Finite element analysis to predict changes of in-forest stored biomass moisture content

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Introduction

Forest harvesting 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. Understanding drying patterns depending on storage time, configuration and weather can help make better management decisions and support further economic analysis for efficient material delivery under different scenarios.

Objective

The main goal of this study is to be able to model the physical changes driving forest harvest residue drying to estimate the optimal storage time in the field given different Pacific Northwest harvest locations, species and logging system. In order to address this general objective, we have proposed three specific objectives:

a) Use finite element analysis to model drying rates for in-forest stored forest harvest residues

b) Calibrate these models with data collected in the field (Pacific Northwest)

c) Through the model, determine best storage configurations to maximize drying .

Data collection and methodology

- Geometry: forest harvest residues are represented as an ellipsoid shape treated as a homogeneous porous medium, and air as a box surrounding the pile with fluid properties.

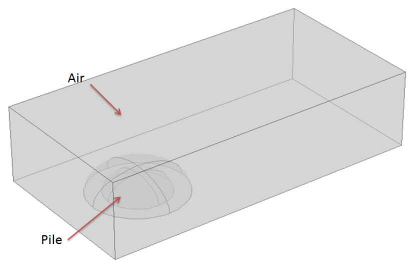


FIGURE 1 – Model geometry. COMSOL Multiphysics 5.1 ®

- Weather input: wind, temperature, relative humidity and rain need to be implemented in the model in order to expose the hypothesized pile to the natural elements. Weather station data gathered over one year was used to build functions and implement them in the model.

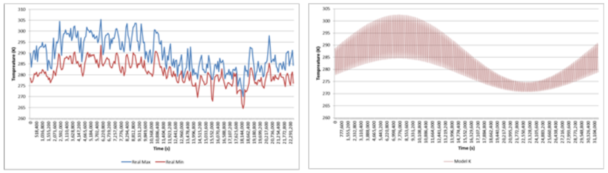


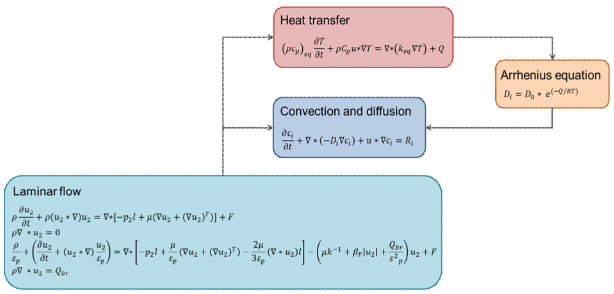
FIGURE 2 – Temperature function built from empirical data (Higher elevation Douglas-fir site)

- Model assumptions: initial conditions and assumptions such as piled material homogeneity and material properties need to be specified to implement the physical models.

	Air	Pile
Porosity	1	0.7
Bulk density (kg/m3)	1	150
Thermal conductivity (W/m*K)	0.025	0.05
Heat capacity (J/kg K)	1,000	1,075

TABLE 1 – Air and pile material properties

- Physics



- Calibration: in-field harvest residue moisture monitoring: 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 weather conditions.

Partial and expected results

- A finite element model has been implemented with weather data from one study location (Higher elevation Douglas-fir). The model simulates one year and the resulting forest harvesting residue moisture content over time is reasonable compared to field data.

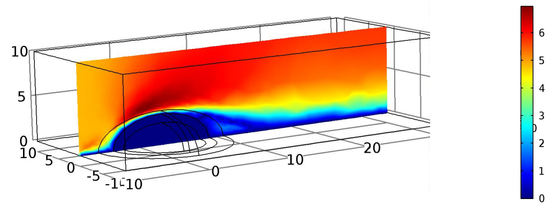


FIGURE 3 – Wind velocity magnitude (m/s). COMSOL Multiphysics 5.1 ®

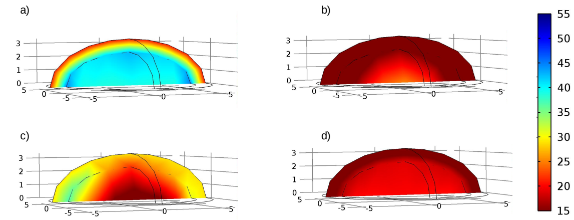


FIGURE 4 – Pile internal moisture (wet basis) gradient (%) a) May, b) September, c) November and d) April. COMSOL Multiphysics 5.1 ®

- A Wilcoxon test shows that the difference in monthly average between actual and modeled moisture content follows a distribution around zero (p-value = 0.4143). Spearman and Kendall's rank correlations are 0.73 and 0.56, respectively. This indicates that the model can explain more than 50% of the actual average moisture content.

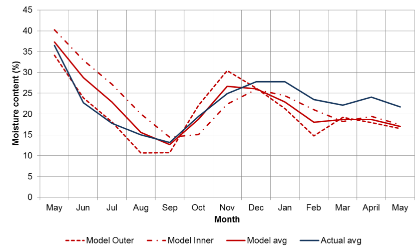


FIGURE 5 – Modeled and actual forest harvest residue average moisture content (wet basis) for High Elev. Douglas-fir forest

- A parametric study is being implemented to learn the effects of piled residue shape, size, porosity, wind direction, and slope.

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