

Developing an Integrated Logistics Model for Beetle-killed Biomass



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Background

- The ongoing outbreak of the mountain pine beetle has affected over 19 million hectares in the United States
- Beetle-killed wood represents a vast, high-density biomass feedstock resource for bioenergy and bio-based products
- BANR was launched as a USDA NIFA project to explore the use of beetle-killed and other forest biomass as a bioenergy feedstock



Background

BANR

BIOENERGY
ALLIANCE
NETWORK OF THE
ROCKIES



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Utilization of Beetle-Kill and Other Forest Management Feedstocks to Sustainably and Economically Diversify our Nations Transportation Fuels Markets



BANR Basics

- Announced Fall of 2013
- 2014 Project Begins
- 5 Years
- 5 States
- \$10 million
- 1 of 7 Coordinated Agricultural Projects (CAPS)

Structure/Organization

- Task-Centered Across Multiple States and Institutions
- Project Management and Executive Team
- Independent Project Advisory Team




BANR Governance and Guiding Principles

- Collaborative and Multi-Disciplinary
- Science-based with Practical Applications
- What Communities Should Know, Not What They Should Do

Focus Areas and Tasks

- Feedstock Supply
- Harvesting and Processing
- System Performance, Lifecycle and Financial Analysis
- Education
- Extension and Outreach
- Health and Safety




For More Information on BANR Visit
<http://banr.colostate.edu/>





University of Idaho



The University of Montana



OSU
Oregon State University

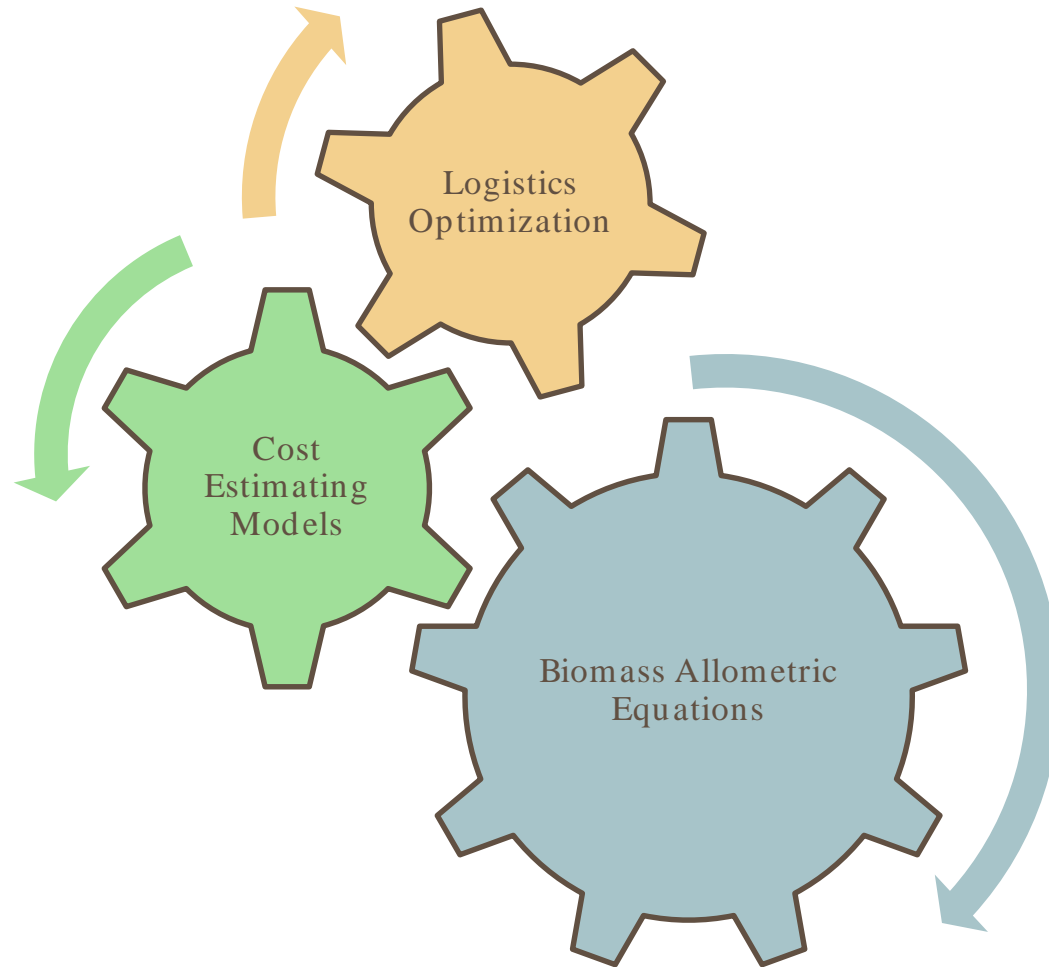


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Integrated Logistics Model?



