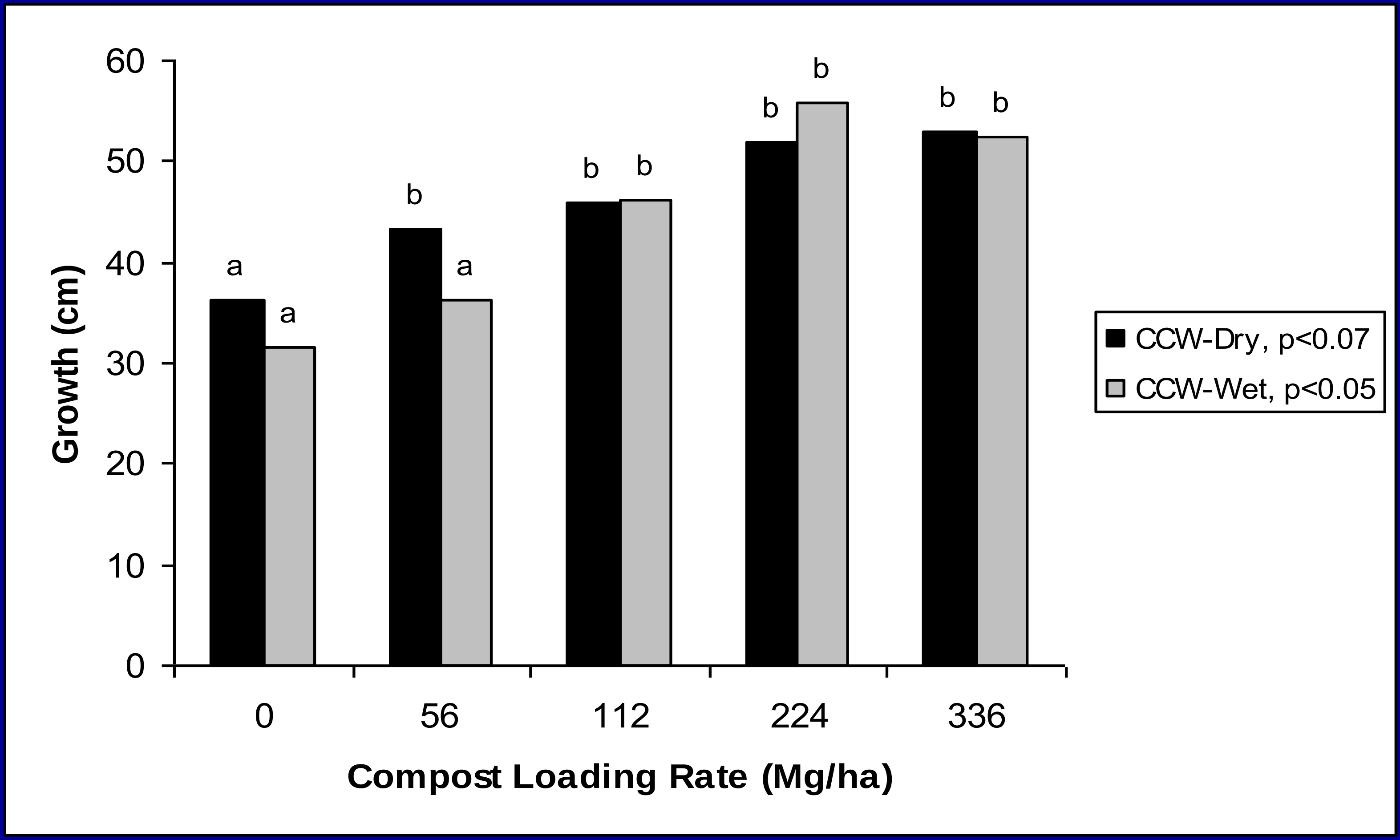
112 Mg/ha rate

224 Mg/ha rate

336 Mg/ha rate

Results: Tree growth

Average (n=4) *Betula nigra* (river birch) height growth as affected by compost loading rate. Significant differences by Wilcoxon rank sums. *Quercus palustris* did not respond.



