Forestry Best Management Practices for Protection of Water Quality: Applied Research Results

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Background for Webinars Series

- Jim Vose: Watershed Hydrology
- Graeme Lockaby: Forest Landscapes and Water Quality
- Today's topic: Forestry Best Management Practices (BMPs)
  - Legislation
  - General BMP considerations
  - Recent BMP Research Results and Potential Applications
  - Summary

What are Forestry BMPs?

- Primary goal: Methods, measures, practices implemented to maintain and protect water quality from nonpoint source pollutants such as sediment, temperature, chemicals, excessive organics, biological pollutants.
- Secondary goal: site productivity, wildlife habitat, wetlands, archeology/historic sites, etc.

Forestry BMPs & The CWA

- Federal Water Pollution Control Act of 1972 and subsequent amendments ("Clean Water Act") provided the motivation for development of State BMP programs for control of Non-Point Source Pollution.

Forestry BMPs & Silvicultural Exemptions

- Silvicultural operations operate under a general permit typically known as "Silvicultural Exemptions". Silvicultural exemptions assume:
  - Normal silvicultural operations
  - Ongoing operations
  - Follow Federal BMPs (State BMPs implied)
  - Do not introduce toxins
  - Do not alter hydrology
  - Permits may be required under some situations such as permanent stream crossings for large watersheds.

Federal BMPs

- Federal BMPs for private lands exist:
  - 15 are primarily related to roads in wetland areas.
  - 6 are for site preparation for establishment of pine plantations in certain wetlands.

Voluntary State BMP Programs

- Primarily in Southeast, Central US.
- Differing levels of state harvest inspections to monitor BMP compliance.
- May be linked to industry standard programs such as the Sustainable Forestry Initiative program.
- May have additional legislation to fine water quality problems.

Regulatory State Programs

- Primarily in NE and PNW.
- Many are linked to State Forest Practices Acts.
- May involve multiple agencies and disciplines.

"Oregon Department of Forestry
Forest Practice Administrative Rules and Forest Practices Act
CHAPTER 629
Forest Practices Administration
January 2010 *"STEWARDSHIP IN FORESTRY"*
This publication includes the text of the Forest Practices Act and the Forest Practice Administrative Rules as they exist on January 1, 2010.
Divisions 670 through 680 of the forest practice rules are not included in this publication, but are available as separate publications upon request. The rules in these divisions address civil penalties, appeals from orders of the State Forester, hearings procedure, stay of operations, access to notifications and written plans, regional forest practice committees, and the resource site inventory and protection process." (ODF 2011)

Multi-State BMP Programs

- Under the Chesapeake Bay Program some states actually mandate stricter BMP in the Chesapeake Bay region.
- Southern Group of State Foresters meets annually to discuss BMP compliance and problems.
- National Association of State Foresters periodically surveys state foresters to assess nationwide compliance levels.

"On all harvest operations that take place in Tidewater Virginia, all necessary forestry BMPs must be implemented properly according to the Chesapeake Bay Preservation Act. The SMZ is one such BMP and must be left according to the specifications in this section." (VDOF 2011)

Recent Court Cases Involving Forestry BMPs

- 9th Circuit Court of Appeals (*NEDC v. Brown)*
- US Supreme Court
  - Challenged whether ditched forest roads and stream crossings should be considered as Point Sources of Pollution and require a Nationwide Point Discharge Elimination System permit.
  - Supreme Court is allowing EPA to use existing policy.
  - Case will probably focus additional attention on BMPs used at stream crossings.

Forest Operations Typically Encompassed by State BMP Programs

- Preharvest Planning
- Harvesting
- Roads
- Decks
- Skid Trails
- Stream Crossings
- Site Preparation
- Fertilization
- Fire-lines
- Streamside Management Zones

BMPs & Forest Operations/In-woods Transport

- Permanent Roads
- Temporary Roads
- Decks/Landings
- Skid Trails
- Stream Crossings
- Harvest Area
- Streamside Management Zones (Riparian Buffers)

BMPs, Erosion, & Water Control

- Location of operations
- Minimize bare soil areas
- Maintain infiltration rates
- Restore evapotranspiration
- Minimize slope %
- Minimize slope distances
- Minimize contact with streams
- Reduce water velocity-trap sediment

Preharvest Planning

- What does preharvest planning typically consider?
  - Roads
  - Decks
  - Skid trails
  - Stream crossings
  - SMZs

Preharvest Planning Research

- Shaffer and Mead (1997) compared two groups of loggers: BMP-Trained vs Non-Trained.
- Collected data from VDOF BMP inspections, Landowners satisfaction, and Logger work data for 8 months.
- Trained group reported increased use of topographic maps and planning stream crossings.

