

Residual Woody Biomass Inventory Techniques: A Comparative Analysis of Prism Sweep and Line Intersect Sampling Methods

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Abstract:

Prism sweep and line intercept methods were compared for accuracy and efficiency to measure woody biomass residues on a recently harvested site in Eastern North Carolina. A 100% tally control on 0.1 acre plots was used to compare volume estimates of tested methods. Estimates of residual volume were accurate and not significantly different. Prism sweeps required an average of three minutes per plot, whereas line intersect samples averaged seventeen minutes per plot. Prism sweeps were accurate and five times more efficient than line intersect samples.

Introduction:

Policy and public sentiment are coalescing to promote renewable energy. The most economically available source in North Carolina is woody biomass. Harvesting biomass residues may create markets for diseased and damaged trees, reduce wildfire risk, lessen site preparation costs and allow opportunities to restore unique ecosystems. Studies suggest new markets may significantly increase the amount of harvested total stand biomass (Hess and Zimmerman, 2001). However, woody biomass residues from forest harvesting are important for carbon sequestration, nutrient cycling, wildlife habitat and water quality. Some have expressed concern that market-driven removal of woody biomass will adversely impact site conditions. The total amount of biomass that may be sustainably harvested is unknown. Studies with accurate and efficient sampling methods are needed to inform the dialogue on sustainability. One recent study has been established to compare accuracies and efficiencies of a point relascope sampling method (Brissette et al. 2003). Their study compared line intersect sampling (LIS) to point relascope sampling (PRS) in Northeastern managed forest stands with different silvicultural treatments. Yet, no studies have been established to compare sampling methods on recently harvested forestlands.

Prism sweep sampling is a probability-proportional-to-size method which is a simple, time-saving alternative to other commonly used sampling methods. Prism sweep sampling uses the same principles as point relascope sampling with inexpensive, readily available equipment. Woody biomass to be measured must be subtended by a prism angle where the midpoint diameter viewed from the point center is greater than the critical prism angle. The only required measurement is piece length. The LIS method measures pieces intersected by a chosen line segment. This probability based sampling method requires measuring length and diameter. The goal of this study was to field test and identify the optimal method for estimating woody biomass residues on recently harvested forestlands.

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Objective:

To compare the accuracy and efficiency of sampling methods used to estimate woody biomass residues on an upper coastal plain forest harvest site in North Carolina.

Methods:

Our study was established on a rectangular, nineteen acre site in Johnston County, North Carolina. Six acres of the site was initially composed of eighteen year old naturally regenerated loblolly pine forest (Eyre, 1980) on Marlboro-Cecil soil with an average site index of eighty-two feet at base age fifty (Coile and Schumacher, 1953). Another ten acres was composed of sixty year old loblolly pine-hardwood forest (Eyre, 1980) on Bibb sandy loam, Marlboro-Cecil complex, and Pacolet loam soils. Across this harvest area the average site index was eighty-three feet at base age fifty (Coile and Schumacher, 1953). Select harvested streamside management zones and the logging deck accounted for the remaining three acres of site area.

A systematic grid of fifty potential comparative sampling points was established on the sixteen harvested acres of our study site. These potential comparative sampling points were equally spaced at eighty foot intervals, omitting points within forty feet of the log deck, streamside management zone and property boundary. Twenty of the fifty comparative sampling points were randomly chosen for sampling. Thirteen of these chosen points fell within the loblolly pine-hardwood harvest area and seven in the loblolly pine area. LIS, prism sweep and 100% tally control methods were installed on chosen comparative sampling points to estimate volume of harvest residues and record sampling time. The null hypothesis was that sampling methods were not significantly different from another ($H_0: X_1=X_2=X_3$) where X_1 , X_2 , and X_3 are the means of 100% tally, LIS and prism sweep sampling respectively. The main contrast was comparing line intersect and prism sweeps to 100% tally controls. The dependent response variable was the woody biomass residues left on site.

