Rebuilding Soils for Forest Restoration in Appalachia

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Eastern United States Coalfield Regions

- Appalachian Coalfield
- Midwestern Coalfield

Native Hardwood Forest

Surface Mining for Coal

700,000 hectares disturbed by mining in the Appalachian Region
Reasons to do better:

- SMCRA
- Environmental stewardship - restore ecosystem services - landscape aesthetics.
- Negative public perceptions - negative effects on industry.
Forest Reclamation Approach (FRA):

1. Create a suitable rooting medium for good tree growth no less than 4 ft deep, comprised of topsoil, weathered sandstone and/or best available material.

2. Loosely grade the topsoil or topsoil substitute established in step one to create a noncompacted growth medium.

3. Use ground covers that are compatible with growing trees.

4. Plant 2 types of trees - early successional for wildlife and soil stability, and commercially valuable crop trees.

5. Use proper tree planting techniques.
Presentation Purpose:
Describe “best available material” for soil construction when reforesting mines in Appalachia, Interpreting available science.

Outline:
1. Review studies that identify mine soil properties favorable to growth of native trees.
2. Review studies that compare material selection effects directly.
3. Review tree productivity studies.
4. Describe “best available” materials for reforestation, based on reviewed studies.
This presentation is based on published work:


Soil compaction is well known as a factor that inhibits tree growth – avoiding soil compaction is essential for mine reforestation.

That is FRA Step 2 – Not the focus here.
1. Mine soil properties favorable to growth of native trees.

"Regression Studies"
- Identify growing trees on different mine sites.
- Identify tree-growth metric that is comparable among sites.
- Measure tree-growth metric and soil properties.
- Identify soil properties that exhibit statistical associations with tree-growth metrics.
Soil properties controlling height (proxy for growth rate) of 10-yr old Eastern white pines (n=34), Virginia.

- Rooting volume (+ soil depth, - coarse fragments)
- Electrical conductivity (soluble salts)
- Soil Phosphorous

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Soil factors controlling Eastern white pines 2-year terminal height growth; 78 trees, ages 4 - 5, on 14 mines in VA & WV.

Photos: both are 8 yr old eastern white pine (EWP)

↑ Rooting depth  ↓ Elec conductivity
↑ Soil Phosphorous  ↑ Slope (compaction proxy?)

Jason Rodrigue studied forest growth on pre-SMCRA mines: 14 study plots, 7 locations, 6 states.


Measured site productivity for the species present was converted to 50-year white oak SI using published equations.
Rodrigue’s Findings:
Soil properties controlling 50-year White Oak site index for reforested pre-SMCRA mine sites.

- Base saturation (soil nutrients)
- Coarse fragments
- Total available water
- C-horizon porosity
- Elec. conductivity
Soil factors controlling the first 5 internodes from breast height of 10-18 year old Eastern white pines on 49 sites (4 trees/site) in VA & WV.

- Bulk Density
- Rooting depth
- Loamy Texture
- Moderately Acid pH

Texture and pH Effects are non-linear

What mine soil properties are favorable to tree growth - and are controlled by material selection?

Soil pH: Moderately acidic is best.
EC / soluble salts: should be low.
Soil P: must be adequate (but measurement technique makes a difference!)
Coarse Fragments: No evidence of negative effects up to ~ 60-70% - if soil depth is adequate.
Textural composition of soil fines: Loamy / sandy textures are best (may be less important on slopes than flats?).
Materials selected for use in mine soil construction will influence mine soil properties. Generally, properties of weathered rock and soil are more “favorable” (as per these studies) than unweathered overburden material.
Researchers established experimental plots using different types of spoil material, compared tree survival and/or growth among the materials.
Controlled Overburden Placement "Rock Mix" Experiment. Powell River Project, Va Tech.
(VT) Controlled Overburden Placement: Mix *weathered* sandstone (SS) + *unweathered* siltstone (SiS) in various ratios.

WVU: Weathered versus Unweathered Sandstone Catenary Coal Co. Samples Mine in Kanawha Co. WV.

Photos show tree growth after 6 years (10 App. hardwoods + e. white pine)

Unweathered gray sandstone

Weathered brown sandstone

UKy Experimental Plots at Bent Mountain KY.