Preharvest Planning Research

- At end of study, both groups performed well, but Trained group had marginally better performance

	Trained	Non-Trained
BMP Inspections	**90%**	**86%**
Landowner satisfaction	**3.5**	**3.3**
Weather related time loss	**10%**	**13%**

Harvesting BMPs

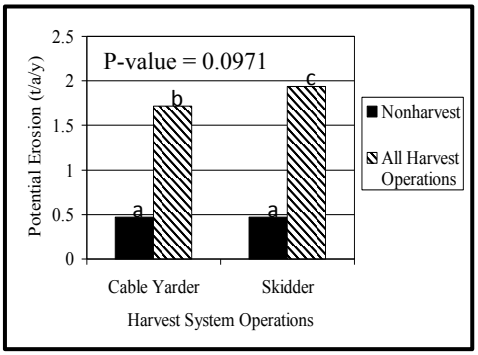
- Aust and Blinn (2004) reviewed 50+ research papers regarding harvesting and water quality and concluded:
- Harvesting (without consideration of roads and skid trails) has minimal and short term (2-8 years) effects on water quality with the following caveats:
  - Appropriate BMPs were applied
  - Area was revegetated
  - Roads and skid trails were retired

Harvesting Research

- Christopher and Visser (2007) used the Universal Soil Loss Equation to monitor 54 closed harvest sites across three physiographic regions and concluded:
  - Harvest areas have low erosion rates after closure.
  - Roads and skid trails continued to deliver sediment even after harvest closure.
  - Unauthorized 4-wheeler traffic is a problem for closure.

Alternative Harvest Systems (Cable Yarding) Worrell et al. 2011

- Cable Yarding vs Bladed Skid trails (3 side by side sites).
- Cable produced slightly lower erosion (1.7 t/a/y) than skidder (1.9 t/a/y)
- Cable Yarding COULD be much better IF spur **roads were planned better**.



Alternative Harvest Systems: Helicopter vs Skidder Harvesting in Bottomland Hardwoods (McKee et al. 2011)

Forest Productivity was same or better with SKID than HELI after 23 years

Total Overstory Stems per ha by Treatment and Species						
	Cypress	Tupelo	Ash	Willow	Other Spp.	Total
HELI	115	889	988	66	49	2108
SKID	329	1482	478	132	66	2486
GLYPH	82	263	173	296	206	1021
Average	176	878	546	165	107	1872

Total Overstory Volume in Megagrams per hectare by Treatment and Species						
	Cypress	Tupelo	Ash	Willow	Other Spp.	Total
HELI	12.9	125.9	22.6	10.5	1.9	173.7
SKID	38.8	175.6	10.1	17.1	1.2	242.7
GLYPH	25.5	24.9	3.6	27.3	5.6	86.8
Average	25.7	108.8	12.1	18.3	2.9	167.8

Mechanism of Site Recovery

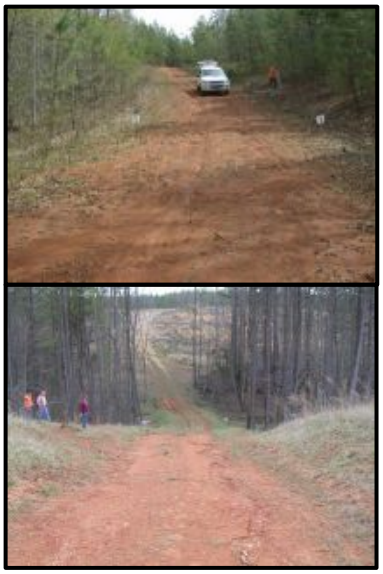
- Skidder created microtopography
- Shrink swell
- Sediment
- Active soil fauna
- Carbon inputs
- Species flood tolerance
- Species coppice potential

Biomass Harvesting and Sediment (Barrett et al. 2013)

- Compared 20 conventional and biomass harvested sites selected from VDOF audits.
- Estimated erosion potential within operational areas and found no significant differences.
- Found that Biomass harvests were too aggressive in harvesting within-in SMZs and left smaller SMZs.
- Concluded that sufficient slash remained for use as BMPs.
- Concluded that existing BMPs were adequate for biomass harvests, BUT biomass harvests need to pay closer attention to SMZs.