WETLANDS, Vol. 27, No. 4, December 2007, pp. 936–950

VEGETATION DYNAMICS IN RESPONSE TO ORGANIC MATTER LOADING RATES IN A CREATED FRESHWATER WETLAND IN SOUTHEASTERN VIRGINIA

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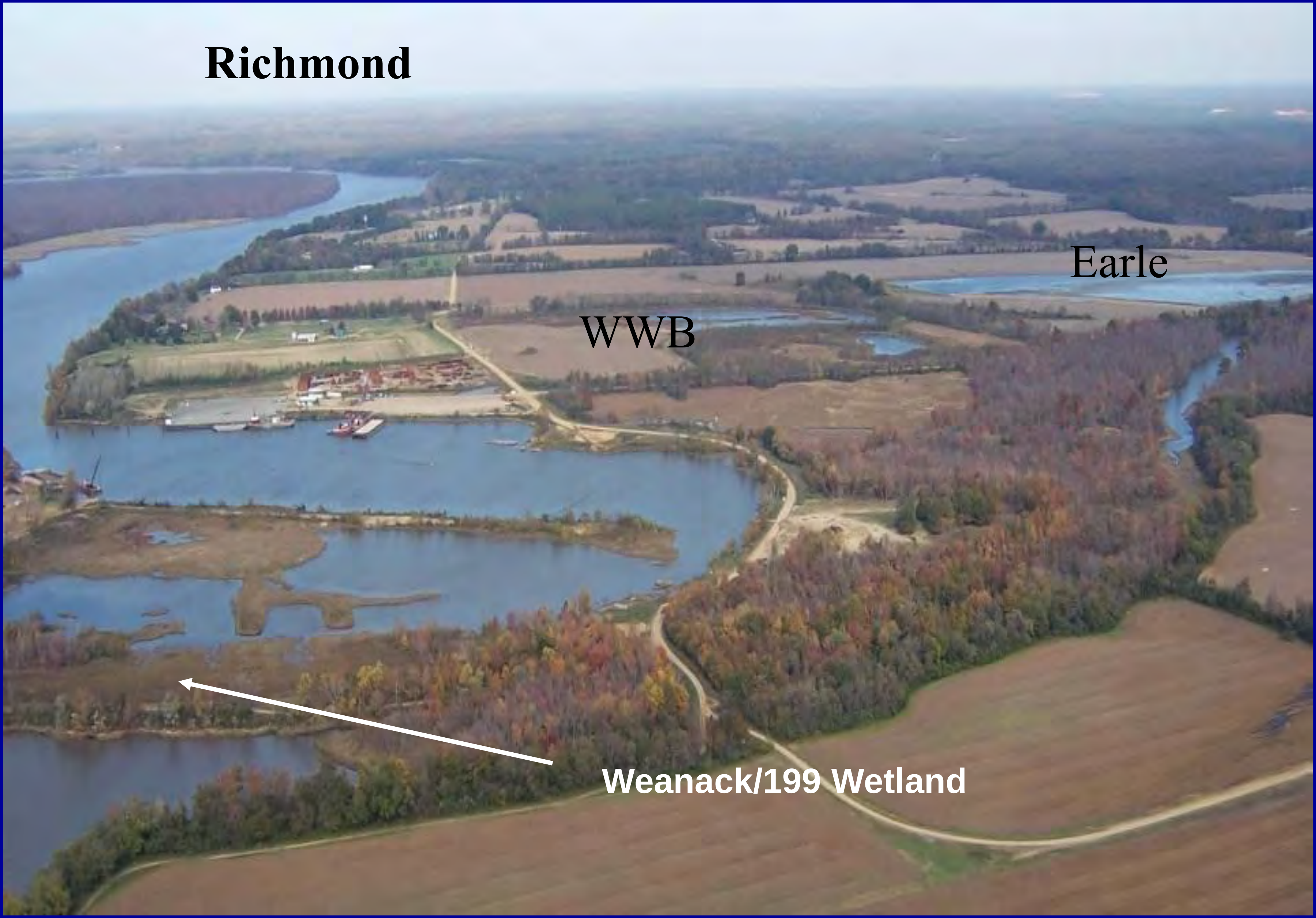
Bailey found that OM loadings had little effect on herbaceous vegetation, but did result in increased tree growth. Optimal addition was 112 Mg/ha (50 T/Ac).

Long term effect of original compost loading (112 Mg/ha – 50 T/ac) at CCW dry experiment – Summer 2015.

You can't create a wetland in a sand?

