Logging Residues: Preliminary Predictive Models

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Introduction

Forest managers need to know how much timber residue remains on site after a logging operation to predict feedstock potential for woody biomass energy uses and to gauge the efficiency of their operations. Logging utilization studies quantify the amount of growing stock volume cut and either delivered to the mill or left in the forest as logging residue at the ***state*** level. However, managers lack ***site-specific*** residue information that could be used to inform their prescription efforts. The authors used logging utilization data to develop predictive models that provide the residue information needs of land managers.

Objectives

- **Relate:** the logging utilization residue factor "F3" (tree bole logging residue cubic foot volume /mill delivered cubic foot volume) (fig. 1) to tree and stand variables. Landowners could then use this information to refine their residue management prescriptions for site-specific conditions.
- **Keep it simple:** Use variables easily obtained by landowners.
- **Reduce costs:** Logging utilization surveys traditionally characterize residues at the *state* level. The *same data* could be used to model residues at other spatial scales, including tree and stand-levels.

- ***Two levels of residue prediction*** :

- **Individual tree**: Develop predictive models to better understand how logging residue varies with tree attributes such as species and diameter.
- **Site or stand-level**: Parameterize models at the stand level to enable land managers to predict residue loading for fuels and biomass management, smoke production, and debris retention purposes.

Methods

- **Sample logging sites and trees:** The authors measured 814 recently felled live trees from 33 logging sites (usually 25 trees per site) selected within 10 Idaho counties in 2008 and 2011.

- **Tree measurements**: Outside bark diameter and section lengths were measured along the bole at:

- The cut stump
- 1-foot above ground (FIA stump section definition)
- DBH (diameter breast height)
- Log lengths less than or equal to 16 feet
- The 4-inch diameter at the top end of growing-stock (fig. 2)
- The small-end tree diameter at the end of utilization of each tree
- The tip of the tree

- **Residue vs. delivered volume:** Measured tree sections were identified as being either cubic foot residue volume or mill delivered cubic foot volume (computed with Smalian's formula).
- **Individual tree models**. Sampled tree data were used to parameterize hierarchical (trees nested within logging sites) individual tree mixed models incorporating variables easily obtained by land managers. The response variable was F3.
- **Logging site level models**: The *site-level* F3 growing stock logging residue factor (individual tree volumes were summed to create the site level ratio) was related to site-level variables through linear mixed models.

FIGURE 3: Dangle-head processor.

F3, the "growing stock residue factor" =  ÷ 

Growing stock logging residue cubic foot volume (bole wood only) — **Delivered cubic foot volume**

FIGURE 1: The growing stock residue factor, F3- cubic feet of growing stock logging residue vs. cubic feet of mill delivered timber