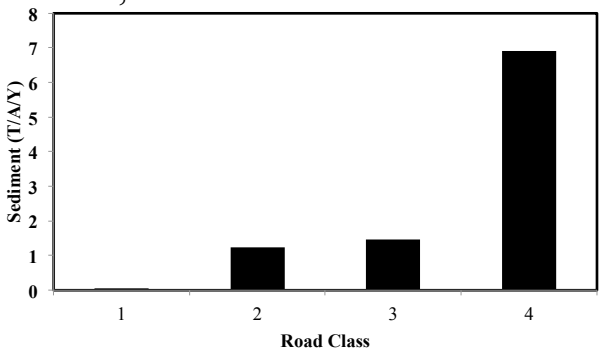
Roads & BMPs

- Forest roads are necessary for access and roads typically enhance land and timber values.
- However, since the 1950's, numerous studies have identified forest roads are major sources of sediment.
- Problems:
  - Bare soil
  - Steep grade
  - Long grade
  - Water control
  - Costs of BMPs



Road Class, Stream Crossings and Sediment (Lang et al. 2013)

- Evaluated 40 haul roads stream crossings in Mountains and Piedmont.
- Sediment was found to be a function of road standards, traffic, BMPs.

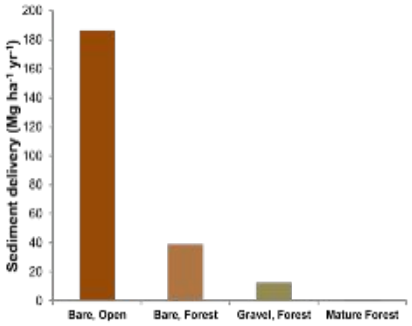


Designed Roads vs Legacy Roads (Feldt 2006)

- Evaluated forest roads in the Allegheny Plateau and Piedmont.
- Piedmont has more gentle terrain than Plateau, BUT sediment was greater from piedmont roads.
- Why?
  - Poorly designed legacy roads in piedmont vs forest engineer designed road in Allegheny Plateau
  - Gravel used more commonly in Allegheny Plateau.

Legacy Roads and Sediment (Brown et al. 2013a)

- Evaluated sediment contributions from 15 legacy roads in Piedmont.
- Some legacy roads were contributing > 180 Mg/ ha/y
- Major factors controlling sediment were road area, road length (spacing between water controls), and gravel.

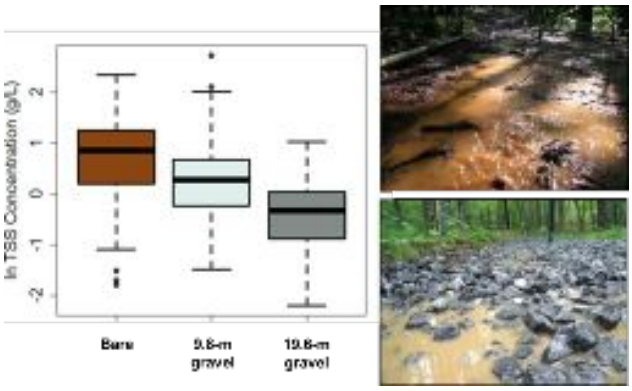


Road Stream Crossings and BMPs (Brown et al. 2013b)

- 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 BMP compliance was contributing 7x more sediment than medium level of BMPs
- Concluded that the medium level of BMPs provided 2x of the effect of full gravel.



Roads and Water Yield (Dymond et al.)

- Modeled road standards and road density effects and compared to 5 years worth of water yield from monitored watersheds (Coweeta) with DHVSM.
- Higher road densities (>2% of area) increased water yield significantly, lower increases did not.
- Take home message: Minimize areas in roads and skid trails.