The 3 Components



Component 1: Allometric Equations



Live



Dead

Component 1: Allometric Equations

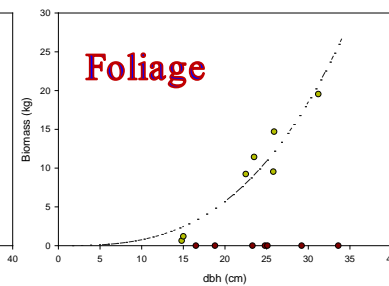
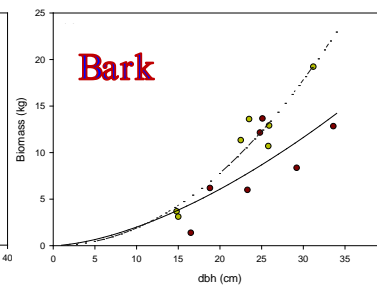
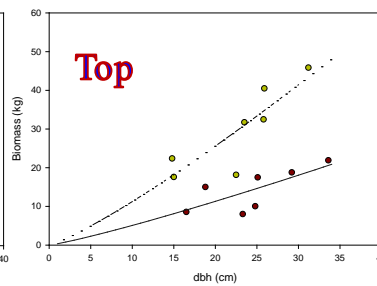
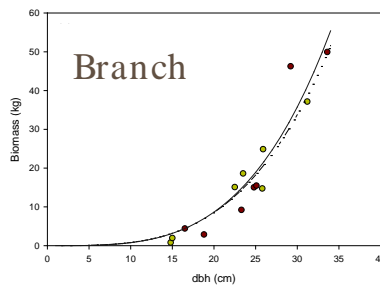
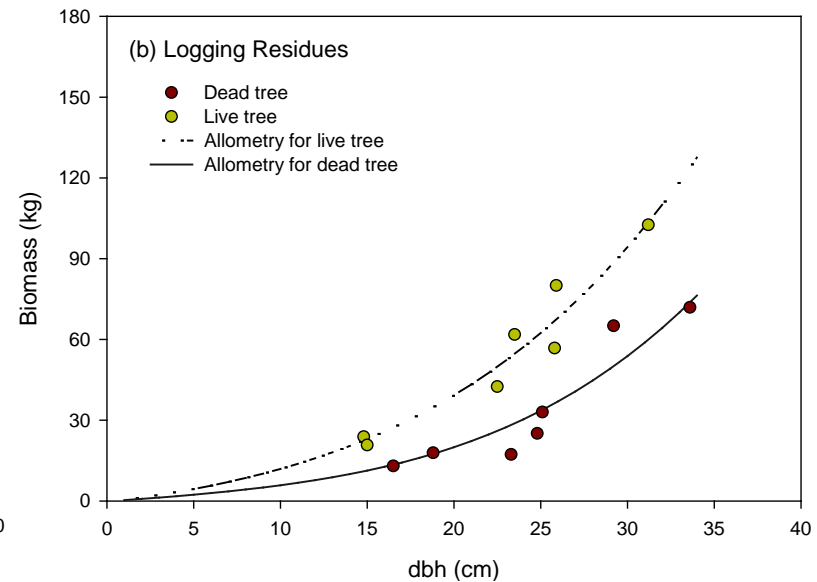
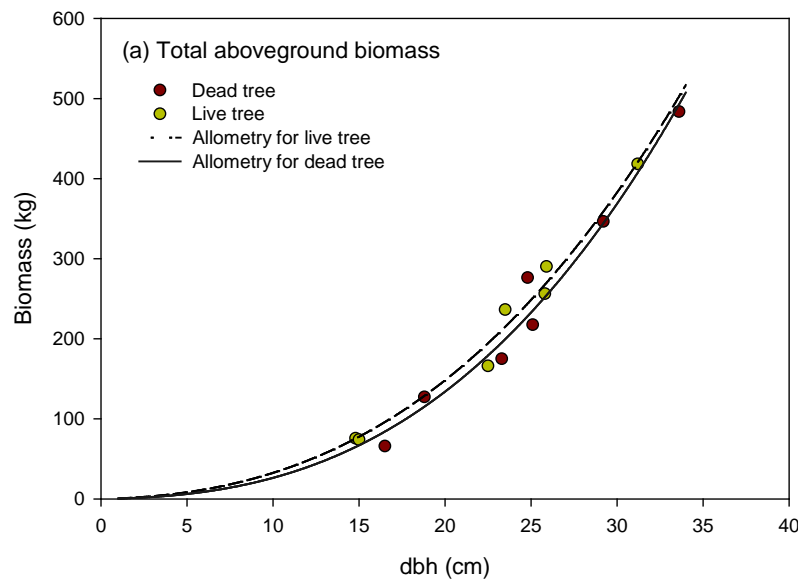


Live vs. Dead
?

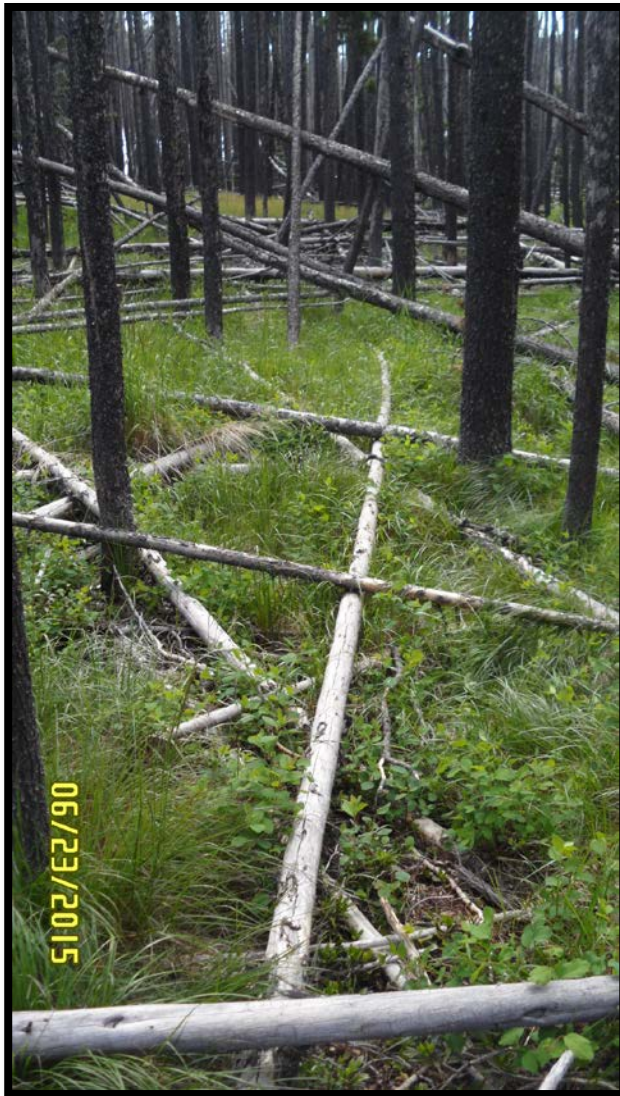


Component 1: Allometric Equations

- The amount of logging residues (top + branch + foliage) is significantly different between live and dead trees