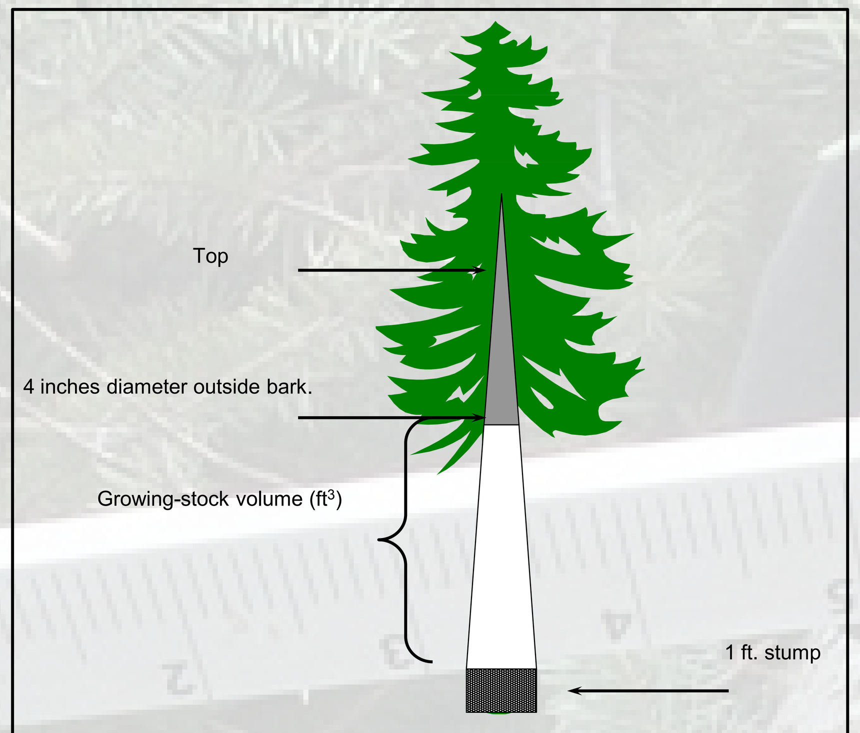

FIGURE 2: Growing stock; bole from a one foot stump to a 4 inch top in trees ≥ 5.0 inches DBH

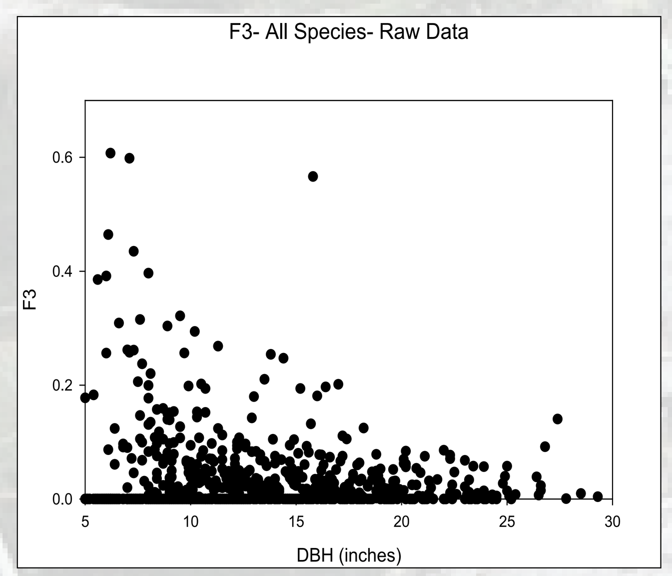

FIGURE 4: F3 (cubic feet of growing stock logging residue/delivered cubic foot volume) per tree vs. DBH for all 814 measured trees.