Decks (Passauer et al. 2013)

- Examined the long-term (16 Year) effects of severe wet weather churning on loblolly pine including decks. Found that bedding negated the effects even for the decks.
- Similar study in Arkansas on 1:1 clays is indicating longer term problems on decks.

Bladed Skid Trail Closure Treatments (Wade et al. 2012)

Control (waterbars only)

Seed

Mulch

Hardwood Slash

Pine Slash

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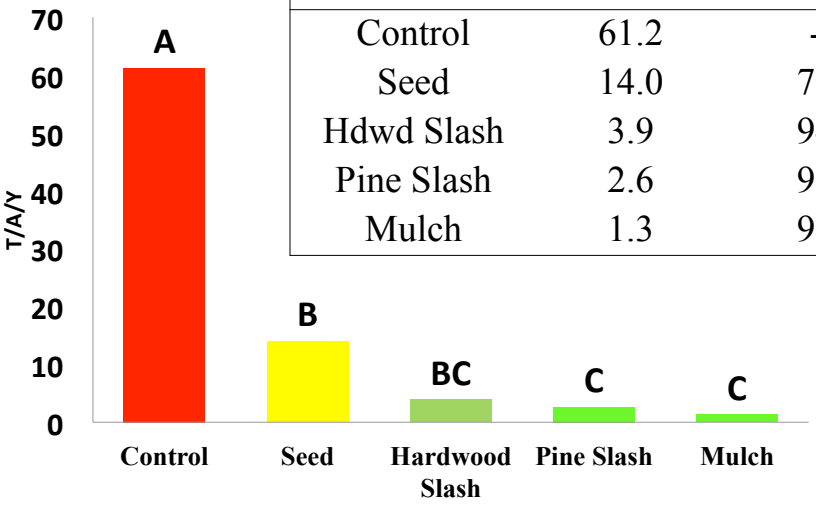
Overall Erosion on Bladed Skid Trails

Treatment	Actual T/A/Y	% Reduction
Control	61.2	-
Seed	14.0	77
Hdwd Slash	3.9	94
Pine Slash	2.6	96
Mulch	1.3	98



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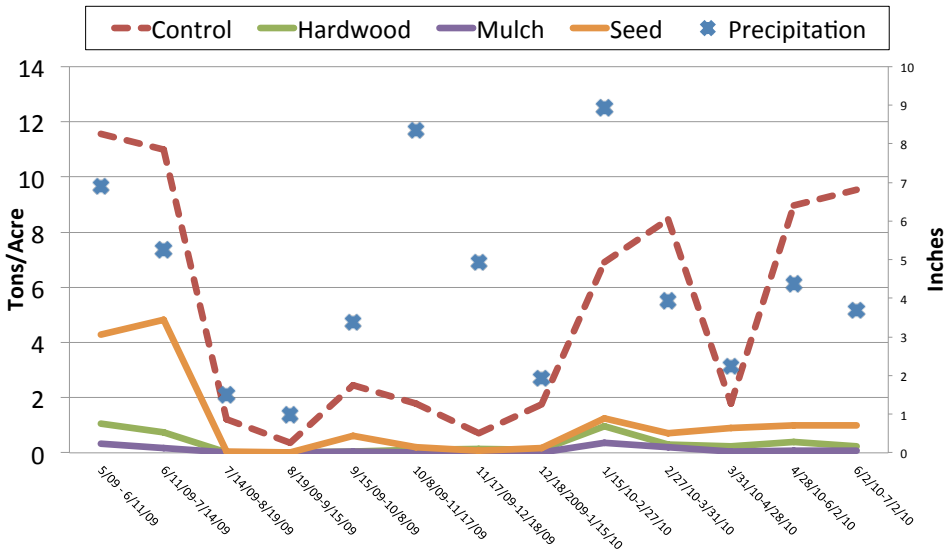
Treatment Erosion per Measurement Period



