FOREST GROWERS RESEARCH

HARVESTING TECHNICAL NOTE

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Measuring Woody Residues on Steepland Harvest Landings and Cutovers

Summary

Measuring woody residue volumes as harvests are completed gives the opportunity to build an understanding of the resource without the trial-and-error approach using machinery, labour, and short-term sales of the product(s). This Tech Note details the methods that can be used to measure the accumulations of woody residues along with recommendations to improve the accuracy or efficiency of data collection. The methods cover measuring residues in piles at the landing, both on flat or complex surfaces; and also options for measuring residues that are distributed over the cutover by manual and remote sensing means.

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Introduction

Measuring harvest residue volumes has, historically, been a difficult task to complete with accuracy, and was also one that had little incentive unless used as a harvesting quality assurance measure, or large volumes of merchantable timber clearly remained post-harvest and those required quantification. Now with increasing demand for previously unmerchantable wood fibre, operational knowledge of 'how much', 'where' and 'at what harvesting cost' is increasingly important as the industry markets the material and supports industries that need assurances of long-term supply.

This report leverages existing technologies, established methods, and common software packages to give options to forest operations managers who wish to establish a dataset of residual volumes on harvest sites.

Methods

Accumulations of harvest residues on harvesting sites can be broadly divided into two categories, landing residue piles and cutover residues. The two categories lend themselves to separate measurement methods:

Landing Residue Piles:

Landing residue piles rarely conform to a recognisable geometric shape like a half-dome or a cone, which makes accurate volume assessment from manual measurements prone to inaccuracy. The accessibility of photogrammetry has vastly improved the ability to accurately model the complex pile shapes and therefore, measure volume.

For piles that are located on a near-flat surface such as a landing's working surface, a single 3D photogrammetry mission flown with a UAV is all that is required. This will generate a model of the visible pile surface, and volume analysis relies on the knowledge that the lower surface is reliably represented by the landing surface that surrounds the pile. As an entry point, non-RTK UAV's can often be used for photogrammetry missions, so long as the image overlap is high (target >70% front and side). *Important note:* check compatibility with flight control applications such as DroneDeploy and Pix4D as not all UAV models are compatible.

For piles that drape over complex terrain shapes, such as the landing top and fill slope, or where seated into a natural terrain bench, pre-harvest planning is recommended along with accurate georeferencing via Ground Control Points (GCPs). While many missions for volume estimation do not need georeferencing (per se), this method requires both before and after models to be in the same place in space, requiring the accuracy given by georeferencing.

For best results; following landing construction and prior to logging, set the datum surface for the pile measurement by flying a 3D photogrammetry mission over the proposed storage site. *If using an RTK-enabled UAV*, set at least one Ground Control Point (GCP) (see Figure 1) within the mission boundaries and capture its waypoint with a high-accuracy GNSS receiver. Target sub-10 cm accuracy of the GCP's location where possible. Waypoint accuracy to this degree requires differential correction; which is either achieved on the device in the field or through post-processing, depending on the GNSS receiver and service used. *If using a non-RTK UAV*, target a minimum of four GCP's, spread across the mission in both the x, y and z directions and locate these with the

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high-accuracy GNSS receiver. Good practice is to distribute additional GCPs (with waypoints captured) for use as check points, establishing the model's accuracy.

Figure 1: Ground Control Point target with approximate dimensions of 0.75 x 0.75 m.

When using GCPs, Ground Sampling Distance (GSD) is particularly important when setting up the automated flight and image capture. The GCP target centres need to be located accurately in the photos. A GSD < 3 cm will generally return acceptable results with large GCP targets such as that in Figure 1.

