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# Windrowing and Fuel-Chip Quality of Residual Forest Biomasses in North Sweden

*Utilization of forest residual biomasses, including logging residues (LR) and whole tree-parts (WT) from small-diameter trees, in the Botnia-Atlantica region is expected to increase in response to increases in demand from the bioeconomy. LR and WT are often seasoned in windrows (stacks) at forest roadsides, and more knowledge (prior to comminution and / or transport to terminals) of stacks dry mass content would be highly useful for logistic planning and value estimations.*

## AIM OF THE STUDY

The aims of this study were to describe and compare storage conditions and fuel-chip quality of LR and WT windrows, delivered to the same plant by the same supplier during one season, and develop a model for estimating dry mass contents of LR and WT windrows.

## MATERIALS AND METHODS

Bulk LR and WT are stored in windrows at roadsides for drying and balancing supply and demand. Forest fuels are mainly comminuted at forest roadsides/landings, but sometimes at terminals or end-users' facilities.

76 windrows in northern Sweden (Figure 1) were surveyed (measuring height, length and width, amongst other parameters, Figure 2) and chipped (Figure 3). Fuel-chips from 25 windrows were also sampled to assess their moisture content (MC), ash content and particle size distribution.

All material was delivered to a combined heat and power plant belonging to Umeå Energi. Relevant data such as weights, MC, energy content and storage length was provided by the chipper, the energy plant and the forest owner.

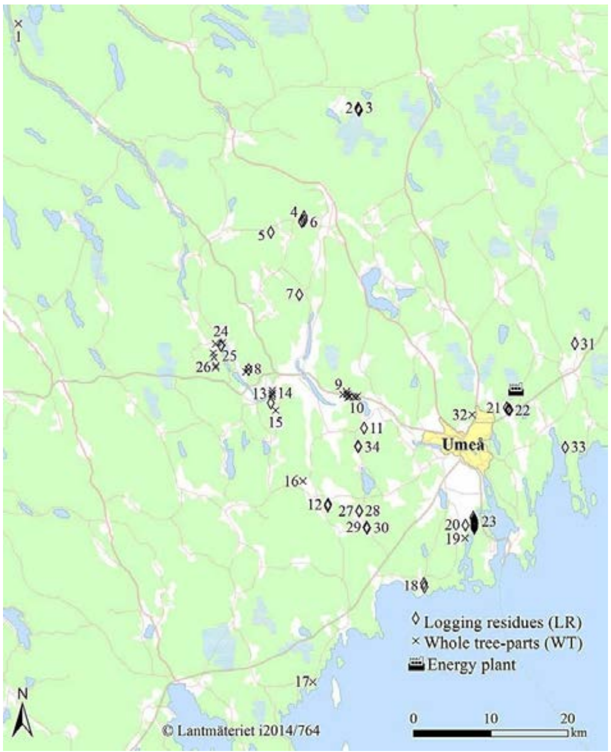


*Figure 1. Sites (numbers) and windrows (rhombuses or crosses) in the study area. Some windrows close to each other cannot be distinguished at the represented scale.*


*Figure 2. Dimension measurements on a windrow approximated, in this example, to a trapezoidal prism.*

## RESULTS

The mean MC (45 %) did not significantly differ between LR and WT, but varied substantially within and between sites. LR fuel-chips had higher ash content than WT: 2.4 % vs. 1.5 %.

LR fuel-chips also had two-fold higher proportions of fines (particle size < 3.15 mm) and oversized (> 63 mm) fractions: 12.2 vs. 5.8 % and 2.2 vs. 1.1 %, respectively.

Fuel-chips from WT had higher quality than LR (less ash, fines and oversized fractions) for the considered enduse, but quality requirements vary dependent on end-user process.

Screening technologies could allow improved use of different particle sizes. For example, fines (which are ash-rich) could be used in biorefinery or potting-soil industries, medium-sized fractions for torrefaction, pelletization or combustion, and coarse fractions for further chipping/shredding.

Fractionation can be combined with wind shifting to reduce amounts of impurities (e.g. stones). The resulting improvements in feedstock quality and logistic efficiency, together with reductions in risks of failure in the feeding systems and damage at end-user facilities could compensate for the extra costs of such systems.

Average bulk densities of LR and WT were 66 and 59 dry kg per bulk m³, respectively. The study enabled development of models for estimating LR or WT windrows' dry mass contents (Figure 4). Models should only be used within the range of bulk volumes observed during fieldwork (72–1729 bulk m³).

Models can be useful for logistic planning (e.g. chipper routes, required comminution times and truck requirements), also, in case the material is transported to terminal for storage or/and comminution (often, small terminals lack of a weighbridge). Models may allow rough economic estimates within given confidence levels, but they should never serve as a basis for payment, due to the large spread in windrow bulk densities.

This study also highlighted the need for holistic supply chain management for cost-effective delivery of high-quality residual forest biomasses, since a poor job in early stages can result in high costs and low product quality in later stages.

*Figure 3. Machine system (forwarder-mounted chipper and chip-truck with self-loading crane) for working at the forest roadside and delivering chips to end-user or terminal.*

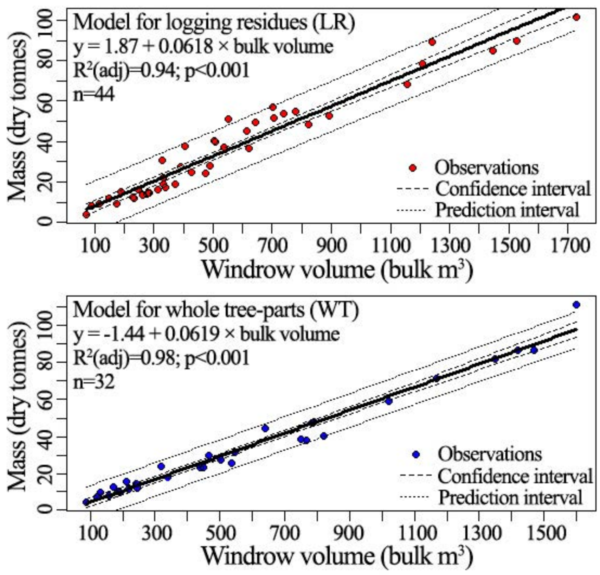


*Figure 4. Models for predicting the mass (dry tonnes) of LR and WT windrows. Confidence intervals and prediction intervals are represented by dashed lines and dotted lines, respectively.*

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**References:**

[1] Raul Fernandez-Lacruz, Dan Bergström. Windrowing and fuel-chip quality of residual forest biomasses in northern Sweden. Submitted manuscript to the International Journal of Forest Engineering.