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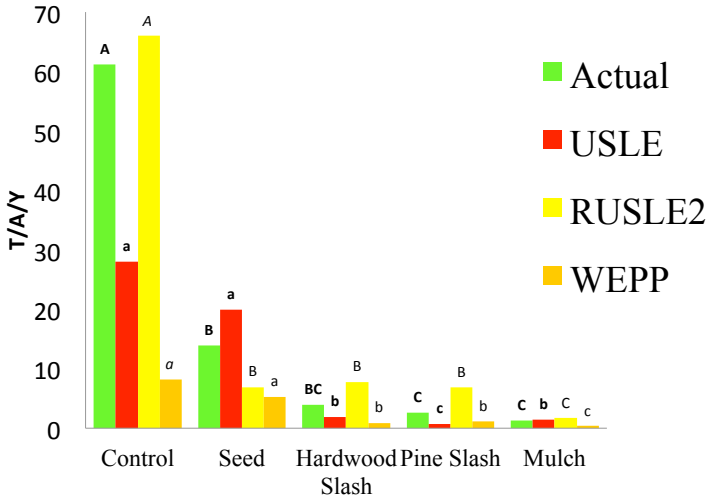
Measured vs. Modeled Erosion followed similar trends.



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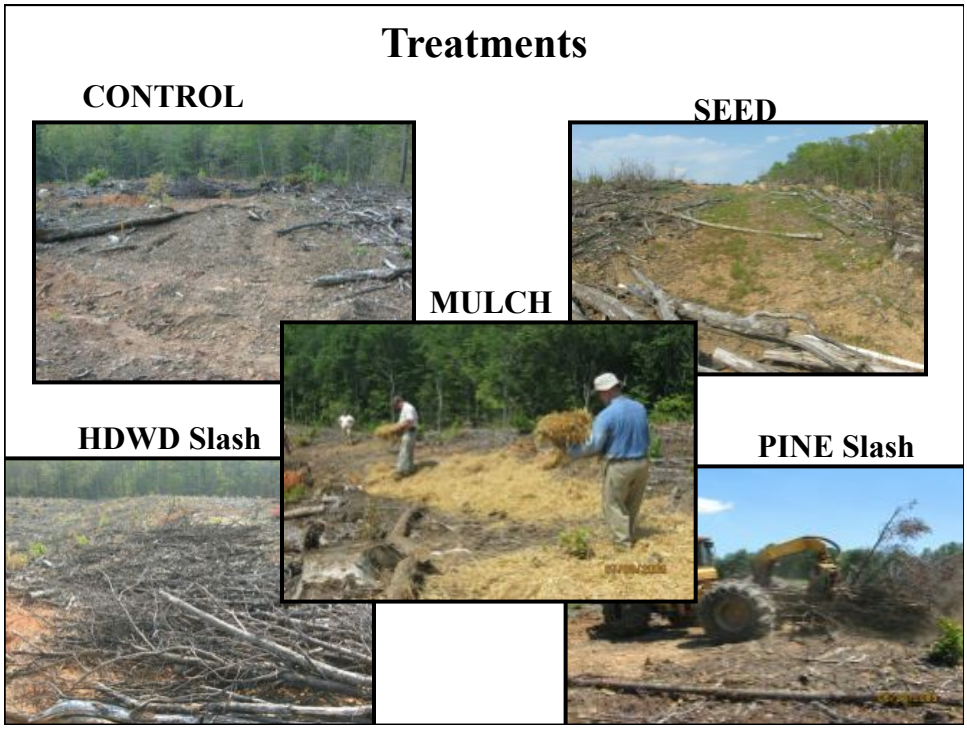
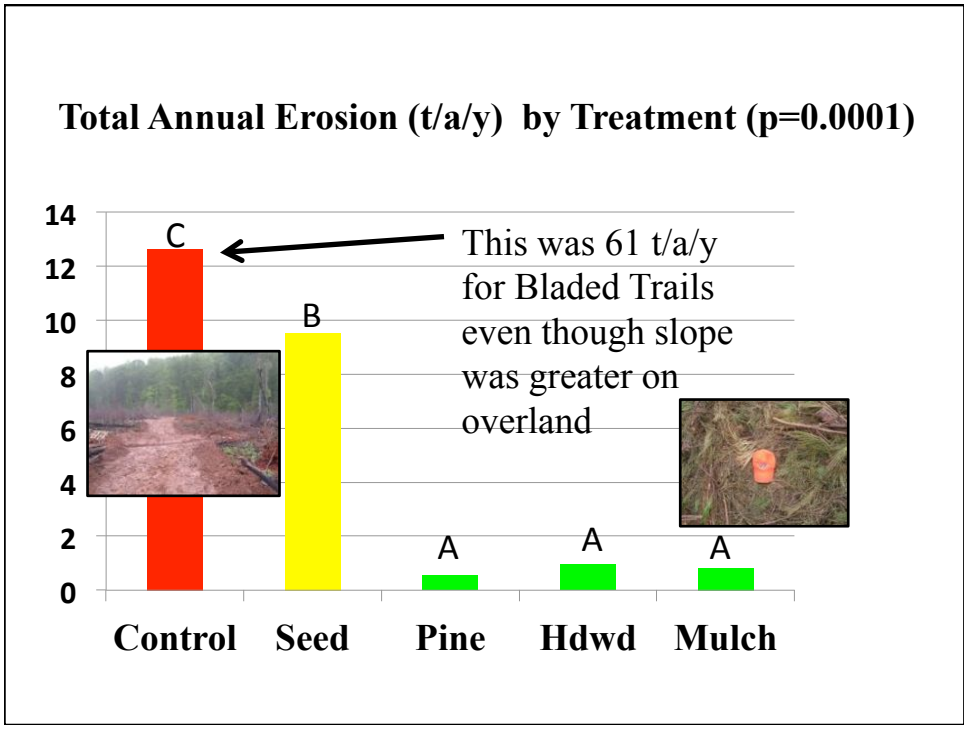
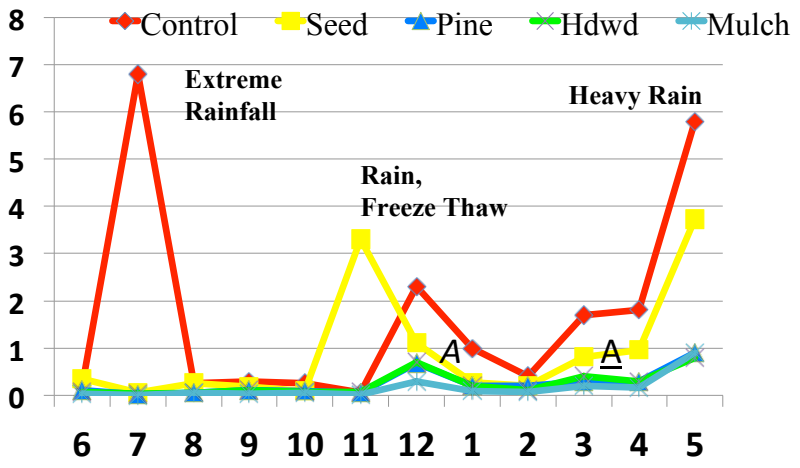
Overland Skid Trails Trail Closure (Sawyers et al. 2012)