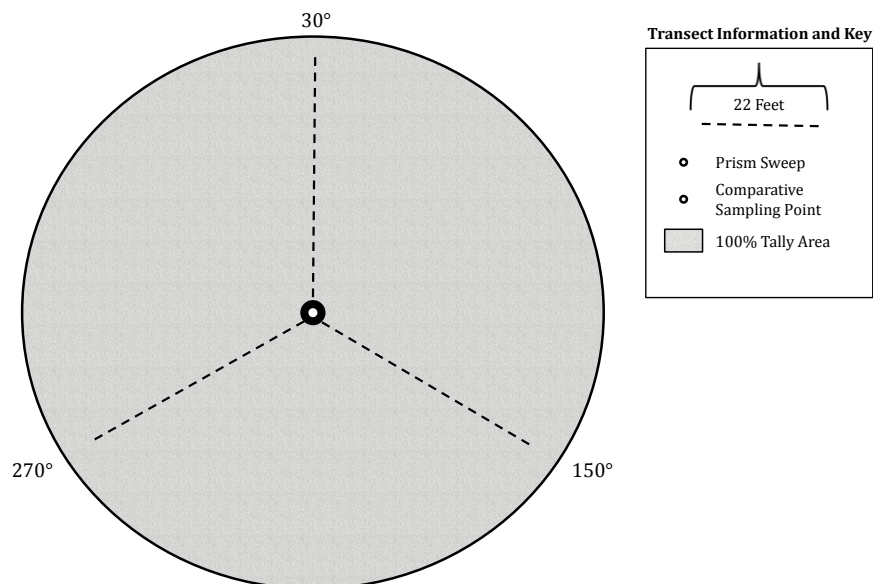


Figure 1. Comparative sampling design for prism sweep, LIS, and 100% tally control methods.

100% Tally Sampling (Control)

100% tally controls measured all woody biomass residues within a 0.1 acre fixed-radius circular plot centered at each selected comparative sampling point. All woody biomass residues within the area of inclusion greater than one inch in diameter and one foot in length were measured for total length, small and large end diameter, percent bark, and species. Length was measured to the nearest foot and diameter to the nearest inch.

Prism Sweep Sampling

Prism sweeps were installed at the center of each comparative sampling point. All woody biomass with a midpoint diameter greater than the critical prism angle was tallied. Tallied pieces were measured for total length, percent bark and species. Time to complete each point was recorded to the nearest half minute.

Line Intersect Sampling

Line intersect samples were installed at the center of each comparative sampling plot. Three transects were established at 30°, 150°, and 270° azimuth. Each transect was precisely twenty-two feet in length. Pieces intersected by transects were measured for length, small and large end diameter, species and percent bark. Length was measured to the nearest foot and diameter to the nearest inch. Time to complete each sample was recorded to the nearest half minute.

Results and Discussion:

On our study site, estimated volumes of tested methods did not statistically differ. Prism sweeps were five times more efficient than line intersect samples. Piles and clumping of harvest residues strongly impacted the measurement time of line intersect samples. This may account for the relatively wide range of LIS sampling times.