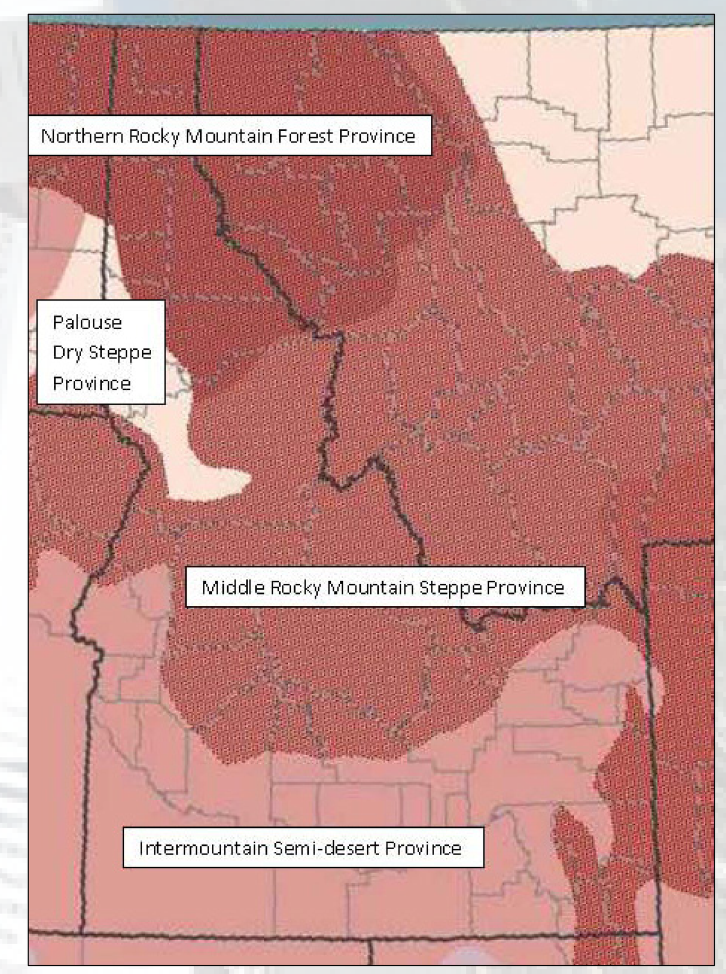

FIGURE 5: Bailey's Ecoregion provinces in the state of Idaho. Lands in the same province share common climate and vegetation; province was a categorical site quality variable in the F3 models. 27 sample sites were located in the Northern Rocky Mountain Forest Province (north Idaho) and 6 in the Middle Rocky Mountain Steppe Province (southern Idaho).

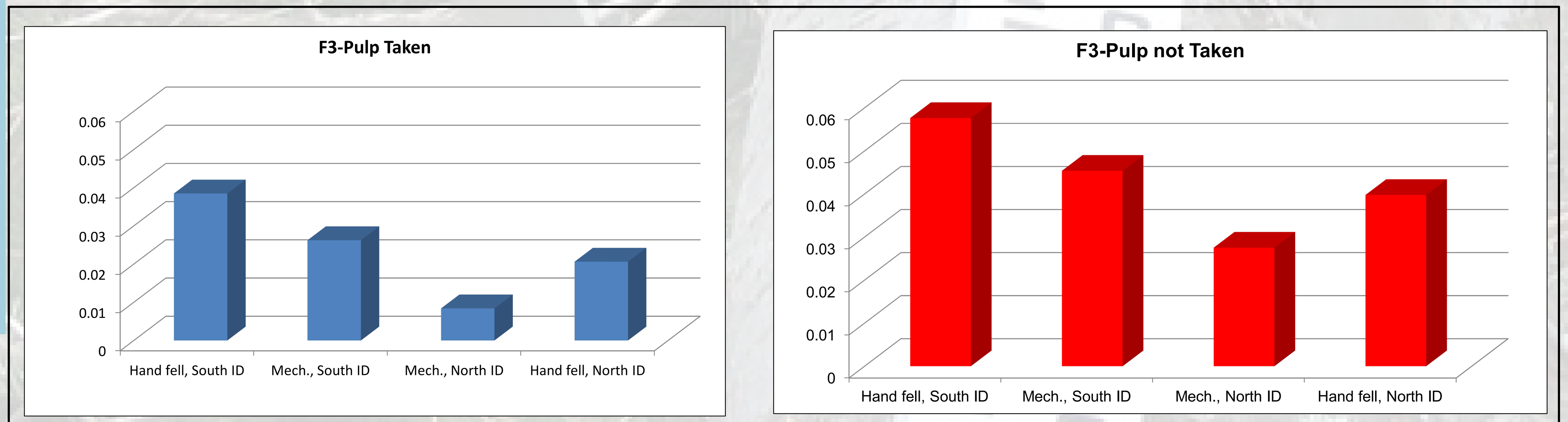

FIGURE 6: Site level model. F3 was reduced when timber was mechanically felled and on productive sites in north Idaho. Removing pulp substantially reduced logging residue.

Analysis

Variable	Categorical or Continuous Variable	Explanation	Parameter Estimate	Standard Error	Prob > |t|	Comments
Intercept			0.1152	0.01952	<.0001	
MERCHMETHOD	Categorical	0= mechanical merchandising; 1= hand merchandising	-0.01477	0.006337	0.02	parameter for 0, mechanical
SPECIES	Categorical	FIA codes	0.05557	0.0112	<.0001	for western redcedar
DBH	Continous	Tree diameter; to nearest 1/10 inch	-0.01174	0.002371	<.0001	
DBH*DBH	Continous	Quadratic term to reflect relationship of F3 with DBH	0.000359	0.000079	<.0001	
REALPULP	Categorical	0=pulp not utilized; 1= pulp utilized	0.1222	0.0153	<.0001	for 0, pulp not utilized
DBH*REALPULP		Interaction	-0.00565	0.001054	<.0001	for 0, pulp not utilized
Ecoregion	Categorical	1=Northern Rocky Mountain Forest Province; 2= Middle Rocky Mountain Steppe Province. Province is a large-scale site classifier.	-0.02316	0.006048	0.0001	for 1, north Idaho