- **Quantify the efficacy of 5 techniques for closing overland skid trails**
- **Provide cost estimates skid trail closure techniques**
- ***Compare measured erosion rates with common erosion models***


Treatments
CONTROL
SEED
MULCH
HDWD Slash
PINE Slash


Total Annual Erosion (t/a/y) by Treatment (p=0.0001)
14
12
10
8
6
4
2
0
C
B
A
A
A
This was 61 t/a/y for Bladed Trails even though slope was greater on overland
Control
Seed
Pine
Hdwd
Mulch

Erosion (t/a) by Treatment and Season (p=0.0001)



Conclusions For Skid Trail Closure

- Overland skidding produced approximately 20% of the sediment as compared to bladed trails even though overland trails were steeper. Overland skidding retains better cover.
- For erosion control, Mulch was an excellent treatment. Slash was also effective, but was expensive in Vendor Format.
- Integrated slash treatment MAY be the best in terms of effectiveness and cost. Oddly, although this treatment is common, published estimates of costs are lacking.
- Slash provides instantaneous cover and may minimize ORV traffic.

Stream Crossings Usage (McKee et al. 2011)

- Survey of 70 loggers
- Coastal Plain loggers use portable bridges.
- Piedmont loggers use bridges and culverts.
- Mountain loggers use culverts.
- All categories spend significant time and money on crossing closures

Road Stream Crossings Types (Aust et al. 2010)

- 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.**
- Stream crossing are more problematic for permanent vs temporary roads.
- **For sediment, Bridges < Ford/Pole < Culverts.**
- Highest erosion during harvest. BMPs should be used on crossing approaches during harvest.