Component 2: Harvesting Costs



Component 2: Harvesting Costs

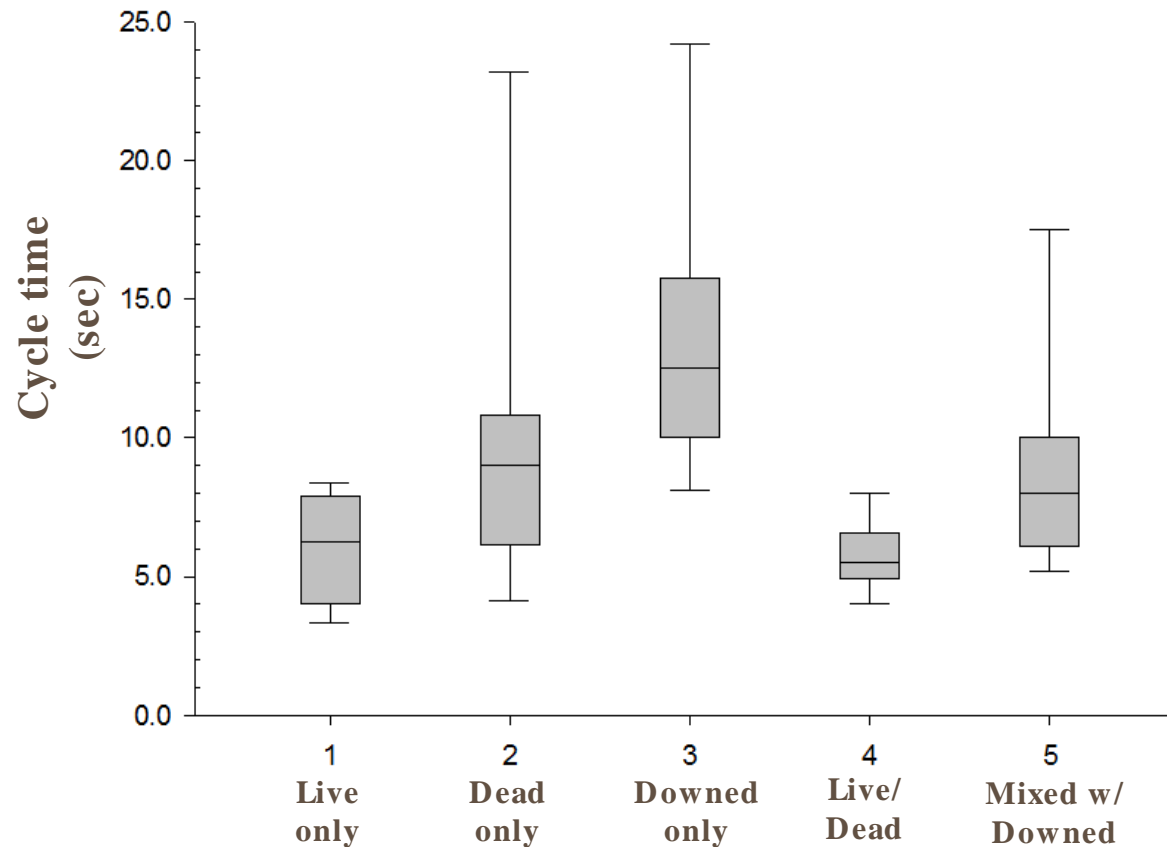


Component 2: Harvesting Costs



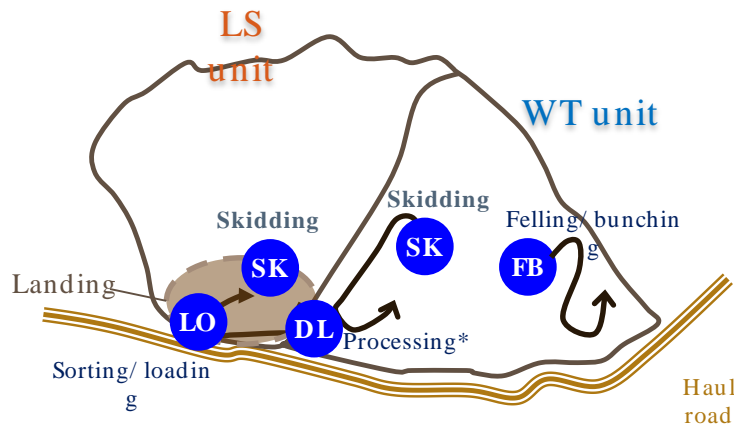
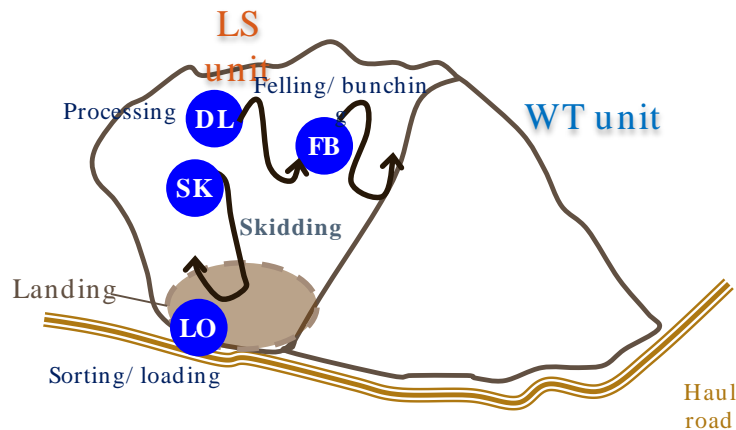
Component 2: Harvesting Costs

- Feller-buncher productivity: **Standing live > Standing dead > Downed**
- Live/Dead/Down has no effect on skidder, processor, delimber and loader



Component 2: Harvesting Costs

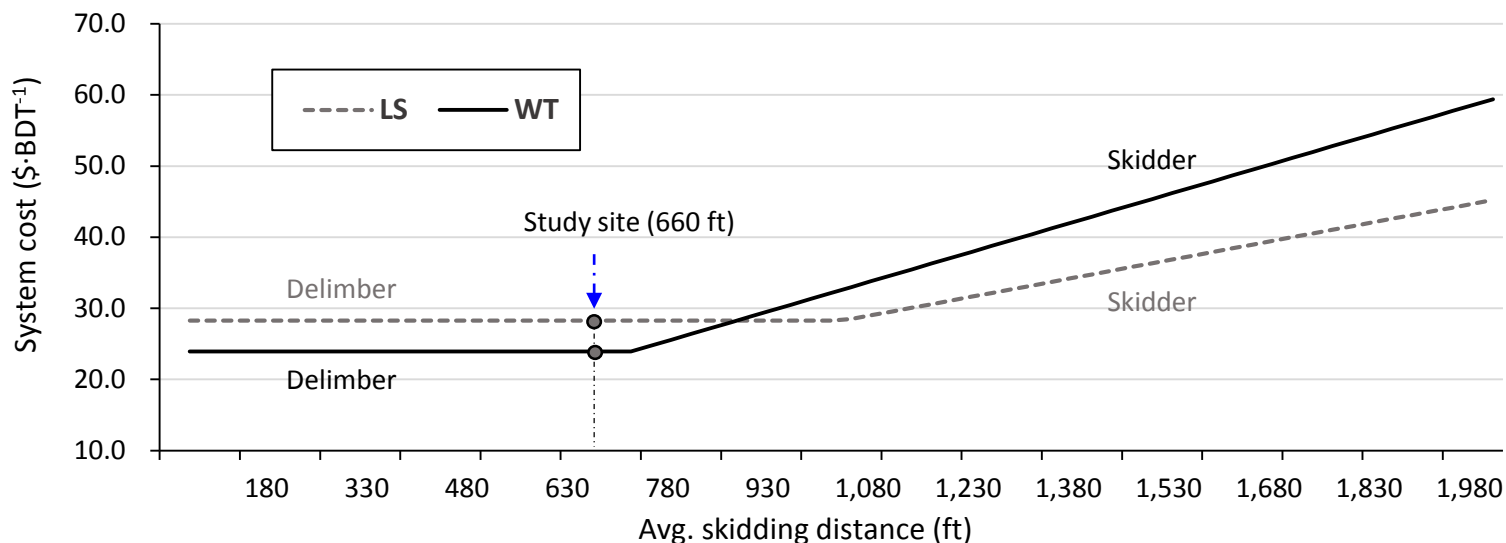
- Lop & Scatter vs. Whole-tree Harvesting



