Conducting Sustainable Forest Operations While Minimizing Environmental Impacts

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About Me

Associate Professor, Virginia Tech
- Forest Operations/Engineering
- Harvesting, Procurement, Harvesting Systems Evaluation, Forest Field Studies

Virginia Tech
- 110 bachelor’s degree programs
- 170 master’s and doctoral degree programs
- 34,440 students
- 1,967 faculty members
- Research portfolio of $531 Million
RESEARCH FOCUS AREAS

1. Evaluating operations with regard to safety, productivity, planning, and logistics
2. Improving the efficiency and profitability of forest operations
3. Analyzing forest business issues such as supply chain management and biomass utilization
4. Evaluating the environmental impacts of forest operations
Environmental Impacts in the United States

Federal Water Pollution Control Act of 1972 “Clean Water Act” provided the motivation for development of State BMP programs for control of Non-Point Source Pollution.
States developed Forestry Best Management Practices (BMPs)

Primary goal: to maintain and protect water quality from nonpoint source pollutants such as sediment, temperature, chemicals, excessive organics, biological pollutants.

Sedimentation is the primary concern for most forest operations.
Forest Operations Typically Monitored by State BMP Programs

- Preharvest Planning
- Roads
- Decks
- Skid Trails
- Stream Crossings
- SMZs
- Firelines
- Harvesting
- Site Preparation
- Fertilization
Recent Forest Roads & Environmental Issues

- Point source vs. Non Point source pollution
- US Supreme Court case regarding Forest Roads and Stream Crossings
  - Questioned the validity of forestry activities being characterized as non-point sources of pollution
  - Led to renewed interest in BMP effectiveness research
Goal of Presentation

- Provide an overview of BMP effectiveness studies conducted at Virginia Tech

1. Can harvesting be conducted without environmental impact?
2. Can impacts be minimized, allowing sustainable harvests?
Forest Operations Graduate Student Projects Related to Roads, BMPs, and Sediment

- 25 graduate students have completed projects since 2008
  - Preharvest Planning
  - Harbsters
  - Roads/Decks/Skid Trails
  - Site Preparation
  - Firelines
  - SMZs
  - Stream Crossings
  - Skid Trail Closure
Lakel et al. 2006, 2010, 2015 evaluated 16 SMZs with 4 levels of BMPs

- Evaluated 25, 50, 50 with thinning and 100 ft SMZs in 16 watersheds.
- Sediment Delivery Ratio for all SMZ widths was 3-14%. Trapped 86-97%.
- SMZs failures associated with roads, skid trails, stream crossings.
Aust et al. 2011

- 24 stream crossings (bridge, culvert, pole, ford) during 4 periods (before, install, harvest, close)
- Stream crossing approaches are of more concern than type of crossing
- For sediment, Bridges < Ford/Pole < Culverts
- Highest erosion during harvest - BMPs should be used on crossing approaches during harvest
  - Harvest vs. closure
Cable yarding vs bladed skid trails (3 side-by-side sites)

Slight overall erosion differences between conventional and cable harvests

Cable yarding COULD be much better IF spur roads were planned better

![Graph showing potential erosion (t/a/y) with labels a, b, and c. The P-value is 0.0971.](image)
Wade et al. (2012)  
5 Skid Trail Closure Treatments

Control  
Seed  

Hardwood Slash  
Pine Slash  
Mulch
Overall Erosion

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Actual T/A/Y</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>61.2</td>
<td>-</td>
</tr>
<tr>
<td>Seed</td>
<td>14.0</td>
<td>77</td>
</tr>
<tr>
<td>Hdwd Slash</td>
<td>3.9</td>
<td>94</td>
</tr>
<tr>
<td>Pine Slash</td>
<td>2.6</td>
<td>96</td>
</tr>
<tr>
<td>Mulch</td>
<td>1.3</td>
<td>98</td>
</tr>
</tbody>
</table>
Sawyers et al. 2012
Overland Skidding
Total Annual Erosion (t/a/y) by Treatment (p=0.0001)

This was 61 t/a/y for Bladed Trails
Skidder Stream Crossing Closure
BMPs (Wear et al. 2013 - *FEM*)

- Operationally installed by BMP contractors
- **Slash**: waterbars and piled slash
- **Mulch**: waterbars, fescue, lime, fertilizer, straw mulch
- **Mulch + Silt Fence**: same as above plus silt fence at stream
Field Methods

Stream

Skid trail
Field Methods

ISCO automated water samplers
Treatments: Slash
Treatments: Mulch

- seed, fertilizer, and straw mulch
Treatments: Slash + Mulch
- slash, seed, fertilizer, straw, and silt fence
Field Methods

