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# How to Evaluate Downed Fine Woody Debris Including Logging Residues?

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**Abstract:** Volume or biomass estimates of downed woody debris are crucial for numerous applications such as forest carbon stock assessment, biodiversity assessments, and more recently for environmental evaluations of biofuel harvesting practices. Both fixed-area sampling (FAS) and line-intersect sampling (LIS) are used in forest inventories and ecological studies because they are unbiased and accurate methods. Nevertheless, most studies and inventories take into account only coarse woody debris (CWD, >10 cm in diameter), although fine woody debris (FWD) can account for a large part of the total downed biomass. We compared the LIS and FAS methods for FWD volume or biomass estimates and evaluated the influence of diameter and wood density measurements, plot number and size. We used a Test Zone (a defined surface area where a complete inventory was carried out, in addition to FAS and LIS), a Pilot Stand (a forest stand where both LIS and FAS methods were applied) and results from 10 field inventories in deciduous temperate forest stands with various conditions and amounts of FWD. Both methods, FAS and LIS, provided accurate (in trueness and precision) volume estimates, but LIS proved to be the more efficient. Diameter measurement was the main source of error: using the mean diameter, even by diameter class, led to an error for volume estimates of around 35%. On the contrary, wood density measurements can be simplified without much influence on the accuracy of biomass estimates (use of mean density by diameter class). We show that the length and number of transects greatly influences the estimates, and that it is better to apply more, shorter transects than fewer, longer ones. Finally, we determined the optimal methodology and propose a simplification of some measurements to obtain the best time-precision trade-off for FWD inventories at the stand level.

**Keywords:** fine wood; downed woody debris; biomass estimates; forest inventory; line intersects; fixed-area sampling



**Citation:** Korboulewsky, N.; Bilger, I.; Bessaad, A. How to Evaluate Downed Fine Woody Debris Including Logging Residues?. *Forests* **2021**, *12*, 881. https://doi.org/10.3390/f12070881

Academic Editor: Blas Mola-Yudego

Received: 24 May 2021
Accepted: 2 July 2021
Published: 6 July 2021



## 1. Introduction

Logging operations, both thinning and final fellings, usually leave varying amounts and types of residue on the forest floor, including large and small downed woody debris containing small-diameter tree branches, twigs, leaves, stumps, roots, tree-tops and bark. All of this logging residue is generally non-merchantable. Nevertheless, the increased concern of climate change has led many countries to sign commitments aiming to increase the share of renewable energies in the total energy mix, and to rank wood energy in first place to reach this goal. Consequently, mechanically harvesting coppice, low-value stands and logging residues for woody biomass energy production has become more attractive.

After fuelwood harvesting operations, on average, 40–50% of the biomass is left on the ground in the form of logging residues, as reported in recent reviews on boreal and temperate forests [1,2]. Nevertheless, Thiffault, Barrette [2] observed wide variations: from 11% to 96%, depending on the field trial. The country of study was the main factor explaining these variations; Nordic countries, i.e., Sweden and Finland, had a higher average recovery rate (72% of the logging residues harvested) than the other countries, including France. A recent