MIXED

BROWN
(weathered)

GRAY
(unweathered)

Trees Planted:
Red Oak
White Oak
Yellow Poplar
Green Ash

P. Angel, C. Barton, et al.
Bent Mountain Project – 3YR Tree Response

(Yellow-Poplar Tree Volume)

Volume Index (cm³)

Survival

- BROWN 86%
- GRAY 88%
- MIXED 81%

(Brown Sandstone, 2007)
### Bent Mountain Project – 2YR Seedbank Response

(Natural Regeneration)

<table>
<thead>
<tr>
<th>Cover Type</th>
<th>Percentage</th>
<th>Species Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>66.4%</td>
<td>61 species</td>
</tr>
<tr>
<td>Mixed</td>
<td>5.8%</td>
<td>35 species</td>
</tr>
<tr>
<td>Gray</td>
<td>2.0%</td>
<td>12 species</td>
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</tbody>
</table>
UKy Experimental Plots, Bent Mountain, Study #2

**Types of Soil:**
- **Brown (Weathered) Sandstone**
- **Gray Sandstone**
- **Shale**
- **Mixed Sandstone & Shale**

**Trees:**
- 9 spp.
- Appalachian hardwoods

Miller et al. (2012) results over 2 years:
Mean tree survival ranged from 75% (unweathered shale) to 94% (weathered sandstone).
Mean tree growth was greater on weathered sandstone (94 cm) than on all other treatments (ranged from 47 – 60 cm)
Forest topsoil and spoils from Pritchard Mine, WV

White ash, red oak, tulip poplar (2-yr stock)

Study ran May-October.

Both oak and ash do better on weathered sandstone (WS) than on other spoils.

(Showalter et al. 2010)

(VT) Controlled Overburden Placement: Mix weathered sandstone (SS) + unweathered siltstone (SiS) in various ratios.
Unweathered materials show different responses to environmental exposure.

<table>
<thead>
<tr>
<th>Material</th>
<th>VT: Burger “Controlled Overburden Placement”</th>
<th>WVU: Emerson, Skousen</th>
<th>UKy: Angel, Barton</th>
<th>VT: Showalter, Burger (pot study)</th>
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<tbody>
<tr>
<td>SiS</td>
<td>VT: Burger “Controlled Overburden Placement”</td>
<td>WVU: Emerson, Skousen</td>
<td>UKy: Angel, Barton</td>
<td>VT: Showalter, Burger (pot study)</td>
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<tr>
<td>SS</td>
<td>2.5 yr</td>
<td>3 yr</td>
<td>3 yr</td>
<td>- 2 yr avg -</td>
</tr>
<tr>
<td>pH</td>
<td>6.4</td>
<td>8.1</td>
<td>8.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

* Miller et al. unweathered shale had high EC, appears to be slightly pyritic
3. Forest Productivity Studies

E.W. Pine, VA, SMCRA- interim

Cotton thesis, KY, W. Oak, Y. Poplar (over 9 years)

STARFIRE Mine

Post-SMCRA species trial, VA, PRP (15 yrs)

Rodrique, pre-SMCRA mines, 6 states

Martiki Mine, KY (compacted & ripped): 5 species, 18 yrs.

Yellow poplar, pre-SMCRA contour mines, TN
Eastern white pines established by active mining operation in 1979.
Measured 50-yr site index = 32 m, vs ~24 m Appalachian Avg.
Bottom Line on Tree Productivity Studies

Pre-mining productivity approached or obtained only when

(1) weathered spoil is used for soil construction [in some cases mixed with soil and/or unweathered spoil]

(2) spoil is loose graded (minimal or no compaction).


Rebuilding Soils for Forest Restoration in Appalachia

• Key mine soil properties influencing forest site quality: depth & density (soil construction) - and pH, salts, coarse P content, fragments/texture, non-pyritic (material selection)

• Reapplying a mix of all soil horizons and weathered bedrock, uncompacted, can produce mine soils that restore forest site quality.

• When weathered materials are not available: unweathered materials vary widely in suitability for restoring forest cover. Selecting materials for favorable properties will influence reforestation success.

• Research issues remain (e.g. long-term capacity of weathered spoils to support tree nutrition, soil structure formation to support aeration and porosity, interpretations of raw-spoil measures vs. short-term weathering, etc.)
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