Haul Road Stream Crossings (Morris et al. 2013)

- Compared TSS above and below a bridge, culvert, and geoweb ford
- 3 levels of BMPs
- 3 levels of rainfall simulation
- Conclusions:
  - Construction phase produced the most sediment for all crossings.
  - Culvert produced more sediment during rainfall events.

Skidder Stream Crossings Closure BMPs (Wear et al. 2013)

- 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.

Stream/Field Measurements

- Daily TSS samples
- Collected above and below stream crossings
- Collected for one year with 18 ISCO and Sigma samplers
- USLE-Forest on approaches (RKLSCP)

Results: Kruskal-Wallis and Wilcoxon

Daily Rainfall Category	ChiSquare	P-value	Treatment	N	Score Mean
Low 0.00 – 0.10 cm	14.9433	0.0006*	Slash	245	193.27 a
			Mulch	96	231.95 b
			Mulch + Silt fence	83	246.77 b
Medium 0.11 – 0.40 cm	9.0407	0.0109*	Slash	27	24.14 a
			Mulch	16	26.25 a
			Mulch + Silt fence	13	40.30 b
High 0.41 – 1.00 cm	11.7111	0.0029*	Slash	37	38.00 a
			Mulch	31	43.90 a
			Mulch + Silt fence	23	61.69 b
Maximum > 1 cm	4.2202	0.1212	Slash	43	42.25 a
			Mulch	24	40.95 a
			Mulch + Silt fence	22	54.77 b

Treatment Costs (Vendor)

(comparable to other Piedmont studies (Sawyers et al. 2012 and McKee et al. 2011)

Treatment	Materials	(cost)	Labor	(cost)	Total Cost per Stream Crossing
Slash	Logging slash	n/a	Skidder machine time (2 hrs)	$120	**$120**
Mulch	Straw mulch (20 bales)	$100	Dozer machine time	$90	
	Lime	$5	Manual labor (2 hrs)	$80	
	Fertilizer and seed	$5			**$280**
Mulch + Silt fence	Straw mulch (20 bales)	$100	Dozer machine time	$90	
	Lime	$5	Manual labor (3 hrs)	$120	
	Fertilizer and seed	$5			
	Silt fence	$25			**$345**

Conclusions

- Slash and Mulch treatments were more effective for sediment reduction.
  - ✓ Choice affected by slash availability and contractor.
  - ✓ Slash is a longer-term solution (grass survival, traffic)
- Costs varied 3x with BMP treatments.
  - ✓ Slash 1x, Mulch 2x, Mulch + Silt Fence 3x
- Mulch + Silt Fence treatment near stream banks allowed more sediment into streams at higher cost.
  - ✓ BMP complexity/cost ≠ BMP effectiveness.

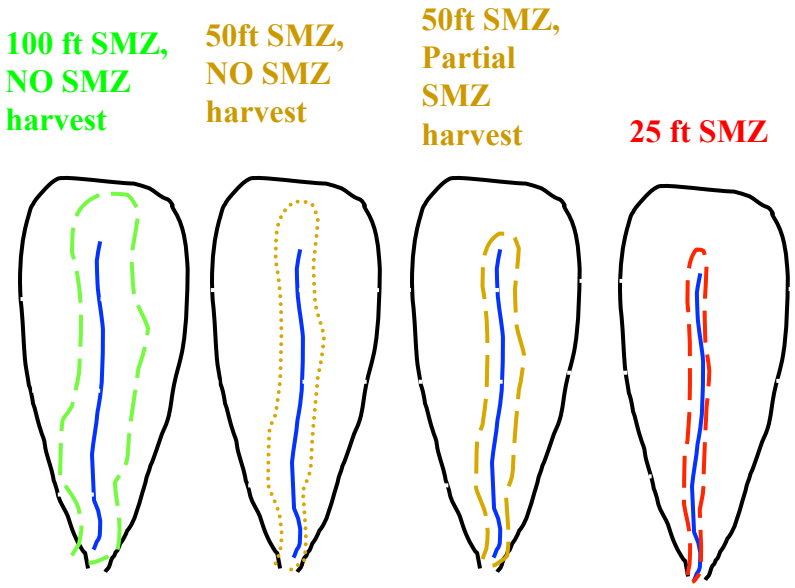
Firelines and Sediment (Christie et al. 2013)

- Fireline BMPs receive less attention than skid trails.
- Fireline erosion can be minimized with better closure and location.
- Using USLE and WEPP to compare burn, fireline, non-burned for steep, moderate, and flat lines before and after rehab.
- Steep firelines are producing > 200 t/a/y of sediment.