"In general, mitigation sites contained more sand and less clay than reference sites at 20 cm ……Whatever their origin, these textural differences may have important implications in the success of wetland creation projects as coarser textures are characteristically loose, well aerated and drained (Brady, 1984)". ***Bishel-Machung et al., 1996. Soil Properties of Reference Wetlands and Wetland Creation Projects in Pennsylvania. Wetlands 16(4): 532-541.***

This was interpreted by many state and federal regulators to mean that you could not build created wetlands in coarse-textured substrates. This was despite the fact that we had over 150,000 acres of coarse-loamy hydric soils in Virginia!


Richmond
Earle
WWB
Weanack/199 Wetland

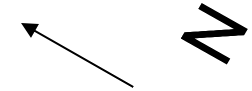
Experimental site before any amendments. Comprised of sandy dredge sediments placed in 1960s and 1970s.

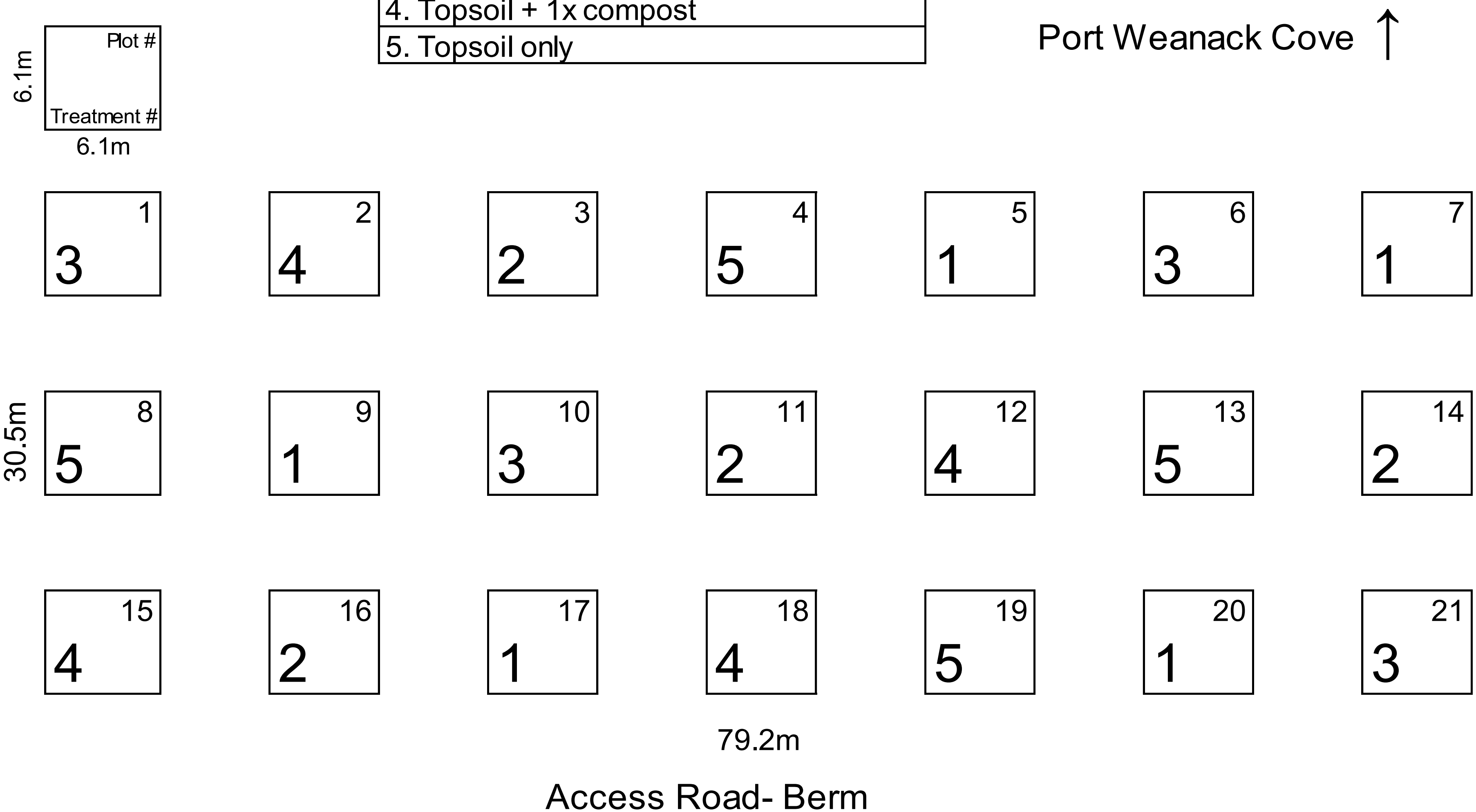
Experimental area graded and flagged. Note uniform brown and oxidized sediment colors across the site.