Component 2: Harvesting Costs

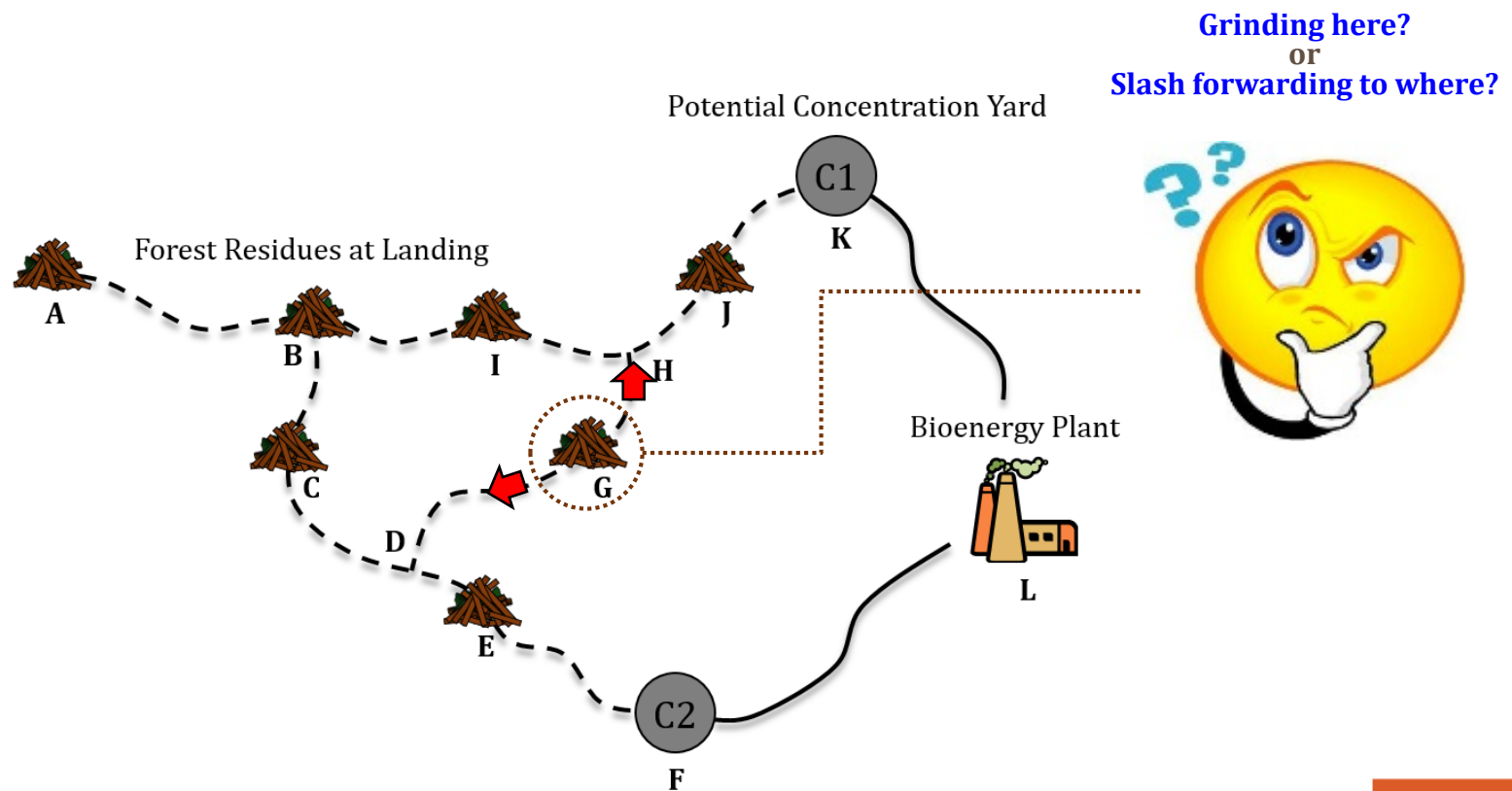
System	Machine	Utilization (%)	Machine		System	
			Productivity (BDT·SMH ⁻¹)	Cost (\$·BDT ⁻¹)	Productivity (BDT·SMH ⁻¹)	Cost (\$·BDT ⁻¹)
LS	Feller-buncher	60.0	29.29	4.91	19.70	28.27
	Delimber*	65.0	19.70	5.82		
	Skidder	60.0	25.74	3.53		
	Loader	65.0	26.31	3.01		
WT	Feller-buncher	60.0	29.29	4.91	23.28	23.92
	Delimber*	65.0	23.28	4.93		
	Skidder	60.0	25.07	3.63		
	Loader	65.0	26.31	3.01		

*Calculated for two delimbers : System bottle neck



Component 3: Logistics Optimization

- What would be the most cost-efficient biomass feedstock logistics for given residue pile locations?



Component 3: Logistics Optimization

- Two alternative systems for forest residue recovery operation

1) In-woods grinding system

Grinder cost ↑, Truck cost ↓

Grinder move-in cost



2) Slash forwarding system

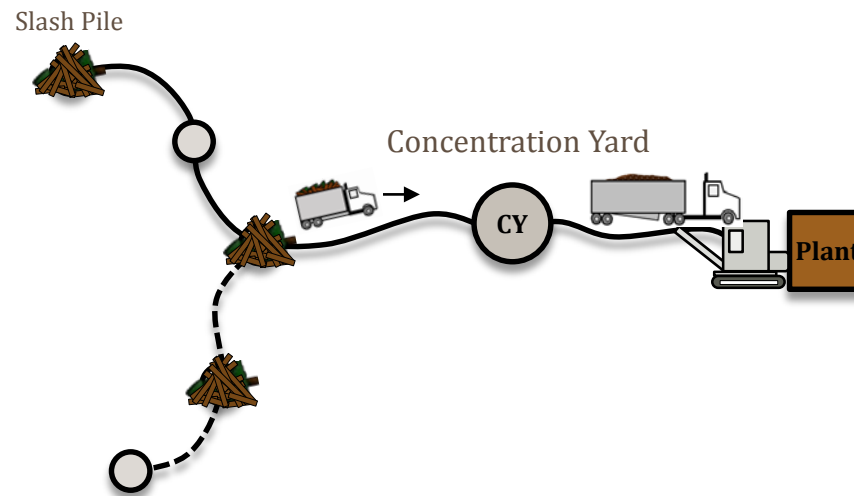
Grinder cost ↓, Truck cost ↑

No grinder move-in



Component 3: Logistics Optimization

■ Slash forwarding system

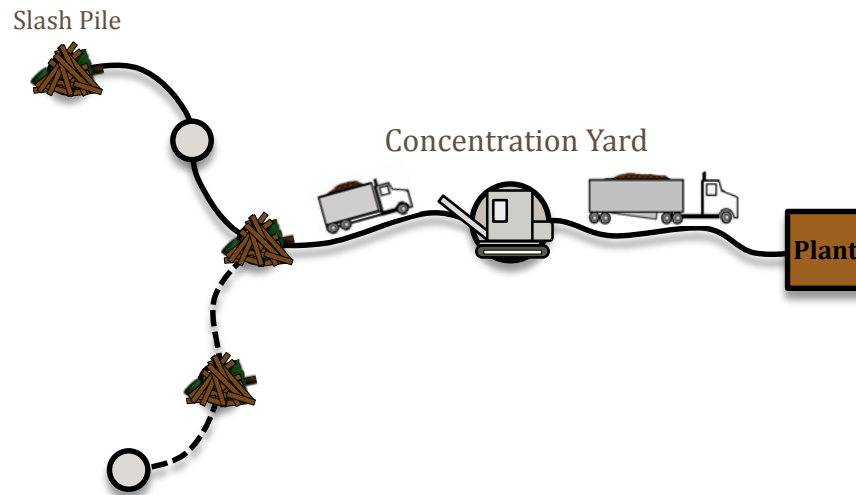


Node hierarchy on forest roads

- **Landing:** a location that forest residues could be piled
- **Concentration yard:** a location that has access to chip vans
- **Bioenergy plant:** the destination of ground residues for bioenergy production