Individual tree model: F3 = *f* (DBH, Pulp Removal, Merchandising Method, Ecoregion Province, Tree species)

Variable	Explanation	Coding	Parameter Estimate	Standard Error	Prob > |t|	Comments
Intercept			0.02623	0.006326	0.0003	
MECHANICAL	Mechanical falling	0=not mechanically felled; 1= mechanically felled	0.01224	0.0049	0.0184	parameter is for 0, not mechanically felled
REALPULP	Pulp utilized	0=pulp not utilized; 1= pulp utilized	0.01915	0.005463	0.0015	parameter for 0, pulp not utilized
Ecoregion	Bailey's Ecoregion Province	1=Northern Rocky Mountain Forest Province; 2= Middle Rocky Mountain Steppe Province	-0.01785	0.006043	0.0062	parameter for 1, north Idaho

Site-level model: F3 = *f* (Pulp Removal, Mechanical vs. Hand falling, Ecoregion Province)

Results

Individual Tree Model

Variable	Change in F3 (residue/delivered volume)
MERCHMETHOD-Merchandising method- mechanized vs. chainsaw.	F3 decreases when timber is mechanically processed (e.g. dangle head on a landing, fig. 3) vs. processed by chainsaw. Mechanized processing is more efficient.
SPECIES	F3 is large for cedar vs. all species pooled *per tree only; statewide* cedar F3 is low because large diameter cedars with high volumes summed across all sites drive down F3. Other species were not strongly related to F3.
DBH	F3 decreases as DBH increases (fig. 4)
REALPULP-Taking pulp-yes or no	F3 *substantially* decreases when pulp is taken.
Ecoregion- north or southern Idaho	F3 decreases in north Idaho sites where the cubic foot volume of trees is greater and tree taper is superior compared to trees in southern Idaho (fig. 5).

Site-level Model

Variable	Change in F3 (residue/delivered volume)
Mechanical harvesting- yes or no	F3 decreases when timber is mechanically felled (e.g. feller buncher) (fig. 6).
Taking pulp-yes or no	F3 *substantially* decreases when pulp is taken.
Ecoregion- north or southern Idaho	F3 decreases in north Idaho where the cubic foot volume of trees is greater than in southern Idaho.

Conclusions

- **Individual tree model**- Tree diameter, species, and site-level variables for merchandising method, pulp extraction, and Ecoregion province were strongly related to F3, the growing stock residue factor. Knowledge gained through developing these models helped identify important variables for the site level model.

- **Site level model**- Simple categorical variables readily available to land managers- falling method, pulp removal, and site quality- were related to F3 at the site level. This site-level modeling approach is designed to meet the information needs of land managers and would not require a tree list for use.

Application

- The F3 ratio is *scalable*.
- Individual tree and site-level models could potentially be used to calibrate predictions of activity fuels, woody debris, and biomass across the NARA 4 state area.
- These predictive equations compare residue volume to delivered timber volume, but they could be adapted to predict biomass per land area- which would be far more useful to land managers.
- This analysis is based on data from only the state of Idaho- creating models across all 4 NARA states could yield a substantially different suite of variables and relationships.
- Logging utilization results could build on other inventory procedures to ***provide a comprehensive picture of available feedstocks.***

Acknowledgements

The authors would like to acknowledge partial support from the USDA Forest Service Rocky Mountain Research Station Interior West Forest Inventory and Analysis unit

NARA
Northwest Advanced Renewables Alliance

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.