Loblolly Pine Survival and Growth on a Reclaimed Mineral Sands Mine in Southeastern Virginia

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Mineral sands mining in Virginia

- Heavy mineral sands
- Coastal sand deposits
- Found further inland

Photo credit: USGS
Mineral sands mining products

• Virginia products
  • Chloride ilmenite (FeTiO$_3$)
    • Mostly sold for TiO$_2$ pigment
  • Zircon (ZrSiO$_4$)
    • High quality ceramics (opacifier)

Iluka Resources 2014, 2015
Mineral sands mining process

• Excavate ore (clay, sand, and heavy minerals)

Photo credits: Iluka Resources
Mineral sands mining process

• Gravity separation to obtain heavy minerals

Photo credits: Iluka Resources
Mineral sands mining process

- Clay and sand pumped into mine cells as a slurry

Photo credits: Iluka Resources, S.K. Klopf
Mineral sands mine reclamation

• Goal: return landscape to productive agriculture

• Primary reclamation constraints
  • Soils with low fertility and pH
  • Soil texture often variable with pockets of “slimes” and sands
  • Compacted soils with high $D_b$
Post-mining land use

- Upland pasture or farmland
- Alternative crops, such as loblolly pines
  - Low maintenance, tolerant of compacted, infertile soils

Photo credit: S.K. Klopf
Mineral sands mine pine trials
Overall site preparation

• Site preparation completed in 2011
  • Subsoil received 11.2 t/ha lime and 280 kg/ha of DAP
  • Topsoil placed
  • 2.2 t/ha lime and 336 kg/ha 15-30-15
  • Seeded with tall fescue, orchardgrass, crimson clover, ladino clover, and cereal rye as a cover crop
Methods: plot layout

Replicate 1 (More Sand)
- Weed Control/Fertilization
- Check

Replicate 2 (More Clay)
- Fertilization
- Weed Control
- Check
- Weed Control/Fertilization

Replicate 3 (More Slope)
- Weed Control
- Weed Control
- Check
- Fertilization
February 2013

- 1 year old loblolly pine seedlings from VDOF planted in grid with 3 m spacing
- 7 x 7 seedlings per treatment per block
  - Border trees around all treatments
Methods: silvicultural treatments

- **Check (C)**
- **Weed control (WC)**
  - Backpack spray 1% glyphosate in 1.5 m circle around tree
  - March and June during first two growing seasons
- **Fertilizer (F)**
  - March 2013 (56-28-56 kg ha\(^{-1}\) NPK)
  - June 2014 (67-33-67 kg ha\(^{-1}\) NPK and 114 kg ha\(^{-1}\) trace minerals)
    - Tissue analysis to determine rates (Waters Agricultural Laboratory)
- **Weed control + fertilizer (WCF)**
Methods: tree measurement

- Initial height and ground-line diameter (GLD) measured after planting
- Height and GLD measured every winter
- DBH measured in winter 2017/2018
Results: Survival

![Bar chart showing survival data for different treatments (C, F, WC, WCF). The chart indicates significant differences at p=0.013.](chart.png)
Results: Ground-line diameter growth

![Bar chart showing total groundline diameter growth for Sandy, Clayey, and Sloped blocks. Sandy block has the highest growth, followed by Clayey and Sloped blocks, all with significant differences at p=0.002.](image)
Results: Ground-line diameter growth

![Graph showing ground-line diameter growth across different treatments. The x-axis represents the different treatments labeled as C, F, WC, and WCF. The y-axis represents total groundline diameter growth (cm) with values indicating p<0.001 for the comparison.]
Results: DBH

- Sandy
- Clayey
- Sloped
Results: DBH

![Bar graph showing DBH (cm) for different treatments: C, F, WC, WCF. The graph indicates a comparison of DBH across these treatments.]
Results: height growth

The graph shows the total height growth in cm for different treatments: C, F, WC, and WCF. The y-axis represents the total height growth, ranging from 0 to 350 cm. The treatments are compared, with WCF showing the highest growth (a) and C showing the lowest growth (b). The p-value is less than 0.001, indicating a statistically significant difference.
Growth comparison

- Iluka control
- Iluka fertilizer
- Iluka weed control
- Iluka weed control + fertilizer
- Carlson et al. 2009
- Amishev 2005

**Mean height (cm)**

**Years after planting**
Root excavations- more next year!

- How does mine soil morphology affect loblolly pine root growth?
- Excavating roots from a selection of representative trees to better understand how mine soils affect root morphology
  - Stay tuned!!

Weed control, sloped block
Clayey soil
Mean Db = 1.36 just above max root depth
Mean Db = 1.42 where most roots stop (~20 cm)
Summary

- Block effects
  - No differences in survival or height growth
  - GLD highest in sandy block
  - DBH higher in sandy and sloped blocks
Summary

• Treatment effects
  • Survival lowest in F, highest in C and WC
  • GLD and height growth highest in WCF
  • DBH highest in WCF
Discussion

• Few differences among blocks
  • Any differences among blocks masked by treatments (and possibly spatial differences within blocks)
Discussion

- Trees in F treatment had average growth, much lower survival
  - Fertilizer increased weed competition
Discussion

- Lower survival in WC and WCF, WCF had better growth
  - Herbicide drift?
- Trees in C treatment were smaller, but had better survival
Discussion

- Trees on unmined soils grow faster than trees on reclaimed mine soils
- Compared to unmined soils, C, WC, and F treatments all similar in size
- WCF trees approaching growth rates of trees on unmined soils
Recommendations

• Trees grown without any weed control or additional fertilizer still perform well
• If fertilizer is applied, weed control is critical to minimize weed competition
• If only weed control is applied, survival will likely be decreased without any benefits in terms of growth, so fertilizer should be added
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