Moisture management model for optimal forest biomass delivery in the Pacific Northwest

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Introduction

Logging residues are an available resource that in many cases are being burned for site preparation and are seen as a green alternative for energy production. However, one of the biggest challenges for this material to be economically competitive with traditional fuel sources in the U.S. is its high transportation cost. Transportation cost is affected by residue moisture content. As forest biomass moisture increases, transportation becomes more inefficient and expensive. In addition, drier material is more desirable for power generation since it has higher net energy content. Wood moisture can be reduced in the forest through drying. Drying rates, and therefore storage time, will depend on residue initial moisture content, climate conditions, species, and storage form. Preparing biomass residues for storage and storage time itself will incur capital costs, interest and risk. Storage costs must be weighed against savings associated with transportation and customer premiums for drier material.

Objective

The main goal of this project is to be able to build and validate a model to estimate the optimal storage time for forest biomass residues given different Pacific Northwest harvest locations, species and logging system. In order to address this general objective, we have proposed three specific objectives:

a) Determine initial moisture content and its seasonal variation in green branch wood.

b) Determine how drying occurs given different locations and logging systems (in-forest storage form) and simulate the effect of different pile shapes through finite element analysis.

c) Build an economic model that can tell us the optimal storage time balancing cost savings against interest and risk costs. For different species, logging systems and location.