Weanack/Shirley Wetland Experiment Plot

1x = 35 wet tons per acre

Treatments
1. Fertilized control
2. 1x compost @ 78 Mg/ha
3. 2x compost @ 156 Mg/ha
4. Topsoil + 1x compost
5. Topsoil only





Compost was added to all plots and to simulated pit floors and mounds working at low tide.

Experimental area after hummock installation and application of topsoil. Picture shot 3 hours after adjacent high tide.


Pits quickly filled with finer-textured local and flood-tide sediments
20. 5. 2004

Mike Nester working at Weanack wetland describing intact soil plug pulled from a "mini-pit"

Distinct redox concentrations and depletions (F3; depleted matrix) formed in replaced upland topsoil within three years. Also note distinct band of concentrations at topsoil/sand contact.

Photo from 2009 of high compost addition treatment vs. original soil from berm.

Image of control plot soil (sand; fertilizer only taken 11/8/15. Note significant accumulation of OM in surface and low chroma below.

Detailed study by Emily Ott (PhD student) & John Galbraith is ongoing.

Bald cypress in pit (left) vs. mound (right).
Note other woody stems invading.

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Microtopographic effects on growth of young bald cypress (*Taxodium distichum* L.) in a created freshwater forested wetland in southeastern Virginia

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Pietrzykowski et al. found no effects of original soil treatments on any tree growth parameters, but <u>trees growing in pits were taller, larger and had more butt swell.</u> Trees in pits also had more competition from other invaders like *Salix nigra* and *Acer rubrum.*

Recommendations for Reconstructing Hydric Soils (*assuming* hydrology is correct!)

- Regrade the subsoil layer of the site, making all efforts to minimize compaction and limit rutting and smearing.

- Rip and/or chisel plow the subsoil layer to attain a non-limiting soil bulk density (e.g. 1.35 for a clayey subsoil and 1.75 for a sand). Use high-flotation tires if possible!

Recommendations for Reconstructing Hydric Soils

- Whenever possible, salvage and direct haul natural hydric or other native topsoil layers to form the new soil’s A horizon.

- Supplement non-hydric soil materials with sufficient suitable organic amendments at 25 to 50 dry tons per acre and thoroughly incorporate the materials to 4 to 6 inches.

Recommendations for reconstructing Hydric Soils

- Disk and/or rip the replaced hydric soil or the manufactured soil zone to remediate any grading associated compaction.
- Wherever possible/feasible/economic, rebuild hummocks etc., to recreate micro-topographic variability.
- Apply any available leaves, wood chips, or other debris as a surface mulch.

Avoid sulfidic materials at all costs! Mattaponi Wetland; bare ground in rear was pH 3.1 as is the wetland floor when it dries down in the summer. Around 25% of VDOT Coastal Plain sites hit sulfidic materials which will then require high liming rates, etc.

Soil bulk density, organic matter content and overall soil reconstruction procedures are detailed by:

COE/DEQ, Norfolk District Corps and Virginia Department of Environmental Quality Recommendations for Wetland Compensatory Mitigation Including Site Design, Permit Conditions, Performance and Monitoring Criteria - July, 2004

http://www.nao.usace.army.mil/Portals/31/docs/regulatory/guidance/Annotated_Corps-DEQ_Mit_7-04.pdf

So, how do I determine "hydric soil success"?

- **Learn how to accurately and completely describe soil morphology, particularly redox features!**
- **Carefully describe soil morphology (a) before any site disturbance and then (b) immediately after final creation/restoration. Quantify/count redox feature abundance; don't simply place them into classes (e.g. few vs. many).**
- **At a pre-determined interval (e.g. 1, 3 and 5 yr?), conduct follow-up soil descriptions on "mini-pits" excavated to 30 cm+ and carefully quantify color, redox feature abundance, etc.**
- **If the soil is "moving in the right direction", you should be able to detect and quantify (a) development of lower overall chroma and (b) increased redox concentrations, pore linings, or other features.**

Acknowledgments

- **Funds for various portions of this research were provided by VDOT and Weanack Land LLLP.**
- **Thanks to all the students, post-docs and research staff cited in this talk. Too many to list!**
- **I particularly want to thank Jim Perry (VIMS) and Rich Whittecar (ODU) for their input over the past 20 years.**