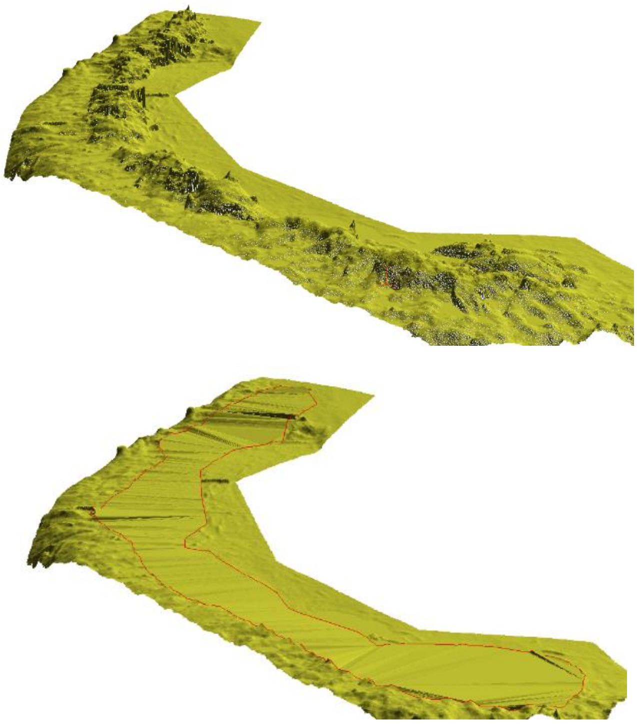


Figure 2: A pile retrieved back onto the (flat) landing surface can have its datum surface interpolated automatically from the terrain surrounding the pile. **Top:** Original pile surface. **Bottom:** Interpolated sub-pile surface.

For piles over complex terrain, a second site visit is required post-harvest, with the same protocols followed as for the pre-harvest UAV mission.

Construction of the photogrammetry model(s) can be completed in software packages such as Agisoft and Pix4D. The basic process is to upload the images into the software, manually locate the GCPs in the images (if GCPs are used), assign the known waypoint locations of the GCPs, build the dense point cloud and output the desired file types (such as *.las* and raster orthophotos).

Finally, pile volume can be computed by the difference in surface heights over the area of the pile. Again, this can be done in several software packages. A straightforward method makes use of the functions in RoadEng Terrain software.

For the pile on the flat surface, produce a duplicate of the model. With the duplicate, cut the pile out of the model and interpolate over the resulting hole to 'close' the surface (see Figure 2). The Calculate Volumes function can then be used to measure the volume that is bounded by the original and duplicated (and interpolated) surfaces – to return the pile's volume. It is best to constrain the analysis to the boundary of the pile. *For the pile draped over a complex surface*, simply constrain the same RoadEng analysis to the boundary of the pile and compute the difference between the before- and after-harvesting surfaces (Figure 3).

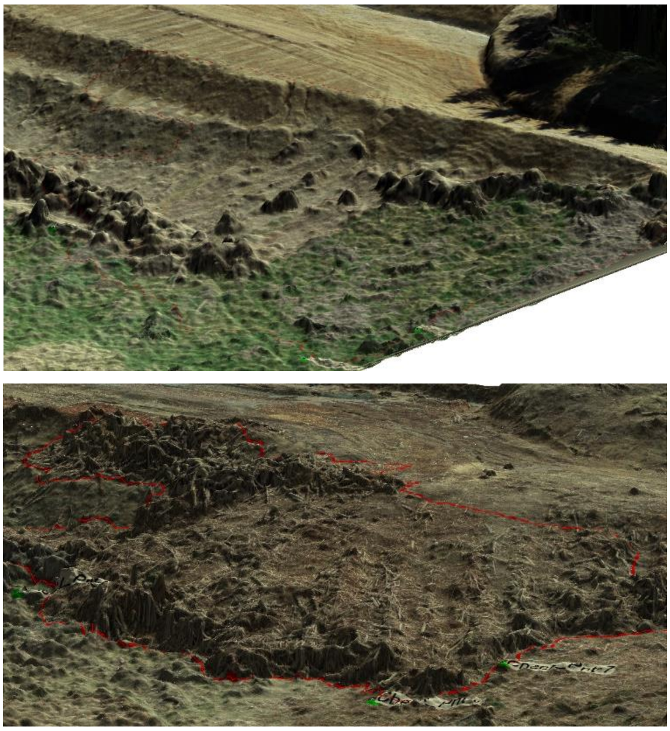


Figure 3: Pre-harvest and post-harvest surface models of the same site. **Top:** Pre-harvest with the landing in place. **Bottom:** Post-harvest with the residue pile covering the previously modelled landform.

With sufficient piles measured, and descriptive statistics collected also, such as the total recovered volume (of logs) to the landing, and log product mix, a predictive model of the residue volume from the estate can be built as the dataset grows over time.

Distributed Cutover Residues:

Measuring cutover residues is a more acute challenge with remote sensing because of their variable depths of accumulation across a cutover.