Component 3: Logistics Optimization

■ In-woods grinding system

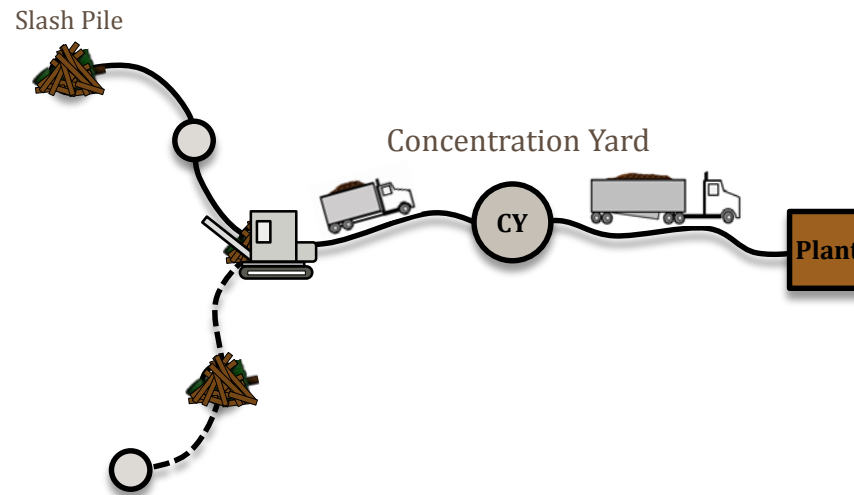


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Component 3: Logistics Optimization

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Component 3: Logistics Optimization

- Mixed Integer Programming (MIP) approach

▪ Objective function

$$\text{Min } Z = \sum_{ij \in L} \sum_{s \in S} \sum_{p \in P} \sum_{t \in T} (cp_{ij}^{sp} + ct_{ij}^{tp}) \cdot X_{ij}^{tp} + \sum_{kl \in N} cm_{kl} \cdot Y_{kl} + \sum_{u \in N} cc_u \cdot D_u$$

cp_{ij}^{sp} : variable processing cost of system s at location i (\$/BDT)

ct_{ij}^{tp} : variable transportation cost of transporting material type p with truck t on link ij (\$/BDT)

cm_{kl} : move-in cost of grinder mobilization on road segment kl (\$)

cc_u : construction cost for concentration yard or landing at location u (\$)

L : set of links in the network

N : set of nodes

P : set of material types (slash or ground residue)

S : set of processing equipment system (slash forwarding or in-woods grinding)

T : set of truck options

Component 3: Logistics Optimization

- Mixed Integer Programming (MIP) approach

▪ Constraints

$$\sum_{j \in N} X_{ij}^{tp} - \sum_{j \in N} X_{ji}^{tp} = \begin{cases} z_i^p & i \in Z \\ 0 & i \in W \end{cases} \quad \text{for } \forall j \in N, \forall p \in P, \forall t \in T$$

$$M \cdot D_u \geq \sum_{u \in N} X_{uv}^{tp} \quad \text{for } \forall v \in C \cup K, \forall p \in P_{\text{grindings}}, \forall t \in T$$

$$\sum_{kl \in R_{uv}} Y_{kl} \geq n_{uv} \cdot D_u \quad \text{for } \forall u \in N, \forall v \in K$$

$$\sum_{j \in K} X_{ij}^{tp} \geq r_{\min} \quad \text{for } \forall i \in N, \forall p \in P, \forall t \in T$$

$$D_w Y_{kl} = \{0, 1\} \quad \text{for } \forall k, l, u \in N$$



$$X_{ij}^{tp} \geq 0 \quad \text{for } \forall ij \in L, \forall p \in P, \forall t \in T$$

