An Investigation of Tree Growth and Colonization on a 19 Year-Old Forestry Reclamation Site

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Introduction/Goals

• Provide a brief overview of the forestry reclamation approach.
• Discuss history of Starfire project.
• Summarize findings on three planted species.
• Summarize findings on volunteer woody plants.
The Forestry Reclamation Approach
Steps of the Forestry Reclamation Approach

The FRA can be summarized in five steps:
1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone and/or the best available material.
2. Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium.
3. Use ground covers that are compatible with growing trees.
4. Plant two types of trees--early successional species for wildlife and soil stability, and commercially valuable crop trees
5. Use proper tree planting techniques.
Site Preparation: Loose-Dump

- When reforestation is planned on active mines, spoil is often dumped in tightly packed piles using large trucks – the “loose dump” or “end dump” method.
- This method achieves the required depth of loose rooting medium and results in an undulating surface topography.
Site preparation: Strike-off

- This option requires a single pass of equipment to level loosely-dumped spoil.
- This results in a smoother topography that may be preferable in some cases.
The Starfire Project

• In 1996, University of Kentucky and government researchers began a reforestation experiment on the Starfire mine in eastern Kentucky.

• The project aimed to investigate the effects of soil compaction and surface amendment on the growth and survival of trees.
The Starfire Project

- Plots were divided into 21.04 ha cells and planted with:
  - Eastern white pine (*Pinus strobus*)
  - White ash (*Fraxinus americana*)
  - Black walnut (*Juglans nigra*)
  - Yellow-poplar (*Liriodendron tulipifera*)
  - White oak (*Quercus alba*)
  - Northern red oak (*Quercus rubra*)
  - Royal paulownia (*Paulownia tomentosa*)
Table 1. Mean survival and height for eight year old trees as influenced by subsurface reclamation treatment at the Starfire research complex. Means with the same letter are not significantly different.†

<table>
<thead>
<tr>
<th>Method</th>
<th>White Oak</th>
<th>White Ash</th>
<th>White Pine</th>
<th>Red Oak</th>
<th>Black Walnut</th>
<th>Yellow Poplar</th>
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</thead>
<tbody>
<tr>
<td>Compact</td>
<td>21 (a)</td>
<td>80 (a)</td>
<td>3 (a)</td>
<td>18 (a)</td>
<td>18 (a)</td>
<td>10 (a)</td>
</tr>
<tr>
<td>Strike-off</td>
<td>69 (b)</td>
<td>81 (a)</td>
<td>50 (b)</td>
<td>64 (b)</td>
<td>55 (b)</td>
<td>52 (b)</td>
</tr>
<tr>
<td>Loose-dump</td>
<td>81 (c)</td>
<td>82 (a)</td>
<td>82 (c)</td>
<td>82 (c)</td>
<td>68 (b)</td>
<td>80 (c)</td>
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<table>
<thead>
<tr>
<th>Method</th>
<th>Survival (%)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact</td>
<td>63 (a)</td>
<td>104 (a)</td>
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<tr>
<td>Strike-off</td>
<td>197 (b)</td>
<td>236 (b)</td>
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<tr>
<td>Loose-dump</td>
<td>217 (b)</td>
<td>308 (c)</td>
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</table>

†Surface treatments pooled to examine subsurface effects; n = 1089 seedlings per subsurface treatment and species.
Current Work - Inventory

- We sought to compare the success of trees planted in levels of surface and grading treatments by inventorying the experimental plots.
- Diameter at breast height (DBH) was measured for all live trees.
- Heights of a subset of trees were measured and crown classes were identified.
Current Work - Inventory

• A mixed model statistical approach was followed.
  – Fixed effects: Grading, Surface Amendment, Interaction
  – Random effect: Plot
Pinus Strobus Survival

- Control (a)
- Strike-Off (b)
- Loose-Dump (c)
**Pinus Strobus Mean Overstory Height (m)**

![Graph showing mean overstory height for Control (a), Strike-Off (b), and Loose-Dump (b). The graph indicates that Strike-Off (b) has the highest mean overstory height compared to Control (a) and Loose-Dump (b).]
Pinus Strobus DBH (cm)
Q. Alba Survival

