Determining an Appropriate Organic Matter Loading Rate for Created Forested Wetlands in the mid-Atlantic USA

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Importance of Wetlands

- Provide critical habitat for half of U.S. endangered and threatened species
- Reduce damage from flooding
- Sediment trapping and erosion control
- Areas of groundwater recharge and discharge
- Provide recreational opportunities

What is a Jurisdictional Wetland?

1. Must exhibit a dominance of hydrophytic vegetation.
2. Must be saturated at or near the surface for a significant period during the growing season.
3. Hydric soils must be present.

(COE Wetlands Delineation Manual, 1987)

Wetland Mitigation

- Where wetland impacts are deemed to be "unavoidable" by the U.S. Army Corps of Engineers, mitigation must occur in the form of preservation, restoration, or creation
- Must be returned type-for-type, preferably in the same watershed, and usually at a mitigation ratio of at least 2:1 constructed:disturbance for forested wetlands

Wetland Creation

- Construction of a wetland where one did not previously exist
- Reasons
  1. Mitigate for wetland disturbance
     - protection of wetlands under CWA Section 404
  2. Increase the quantity of wetlands and quality of water
     - potentially important tool

Construction Practices

- Excavation of an upland adjacent to a natural wetland down to the underlying water table
- Excavated soil is often stockpiled in a nearby location
- Area brought to final grade
- Establish vegetation by applying hydrophytic seed mix and/or hand planting

Since the mid 1990's, the most commonly employed method to "create" new wetlands is to take areas with soils like this, and enough of the upper soil to bring the wet zone (with redox features) close enough to the surface to be wet during the growing season.

Wetland Creation Success

- Maguire (1985) examined 23 mitigation wetlands in VA and determined half to be successful
- Rheinhardt and Brinson (2000) evaluated 23 created wetlands in NC and determined 9 to be successful and 8 to be unsuccessful (not enough information on remaining 6)
- In 2004, the Committee on Mitigation Losses declared the goal of no net loss of wetlands unsuccessful in terms of wetland function

Documented Soil Problems in Virginia Contributing to Wetland Creation Failure.

(Stolt et al., 2000 & 2001; Fajardo, 2006)

1. Compaction due to heavy machinery
   - root limiting bulk densities
   - creation of a perching layer
2. Lack of Soil Organic Matter
   - water holding capacity
   - porosity/ bulk density
   - nutrients
   - microbial populations
   - redox feature formation

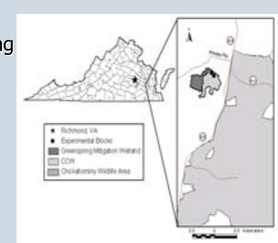
OM additions recommended by late 1990's. Loading rates of 50 Mg/ha (ash free!) or higher were commonly recommended to achieve target SOM content of 5%.

Research Objectives

1. Quantify the overall effects of organic matter amendments in relation to bulk density, water content, and redox potential;
2. To determine the effects of organic matter amendments on redox feature formation;
3. To measure the overall effects of organic matter amendment upon the growth, vigor, and survival of planted hardwood species in a created wetland;
4. To determine an appropriate loading rate of organic matter amendments for non-tidal forested created wetlands in the mid-Atlantic Coastal Plain.

Charles City Mitigation Wetland

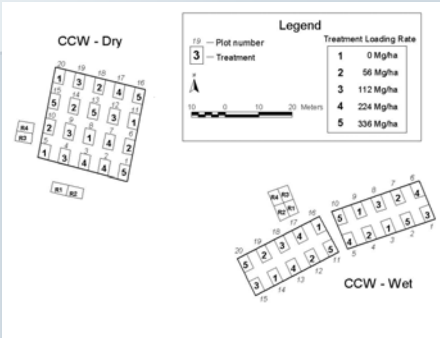
- Located in Charles City County, VA; Coastal Plain province
- VDOT mitigation wetland created in 1997
- 21 ha with 18 ha compensating for bottomland hardwood wetland disturbance



Charles City Wetland Mitigation

- Created via excavation of upper 46 to 61 cm of solum
- Soil surface consists of an argillic, plastic Btg horizon
- Shrink-swell clay present
- Little topsoil replacement evident; renovated later
- Generally poor quality site