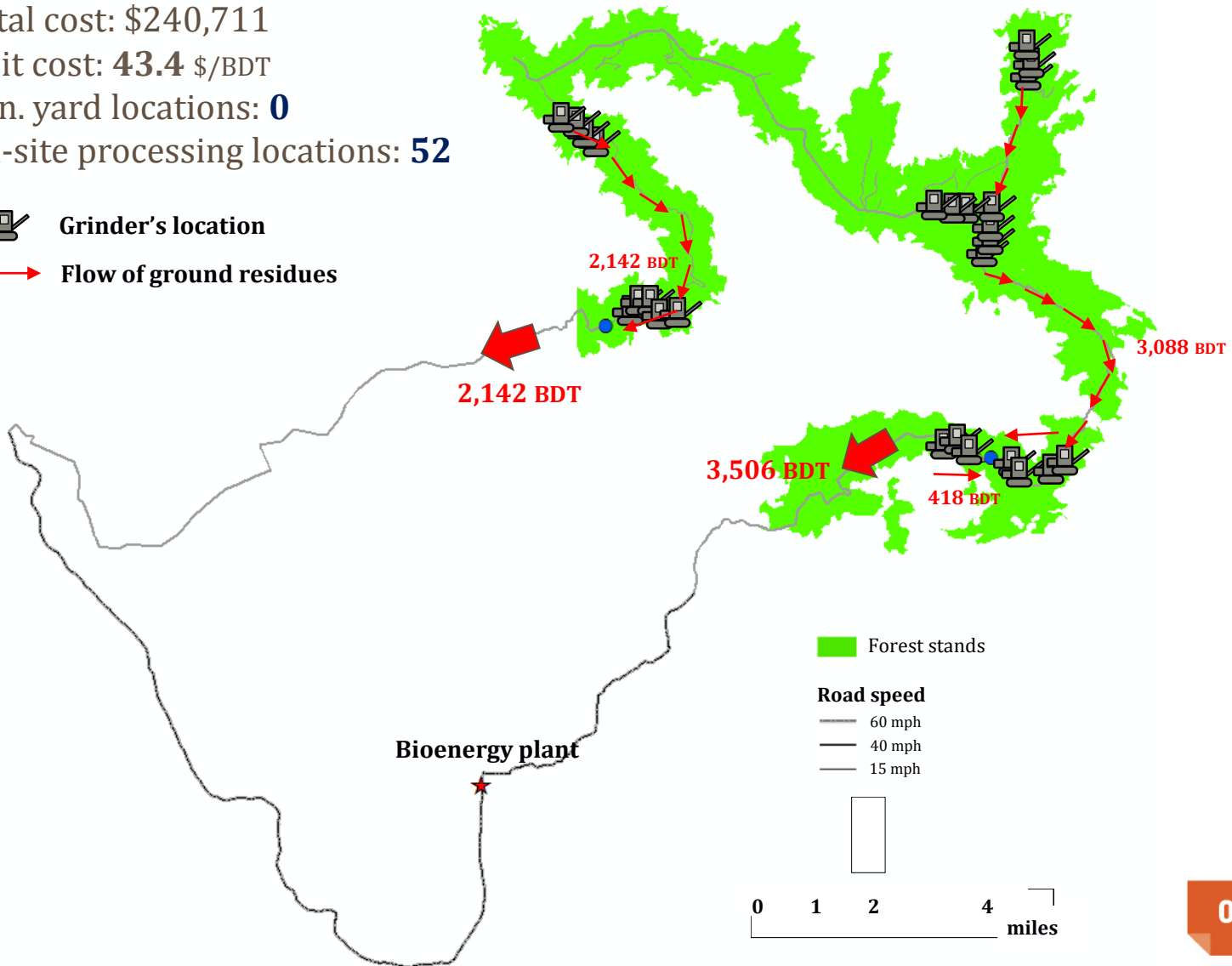
C : set of concentration yards

K : set of bioenergy facilities

Conventional Logistics




- Total cost: \$240,711
- Unit cost: **43.4** \$/BDT
- Con. yard locations: **0**
- On-site processing locations: **52**

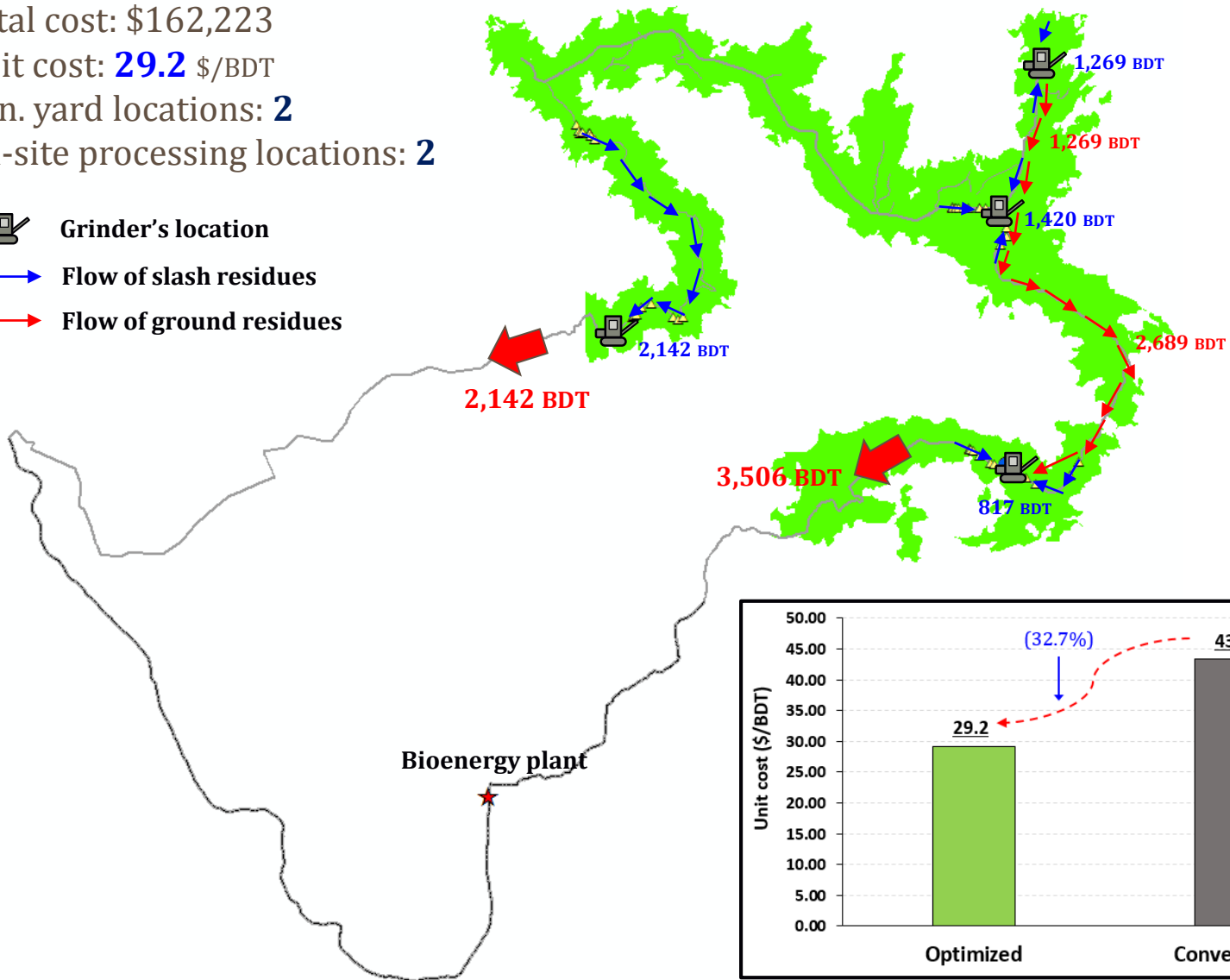
 **Grinder's location**
 **Flow of ground residues**