Study areas

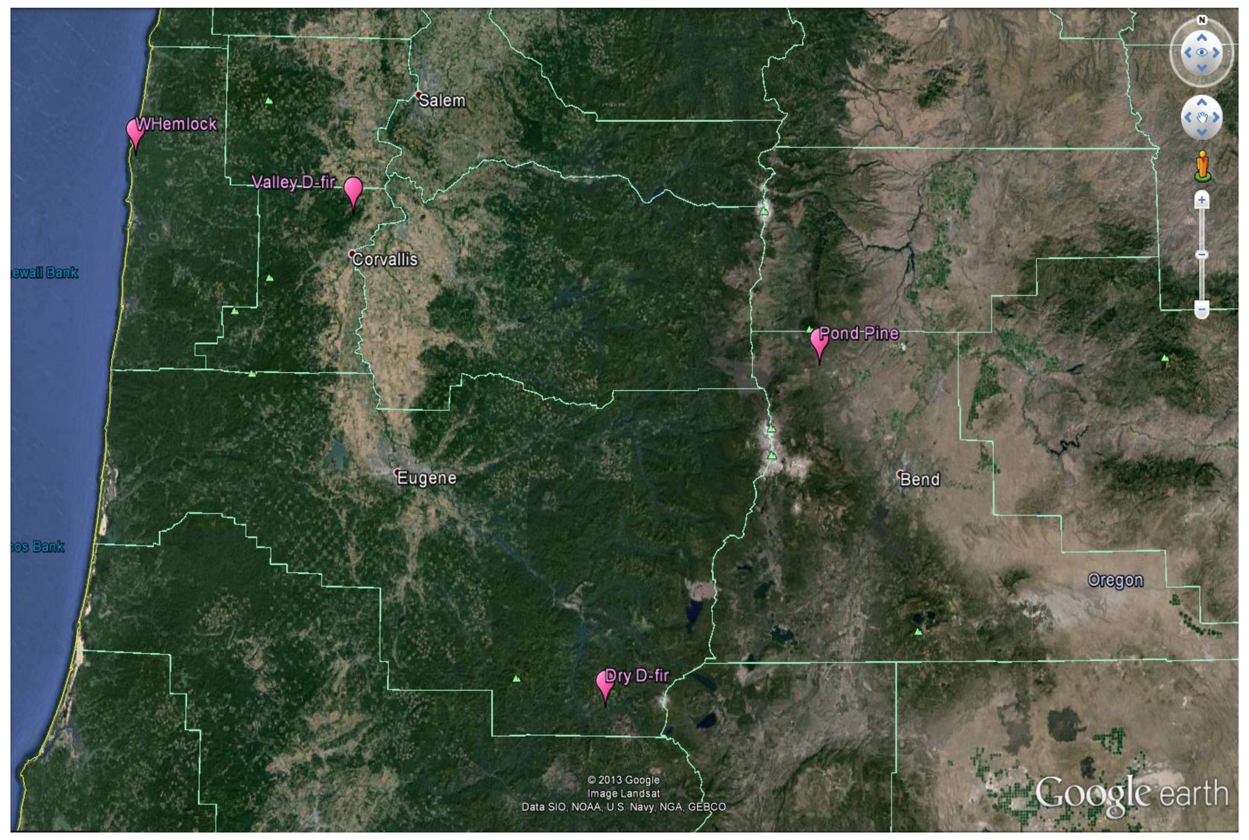

FIGURE 1 – Current branch sampling locations. Map: Oregon. Map. Google earth, March 10, 2014.

Data collection and methodology

- Initial moisture content: repeated branch sample collection over four seasons in four different forest types/climate zones. Sample diameter, heartwood content, branch length and height are recorded, and samples are oven dried for moisture content determination.

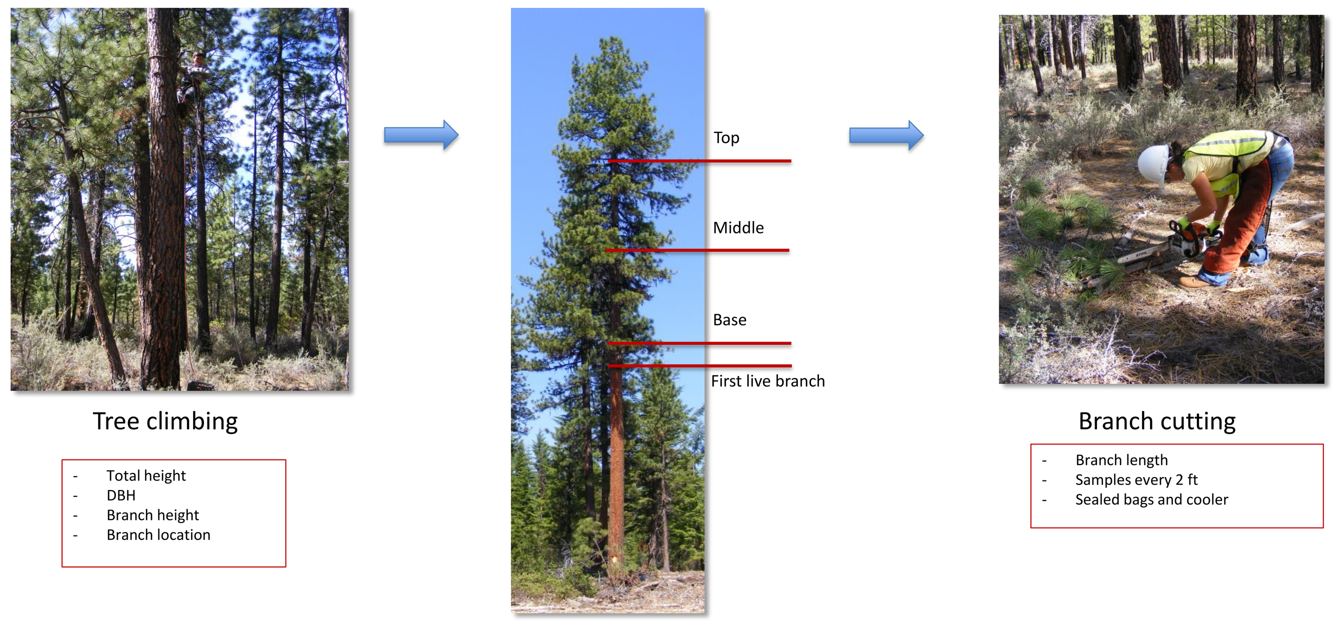

FIGURE 2 – Branch sample collection procedure for initial moisture content determination

- In-field harvest residue moisture monitoring through time: weight monitoring for scattered residue samples, internal environment variable and sample weight monitoring for piled residue. In addition, a local weather station is placed to monitor climatic conditions. Finite element analysis will be performed using COMSOL Multiphysics ® and validated with data collected in the field.