CCW Experiments



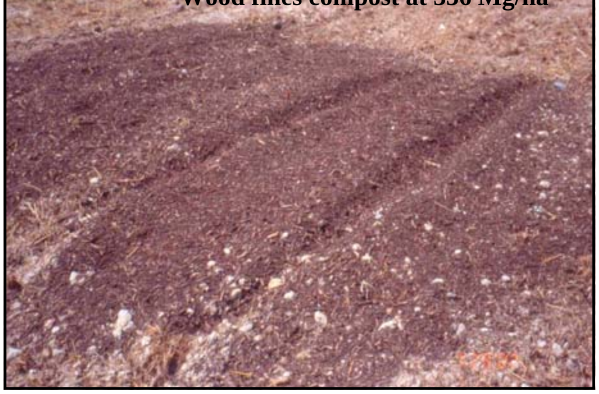
Methods: Installation of Experiments

- Vegetation on experiments mowed and soil deep ripped 15 cm with a root rake
- Organic matter (high quality compost) added to plots and incorporated into upper 12.5 cm soil in July 2002

Dry Experimental Block at Charles City – Rt. 199 Site

Wood fines compost at 56 Mg/ha

Wood fines compost at 336 Mg/ha



Methods: Installation of Experiments

- Two bottomland hardwood tree species, *Betula nigra* and *Quercus phellose*, were planted in December of 2002
  - Each plot received five trees of each species
- Electric and chicken-wire fence constructed around both experiments to avoid herbivory

Methods: Field Sampling

1. Bulk density
   - Subsurface: Two cores collected from each plot at a depth of 25-30 cm with bulk density hammer
   - Surface: Volumetric sample collected by excavating upper 12.5 cm of soil and filling hole with water

Methods: Field Sampling

2. Moisture Content
   - Data collected from each plot with a Trace System Model using Time Domain Reflectometry (TDR)

3. Soil Redox Potential
   - Each plot measured using five Pt electrodes and a saturated calomel reference electrode inserted 12.5 cm below surface

Methods: Field Sampling

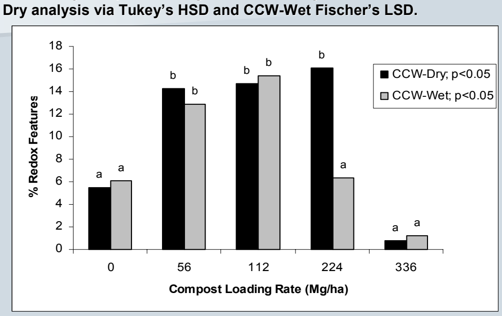
4. Redox feature and pedogenic development
   - "Mini-pits" from each plot evaluated for texture, matrix color, structure, root abundance, and redox features

5. Biomass
   - All vegetation within a 0.5 m^2 collected, separated by species, dried, and weighed

6. Tree measurements
   - Trees measured for total height, number, and length of branches

Results: Pedogenesis- Oct. 2003

Figure 8. Average (n=4) % redox features in upper 15 cm of soil as affected by compost loading rate in CCW-Dry and CCW-Wet. CCW-Dry analysis via Tukey's HSD and CCW-Wet Fischer's LSD.



Results: Pedogenesis

0 Mg/ha rate

56 Mg/ha rate

Results: Pedogenesis

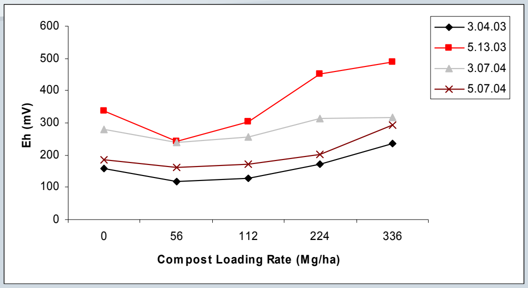
112 Mg/ha rate

224 Mg/ha rate

336 Mg/ha rate

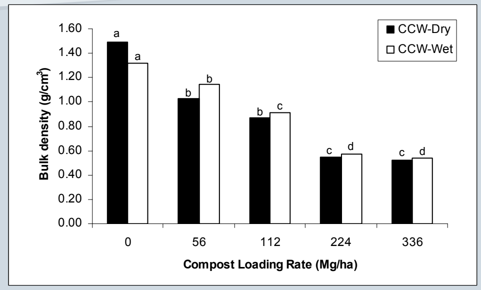
Results: Redox Potential

Figure 7. Soil Redox Potential (Eh) for CCW-Wet.



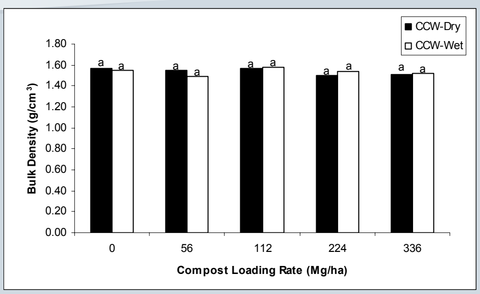
Results: Bulk Density- Oct. 2003

Figure 1. Surface bulk density for CCW-Dry and CCW-Wet (p<0.05; Tukey's HSD)