Collected samples every 3 weeks
<table>
<thead>
<tr>
<th>Rainfall category</th>
<th>BMP treatment</th>
<th>Average ΔTSS</th>
<th>BMP Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Pre-closure</td>
<td>76.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slash</td>
<td>2.1</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>Mulch</td>
<td>0.3</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>Mulch + Silt Fence</td>
<td>456.7</td>
<td>-497</td>
</tr>
<tr>
<td>High</td>
<td>Pre-closure</td>
<td>97.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slash</td>
<td>31.5</td>
<td>68%</td>
</tr>
<tr>
<td></td>
<td>Mulch</td>
<td>127.0</td>
<td>-30%</td>
</tr>
<tr>
<td></td>
<td>Mulch + Silt Fence</td>
<td>475.7</td>
<td>-386%</td>
</tr>
<tr>
<td>Maximum</td>
<td>Pre-closure</td>
<td>100.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slash</td>
<td>37.5</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>Mulch</td>
<td>84.7</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Mulch + Silt Fence</td>
<td>89.9</td>
<td>11%</td>
</tr>
</tbody>
</table>
Road Class, Stream Crossings, and Sediment (Lang et al. 2018)

- Evaluated 40 haul road stream crossings
- Sediment was found to be a function of road standards, traffic, BMPs
Categorized >20 road standards into 4 road classes.

Sediment related to road class & associated BMPs.
Legacy Roads and Sediment (Brown et al. 2013a)

- Evaluated sediment contributions from 15 legacy roads
- Major factors controlling sediment were road area, road length (spacing between water controls), and amount of cover/canopy
Road Stream Crossings and BMPs (Brown et al. 2013b)

- Used rainfall simulations to evaluate sediment contributions from 3 stream crossings (6 approaches), 3 rainfall intensities, and 3 levels of BMPs (no gravel, ½ approach graveled, full approach graveled).
Road Stream Crossings and BMPs (Brown et al. 2013b)

- Concluded that the lowest level of BMPs was contributing 7x more sediment than medium level of BMPs
- Medium level of BMPs provided 2x of the effect of full gravel
Haul Road Stream Crossings
(Morris et al. 2016)

- Compared TSS above and below a bridge, culvert, and geoweb ford
- 3 levels of BMPs
- 3 levels of rainfall simulation
Additional BMPs reduced sediment delivery for the culvert and ford crossings
Lang et al. (2017) evaluated 5 road ditch BMPs and sediment for 60 ditch segments.

- All BMPs reduced erosion, but gravel or erosion mat were most effective.
- Erosion mat was also the most cost effective.
The graph shows the relationship between mean erosion rate (Mg ha\(^{-1}\) y\(^{-1}\)) and bare soil percentage. The data points are color-coded according to the legend:

- **Bare** (diamonds)
- **Seed** (black diamonds)
- **Mat** (gray triangles)
- **Dam** (black triangles)
- **Rock** (gray circles)

The equation of the trend line is given as 

\[
R^2 = 0.5816 \\
p < 0.0001
\]

A dotted red line indicates the threshold of >30% bare soil, beyond which the mean erosion rate increases significantly.
Stream Crossing Upgrade (Dangle et al. 2019)

- Efficacy of Upgraded Best Management Practices at Operational Forest Stream Crossing Approaches (N=154)
  - BMP- → Below standard
  - BMP_{std} → Standard
  - BMP+ → Above standard

- What are the benefits/costs of upgrading stream crossings?
### Potential Erosion Reduction and Cost to Upgrade Crossings

<table>
<thead>
<tr>
<th>Type</th>
<th>Before upgrade (Mg/yr)</th>
<th>After upgrade (Mg/yr)</th>
<th>Upgrade cost ($)</th>
<th>Benefit cost ratio ($/Mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skid Trail</td>
<td>BMP-</td>
<td>1.93</td>
<td>0.33</td>
<td>36.06</td>
</tr>
<tr>
<td></td>
<td><strong>BMP&lt;sub&gt;std&lt;/sub&gt;</strong></td>
<td><strong>0.25</strong></td>
<td><strong>0.03</strong></td>
<td><strong>62.23</strong></td>
</tr>
<tr>
<td>Truck Road</td>
<td>BMP-</td>
<td>0.52</td>
<td>0.28</td>
<td>151.65</td>
</tr>
<tr>
<td></td>
<td><strong>BMP&lt;sub&gt;std&lt;/sub&gt;</strong></td>
<td><strong>0.25</strong></td>
<td><strong>0.05</strong></td>
<td><strong>114.05</strong></td>
</tr>
</tbody>
</table>