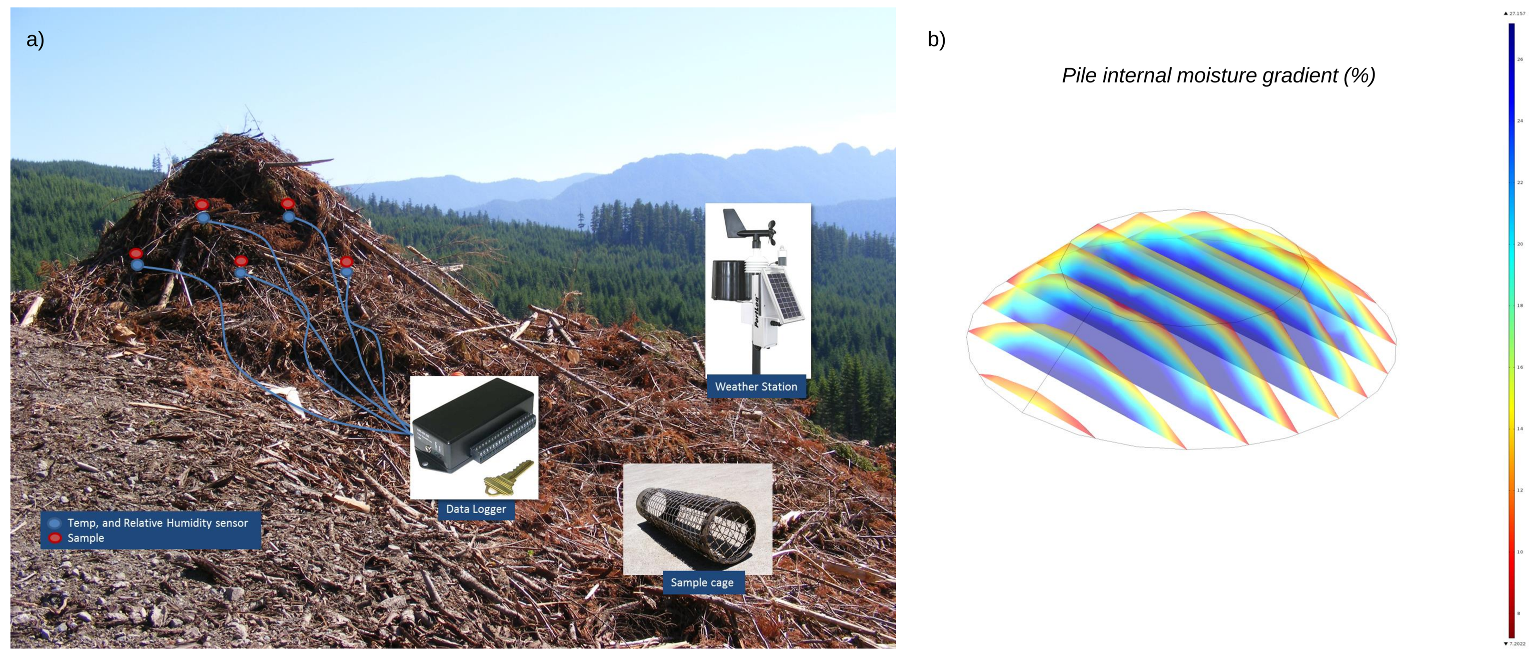

FIGURE 3 – a) Internal environmental variable monitoring on piled residue, b) simulation of pile internal moisture gradient (%). Image source: a) Data Logger: http://www.pace-sci.com/data-loggers-xr5.htm Weather station: http://www.rainwise.com/products/detail.php?ID=6735 b) image from COMSOL Multiphysics ® provided by Dr Ben Leshchinsky

- Economic model: linear programming model with objective to maximize net revenue from forest residues generated by a permanent wood harvest flow from two different logging methods. Planning horizon would be two years, considering moisture content, accessibility and time value of money.

Partial and expected results

- Initial moisture content: branch sampling has been completed. For three different forest types, branches are driest in Summer and moisture seems to increase towards the Winter. Preliminary statistical tests show significant differences in seasonal mean branch moisture content in Valley Douglas fir and Ponderosa pine sites. However, there are no significant differences in Western Hemlock and Dry Douglas fir. None of the sampled plots averaged moisture content higher than 0.50 for live branch moisture content.