Optimized

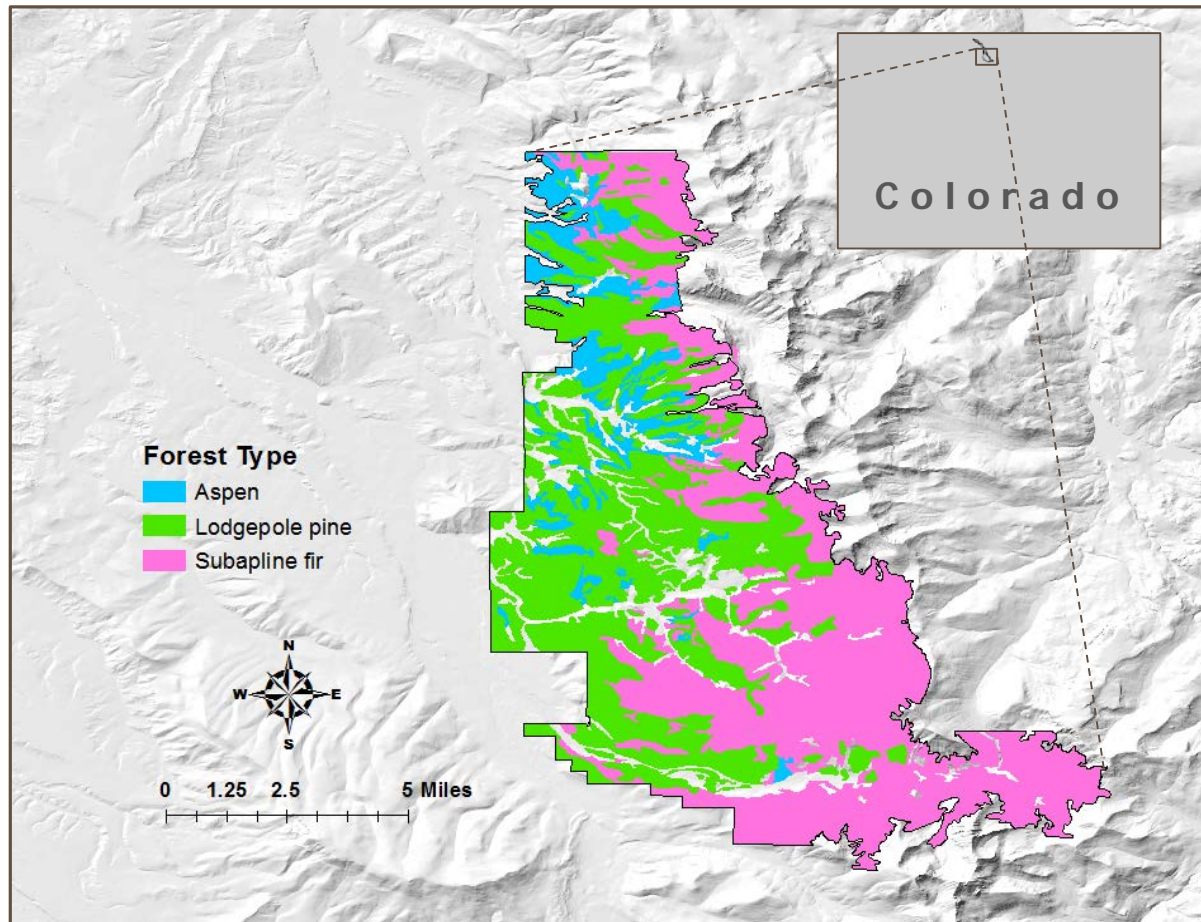
- Total cost: \$162,223
- Unit cost: **29.2** \$/BDT
- Con. yard locations: **2**
- On-site processing locations: **2**