Several manual Line Intersect Sampling (LIS) methods have been used internationally over the years, based on the principles underpinning Buffon's needle problem (Buffon, 1777). Warren and Olsen popularised the method in New Zealand, with it becoming known locally as the 'Wagner Waste Assessment'. Van Wagner (whom the name is from) credits the work of Warren & Olsen in the published derivation of the basic equation for LIS (Van Wagner, 1968).

This method makes use of Van Wagner's basic equation:

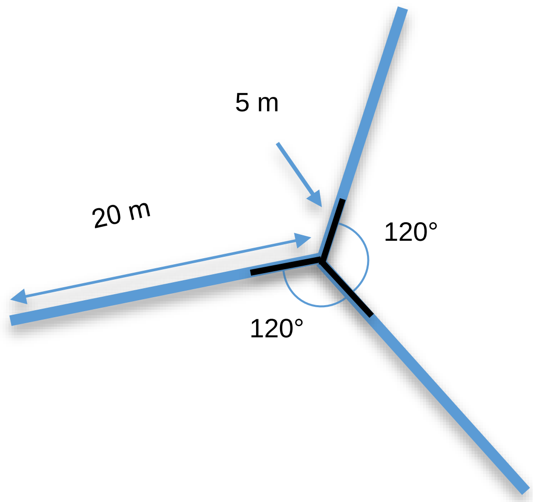
$$V = \pi^2 \Sigma d^2 / 8L$$

Where: V is volume per hectare (m^3/ha), d is the diameter of the intersected residue piece (cm) and L is the horizontal length of transect line (m).

Knowing that woody debris tends to be oriented (somewhat) with the direction of pull and setting up transects can be difficult work on steep slopes, the following method has been developed. It is loosely based on that published by the USFS (USFS, 2011). With a plot centre located, the first 20m transect (length corrected for slope) is laid out in a random direction. All woody material that is greater than a diameter threshold that crosses the transect is measured for diameter at its mid-point. Harvey & Visser (2022) also introduce a 'transect within a transect'; measuring all material down to 25 mm diameter for the first 5 m along the transect, then only material >50 mm in diameter for the remaining 15 m of transect. This 'transect within a transect' approach is not necessary or encouraged for measuring 'harvestable residues'. Instead, set a reasonable limit such as 100 mm as the diameter threshold and measure only material above that threshold for the full 20 m for a more efficient procedure.

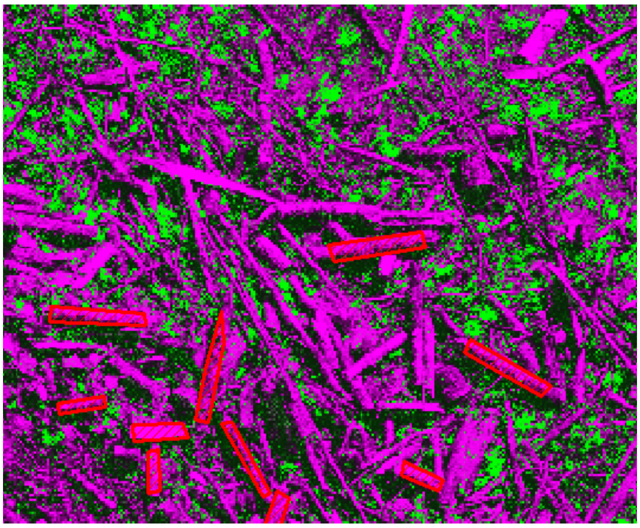
When measurement of the residues that cross the first transect is complete, two more transects of the same length shall be set out at 120-degree intervals and completed, creating a plot with three radial spokes.

With the measures from the three transects collated, a volume per hectare measure for the plot can be calculated using Van Wagner's basic equation above.



<u>Figure 4:</u> Line intersect plot geometry for measuring cutover residues.

Remote sensing alternatives such as supervised image classification and deep learning image segmentation algorithms show increasing promise to improve site coverage, data resolution and cost effectiveness. Further exploration into data collection procedure and processing, along with dissemination with those learnings will assist uptake of these opportunities. Piles of residues may continue to present issues with remote sensing methods (visual obstruction) however the increased resolution is likely to offset this drawback.



<u>Figure 5:</u> False colour image of slash on a cutover with supervised training polygons shown in red.

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