	Summer			Fall			Winter			Spring		
Site	Average*	Max	Min	Average*	Max	Min	Average*	Max	Min	Average*	Max	Min
Valley Douglas fir	0.43	0.58	0.14	0.46	0.58	0.28	0.45	0.67	0.28	0.46	0.75	0.20
Ponderosa pine	0.43	0.59	0.13	0.47	0.59	0.31	0.50	0.63	0.25	0.45	0.73	0.32
Western hemlock	0.47	0.67	0.29	0.47	0.63	0.33	0.48	0.75	0.33	0.47	0.75	0.33
Dry Douglas fir	0.46	0.80	0.29	0.46	0.75	0.26	0.48	0.73	0.31	0.47	0.80	0.28

TABLE 1 – Seasonal weighted average (*) of branch moisture content (wet basis) by forest type

- In-field harvest residue moisture monitoring through time: sampling for scattered residue has been performed for one year over a Douglas-fir site in the Oregon Coast Range. Figure 4 shows how scattered residue acquires moisture through Winter months and it can return to moisture levels that are lower than the previous summer.

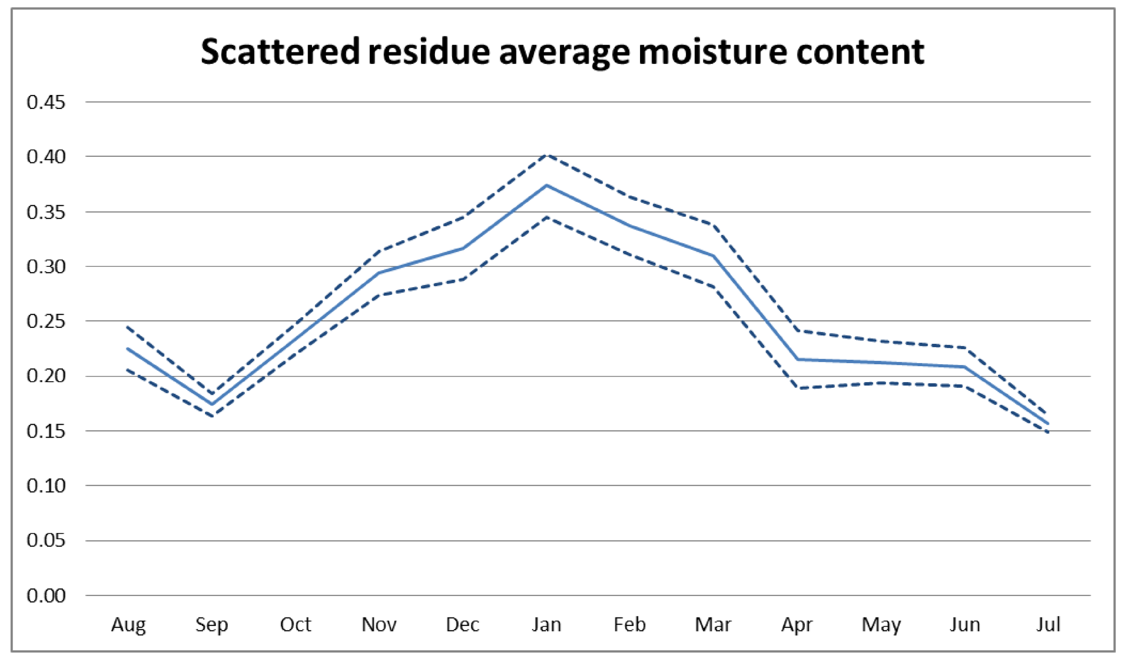

FIGURE 4 – Scattered residue average moisture content (wet basis) and 95% confidence interval for Coastal Douglas-fir forest

- Pile environmental variable monitoring has presented several challenges. A new approach has been implemented in Dry Douglas fir and Valley Douglas fir sites, were each sensor is being paired with a sample. Those samples are being weighed every month over a year to determine moisture content.

- Finite element analysis is being explored to simulate pile internal moisture conditions and be able to model drying for different pile configurations (shapes).

- Once a moisture model can be identified, it will be combined with different parameters to build an economic model and find the optimal volume of delivered residue per period as a function of moisture content.

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