-  Grinder's location
-  Flow of slash residues
-  Flow of ground residues



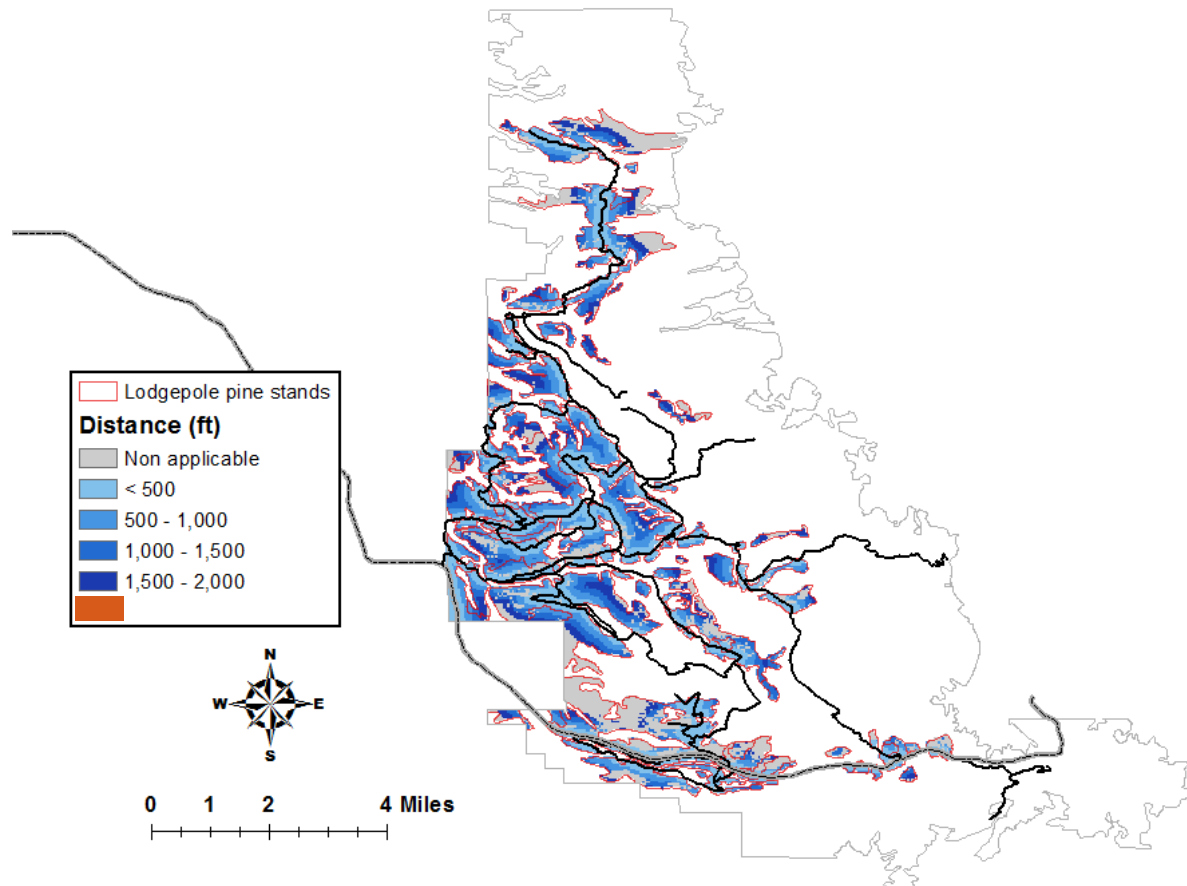
Integration – A Case Study

- Study forest (Colorado State Forest, CO)
- Total area: 36,428 acres



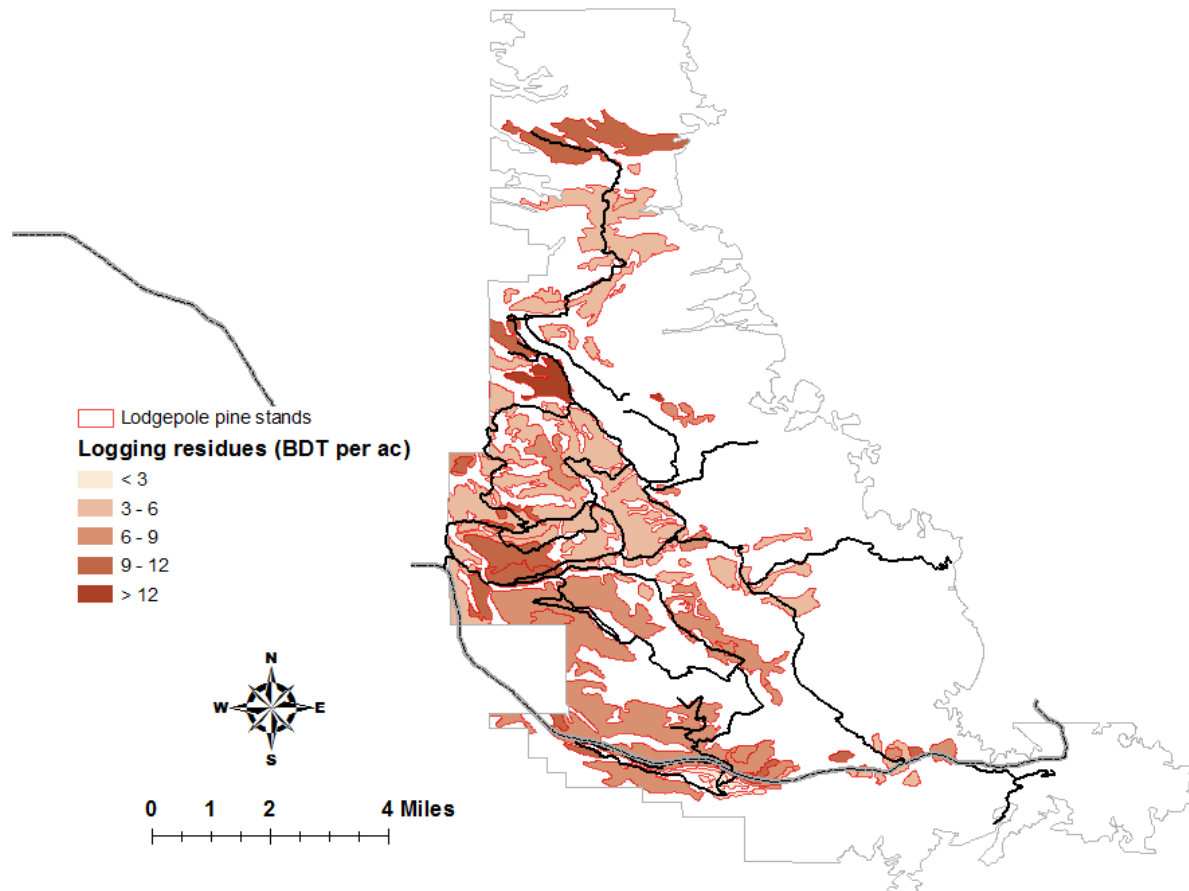
Integration – A Case Study

- Criteria: Lodgepole pine; Slope < 30%; average skidding distance < 2,000 ft



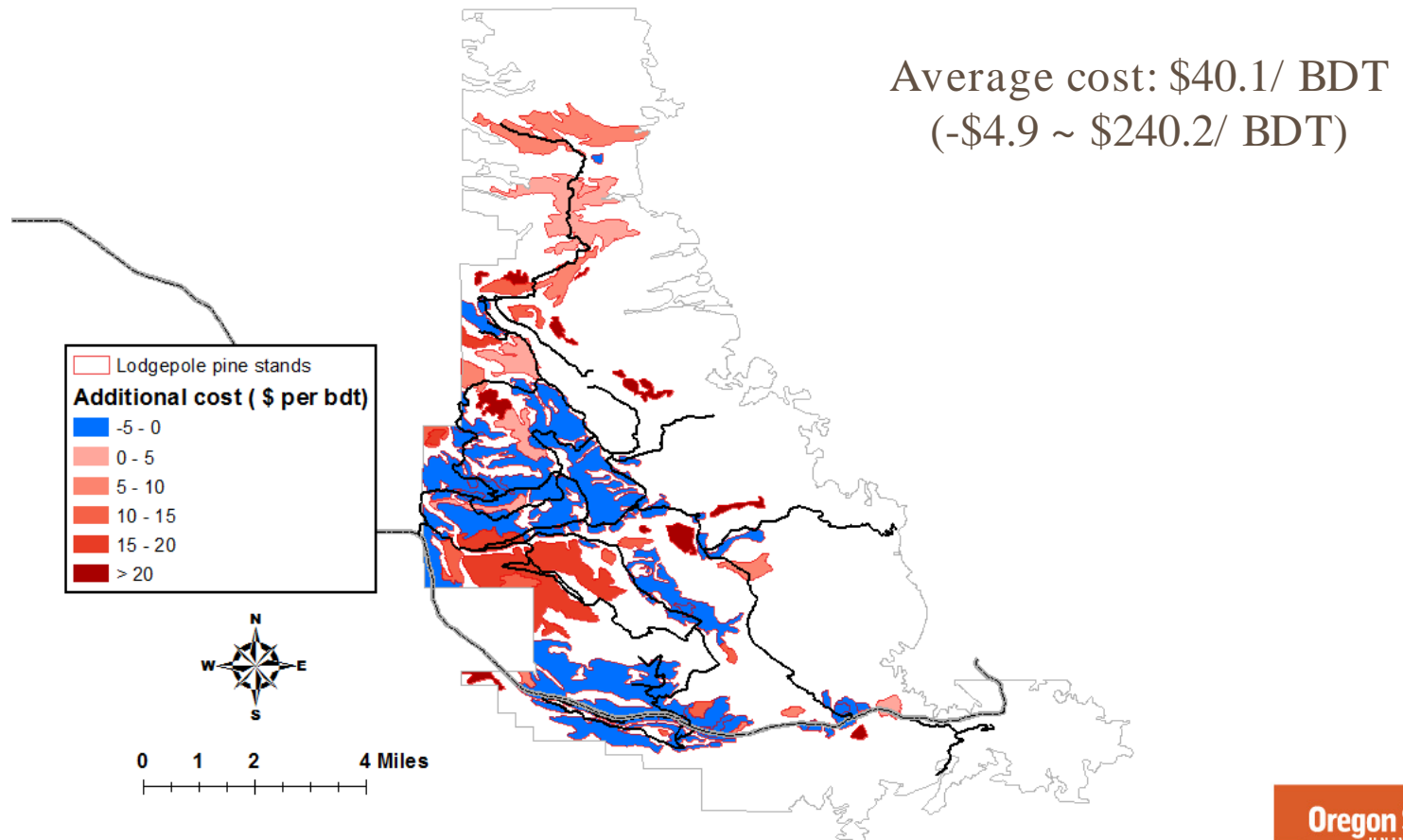
Integration – A Case Study

- Estimated logging residues



Integration – A Case Study

- Cost difference between WT and LS (WT – LS)



- Optimized Logistics



Concluding Remarks

- New allometric equations, new harvesting cost and new logistics optimization approach allow estimation of more realistic beetle-kill biomass supply and costs – addressing the existing uncertainties and knowledge gaps
- ‘Years since dead’ likely affect harvesting costs, timber product mix and therefore project net revenue – will be studied in collaboration with other task teams in BANR
- The logistics model will be further integrated with the downstream supply chain to incorporate facility locations and end-user products for minimum costs and maximum value recovery



Thank you Questions?

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