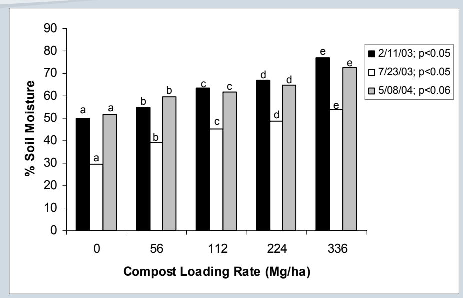
Results: Bulk Density

Figure 2. Subsoil bulk density for CCW-Dry and CCW-Wet (p<0.05; Tukey's HSD)



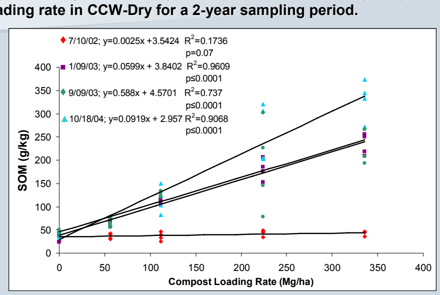
Results: Moisture Content

Figure 4. Average (n=4) volumetric moisture as affected by compost loading rate in CCW-Wet Treatment means by date followed by different letters sig. different using Wilcoxon rank sums.



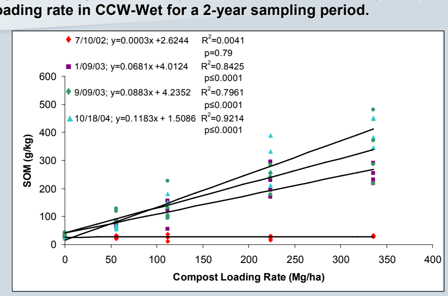
Results: SOM

Figure 9. Regression analysis of % SOM as affected by compost loading rate in CCW-Dry for a 2-year sampling period.



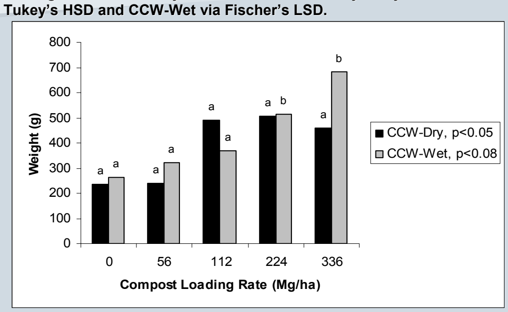
Results: SOM

Figure 10. Regression analysis of % SOM as affected by compost loading rate in CCW-Wet for a 2-year sampling period.



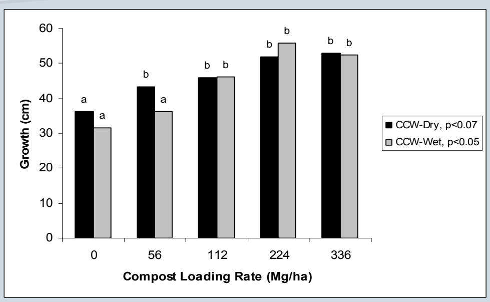
Results: Biomass in August 2003

Figure 11. Average (n=4) plant biomass weight as affected by compost loading rate for CCW-Dry and CCW-Wet. CCW-Dry analyzed via Tukey's HSD and CCW-Wet via Fischer's LSD.



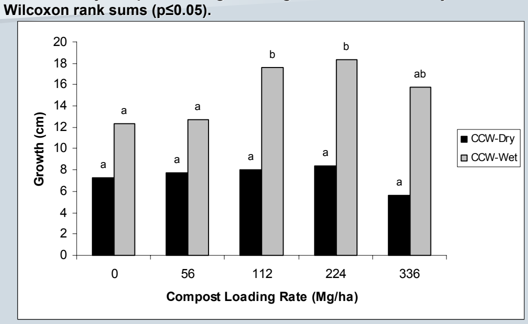
Results: Tree growth- Dec. 2004

Figure 12. Average (n=4) *Betula nigra* (river birch) height growth as affected by compost loading rate. Significant differences by Wilcoxon rank sums.



Results: Tree growth- Dec. 2004

Figure 13. Average (n=4) *Quercus phellose* (willow oak) height growth as affected by compost loading rate. Significant differences by Wilcoxon rank sums (p≤0.05).



Conclusions

- Our findings indicate 112 Mg/ha yardwaste compost appeared optimal in the short-term for inducing hydric soil conditions and plant response in a Coastal Plain forested mitigation wetland
- When organic loading rates exceed 112 Mg/ha, adequate incorporation of the organic matter amendment is challenging and leads to higher surface elevations and higher redox levels in the growing season.

Soil bulk density, organic matter content and overall soil reconstruction procedures are now specifically required 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

www.nao.usace.army.mil/Regulatory/Annotated_Corps-DEQ_Mit_7-04.pdf.

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