![Bar chart showing survival rates for different treatments: Control, Strike-Off, and Loose-Dump. The chart compares survival rates across three treatments, with bars representing Control in blue, Bark in red, and Straw in green.](chart.png)
Q. Alba Mean Overstory Height (m)
Q. Alba Mean DBH (cm)
L. Tulipifera Survival

![Graph showing survival rates for L. Tulipifera under different conditions. The y-axis represents survival rates ranging from 0 to 1. The x-axis has three categories: Control, Strike-Off, and Loose-Dump. The graph compares the survival rates under three different treatments: Control (blue), Bark (red), and Straw (green). The bars indicate the survival rates with error bars showing the variability.]
L. Tulipifera Mean Overstory Height (m)

- Control
- Strike-Off/Bark
- Loose-Dump/Straw
L. Tulipifera Mean DBH (cm)
Biomass Estimation

• We also sought to gauge growth through the estimation of biomass per acre.
• Trees were felled, divided into components, and weighed.
Biomass Estimation

- Subsamples were weighed, dried, and reweighed.
- Dry weights of sampled trees were used to develop regression equations relating DBH to mass.
Biomass Estimation

- A mixed model similar to that used for inventory data was used to test mean values.
P. Strobus Biomass Regression

Linear Regression of Natural Log-Transformed Biomass and DBH

Species: White Pine

Regression Equation:
\[ \text{indry woody total kg} = -1.484842 + 2.047383 \times \text{Indbh} \]

\( n = 18, p < .0001, R^2 = .843 \)
Pinus Strobus Aboveground Biomass Estimate (Mg/ha)
Q. Alba Biomass Regression

Linear Regression of Natural Log-Transformed Biomass and DBH

species=White Oak

Regression Equation:
Indry_woody_total__kg__ = -1.936836 + 2.285499*Indbh

(n= 36, p<.0001, R²= .936)
Q. Alba Aboveground Biomass Estimate

Control Strike-Off Loose-Dump

Control Bark Straw

-20 0 20 40 60 80 100
L. *Tulipifera* Biomass Regression

**Linear Regression of Natural Log-Transformed Biomass and DBH**

*species*= Yellow-Poplar

Regression Equation:

\[ \text{Indry}_\text{woody}_\text{total}_{\text{kg}} = -2.198567 + 2.317234 \times \text{Indbh} \]

\( n = 36, \ p < .0001, R^2 = .948 \)
L. Tulipifera Aboveground Biomass Estimate (Mg/ha)
Woody Species Colonization

• We sought to quantify and characterize colonizing plants.

• All woody plants >1 meter in height and with DBH ≥1.0 were included in our survey.

• GLD, DBH, species and condition were all recorded.
Woody Species Colonization

• Differences in stem density and native species proportions were tested using a mixed model.
  - Fixed effects: Grading, Surface Amendment, Interaction
  - Random effect: Plot
# Species Composition

<table>
<thead>
<tr>
<th>Species</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
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<td>49.94</td>
<td>2543</td>
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<td>Sourwood</td>
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# Species Composition

<table>
<thead>
<tr>
<th>Species</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
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<td>5092</td>
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</tr>
</tbody>
</table>
Stem Density (stems/ha)

Control
Strike-Off
Loose-Dump
Proportion of Native Volunteers

Control
Strike-Off
Loose-Dump

- Control
- Bark
- Straw
Conclusions

• Both strike-off and loose-dump techniques have allowed for survival and growth of planted trees over a 19-year period.
• Straw/manure mulch and loose-dump preparation result in highest mean biomass for Q. Alba and L. tulipifera.
• Straw/manure mulch may introduce/ foster growth of competitive herbaceous species.
• Loose-dump plots show significantly more volunteer stems, most of which are desirable native species.
Acknowledgements

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- Field technicians
- Drs. John Lhotka, Chris Barton, and Jeff Stringer
- OSMRE and Dr. Patrick Angel
- Kat Sasser