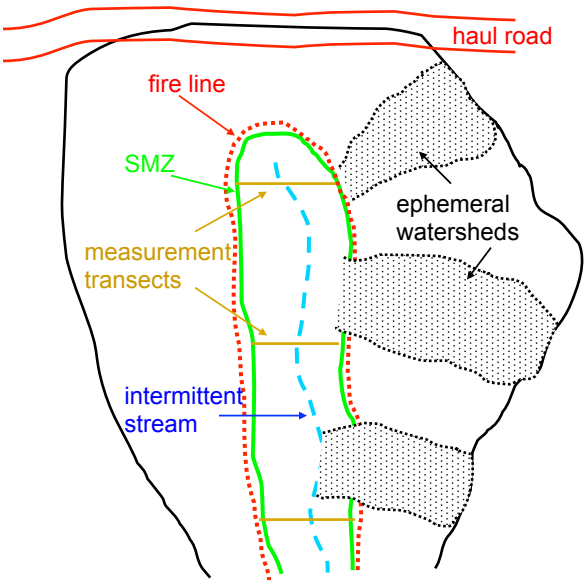
SMZs and Sediment (Lakel et al. 2006, 2010)

- Evaluated 25, 50, 50 with thinning and 100 ft SMZs in 16 watersheds, 24 subwatersheds with sediment pins, sediment traps and models.
- **Sediment Delivery Ratio for all SMZ widths was 3-14%.**
- SMZs may fail due to blowouts associated with roads, skid trails, firelines, stream crossings.

SMZ Width and Harvest Treatments (1 of 4 Blocks)



Study Components



Site Conditions

25 feet SMZ Stringer

Haul road

50 feet thinned SMZ

Harvest/Site Prep

Fire line

100 feet SMZ

SMZs, Fertilizer/Nutrients (Secoges et al. 2013)

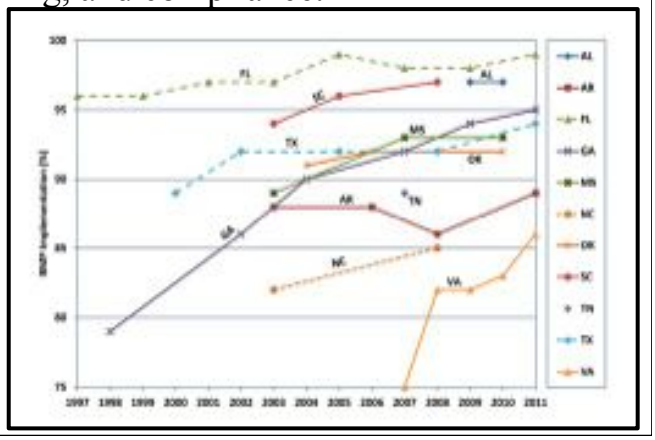
- 50-100 ft SMZs are effective for removal of nutrients following fertilization (25 ft SMZ and 50 ft SMZ with Thin may be too narrow for **fertilizer nutrients**)
- Firelines contribute disproportionately.

Problems with SMZs (Lang et al. 2013)

- Evaluated 6.2 miles of SMZs across 16 harvest sites in Piedmont.
- SMZ sediment break-throughs were associated with gully erosion (38%), harvest (27%) and roads/skid trails (19%)
- Gully stabilization and minimizing crossings are appropriate BMPs.

National Evaluation of BMP Programs (Cristan et al. 2013)

- Surveyed the State Foresters/Water Quality Foresters for 50 states and 4 US territories to evaluate the BMP policy, monitoring, and compliance.



BMP Research: Summary

- Forestry BMPs can effectively reduce sediment from forestry operations.
- Problems are typically associated with improperly applied BMPs, insufficient BMPs, or previous land use history.
- Most BMP issues are associated with roads, skid trails, and stream crossings.