- Truck road crossings are more expensive to upgrade and less is gained.
- Resources are better utilized upgrading skid trail crossings.
- Minimal cost necessary to upgrade from BMP- to BMP<sub>std</sub>.
Surveyed the State Foresters/Water Quality Foresters for 50 states and 8 US territories to evaluate the BMP policy, monitoring, and compliance
Cristan et al. (2018) reported BMP compliance for the US.
-No Statistical Difference Between Regulations-

*State average may consist of up to 16 BMP categories depending on state

<table>
<thead>
<tr>
<th>Regulation</th>
<th>*State average</th>
<th>Timber harvest</th>
<th>Forest roads</th>
<th>Skid trails</th>
<th>Log landings</th>
<th>Stream crossings</th>
<th>SMZ</th>
<th>Wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-regulatory</td>
<td>90.2 (13)</td>
<td>92.4 (7)</td>
<td>90.5 (11)</td>
<td>88.2 (9)</td>
<td>94.4 (10)</td>
<td>88.5 (11)</td>
<td>87.1 (11)</td>
<td>86.2 (9)</td>
</tr>
<tr>
<td>Quasi-regulatory</td>
<td>90.1 (11)</td>
<td>94.6 (7)</td>
<td>89.4 (11)</td>
<td>88.0 (9)</td>
<td>91.6 (7)</td>
<td>84.6 (10)</td>
<td>91.8 (11)</td>
<td>92.8 (8)</td>
</tr>
<tr>
<td>Regulatory</td>
<td>93.4 (8)</td>
<td>91.5 (6)</td>
<td>94.0 (8)</td>
<td>92.7 (6)</td>
<td>95.4 (8)</td>
<td>86.9 (8)</td>
<td>93.9 (7)</td>
<td>95.3 (6)</td>
</tr>
</tbody>
</table>
Conclusions

- No statistical difference between BMP implementation rate and state BMP regulation
- National and state BMP implementation rate is high
- However, some states did show potential deficiencies with some individual BMP categories

<table>
<thead>
<tr>
<th>Harvest (%)</th>
<th>Road (%)</th>
<th>Skid Trails (%)</th>
<th>Log Landing (%)</th>
<th>Stream Crossing (%)</th>
<th>SMZ (%)</th>
<th>Wetlands (%)</th>
<th>Reforestation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>81</td>
<td>70</td>
<td>73</td>
<td>70</td>
<td>67</td>
<td>70</td>
<td>51</td>
</tr>
<tr>
<td>MAX</td>
<td>99</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Average</td>
<td>92.9</td>
<td>91.0</td>
<td>89.3</td>
<td>93.9</td>
<td>86.7</td>
<td>90.5</td>
<td>90.9</td>
</tr>
<tr>
<td>n</td>
<td>20</td>
<td>30</td>
<td>24</td>
<td>25</td>
<td>29</td>
<td>23</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mech Site Prep (%)</th>
<th>Chem Site Prep (%)</th>
<th>Pesticide (%)</th>
<th>Fertilizer (%)</th>
<th>Prescribed Burn (%)</th>
<th>Wildfire Supp (%)</th>
<th>Wildfire Rehab (%)</th>
<th>Public Lands (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>74</td>
<td>75</td>
<td>75</td>
<td>98</td>
<td>60</td>
<td>100</td>
<td>87</td>
</tr>
<tr>
<td>MAX</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Average</td>
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<td>96.5</td>
<td>96.8</td>
<td>99.5</td>
<td>88.5</td>
<td>100.0</td>
<td>97.2</td>
</tr>
<tr>
<td>n</td>
<td>13</td>
<td>11</td>
<td>9</td>
<td>4</td>
<td>13</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Summary of Research

Forest operations can be conducted sustainably!

Keys for success

1. Plan operations with forethought
2. Minimize interaction with streams and steep slopes
3. Maintain proper streamside management zones
4. Cover bare soil with slash or seed and mulch
5. Ensure proper drainage and install water control structures

BMPs work!

- Practices must be implemented and enforced
- Operators need an incentive to implementation
The Industrial Forest Operations program was initiated in 1973 as a cooperative effort among the pulp and paper industry, forest equipment manufacturers, and Virginia Tech to provide undergraduate and graduate education programs that prepare foresters for careers in wood procurement, working with independent contractors, and overseeing the operational aspects of forest industries. To create opportunities for graduate students, research became a larger focus in 1984. Faculty members and students cooperate with forest industry and forest equipment manufacturing personnel in the selection of research projects.

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WHO WE ARE

Based in The Department of Forest Resources and Environmental Conservation at Virginia Tech, the Forest Operations Research Group taps a broad range of university and industry resources to provide students with educational and research opportunities and to address forest industry needs.