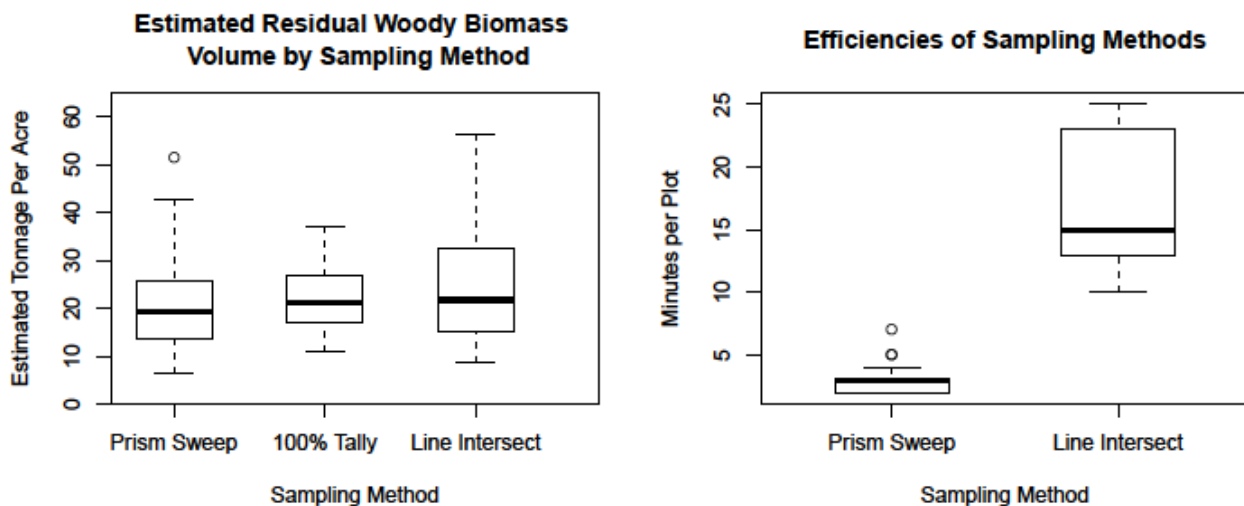


Figure 1. Boxplots of estimated woody biomass volume and efficiency by sampling method.

Conclusions:

Time is commonly the most limiting factor to inventory harvest residues. Prism sweeps allow users to quickly and accurately estimate volume of residual woody biomass. Compared to LIS, prism sweeps tally less and have minimal set up time. Compass orientation, transect measurement and user travel significantly decrease LIS efficiency. Similar results were noted by Brissette et al. (2003) who sampled for downed woody biomass in forested sites. Using LIS volume formulas which accounted for piece taper (Woodall and Williams, 2005) resulted in superior estimates than those which applied the quadratic mean diameter (Van Wagner, 1968). If possible, large and small end diameter should be recorded for accurate volume estimation. Prism sweeps should be used if spatial orientation of residues or size is not important for inventories.

Literature Cited:

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Appendix I:

Table 1 Descriptive Statistics for Estimated Volume (Tons/Acre) for Tested Methods and 100% Tally Control

Method	Mean	Std Err Mean	Confidence Interval (95%)	
Line Intersect	26	3.1	19.5	32.5
Prism Sweep	21	2.5	15.8	26.3
100% Tally	22.3	1.6	19.0	25.7

Table 2 Degrees Freedom, Sum of Squares, Mean Squares, F Ratio, and P Value for Sampling Methods Efficiencies in Minutes to Complete Each Plot.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Sampling Method	2	249	124.5	1.01	0.36
Error	57	6983.5	122.5		
C. Total	59	7232.5			

Table 3 Waller-Duncan K-Ratio t Test for Estimated Residual Volume (tons/acre)

Waller Grouping	Mean	N	Method
A	26	20	Line Intersect
A	22.3	20	100% Tally
A	21.0	20	Prism Sweep

Table 4 Descriptive Statistics for Time to Complete Plots (Minutes) for Prism Sweeps and Line Intersect Samples

Method	Mean	Std Err Mean	Confidence Interval (95%)	
Line Intersect	17.1	0.8	15.3	18.9
Prism Sweep	3.1	0.8	1.3	4.9

Table 5 Analysis of Variance (ANOVA) for Tested Sampling Methods

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Sampling Method	1	1960	1960	128.61	< .0001
Error	38	579.1	15.2		
C. Total	39	2539.1			

Equation 1 FIA Line Intersect equation for volume in ft³/acre (Smalians) on the plot on per-unit-area basis (Y_d)

$$\frac{43560}{144} \left[\frac{\frac{\pi^2}{16} \sum_{j=1}^4 \sum_{m=1}^3 \sum_r (DS_{jmr}^2 + DL_{jmr}^2) \delta_{jmr}}{\sum_{j=1}^4 \sum_{m=1}^3 L_{jmr}} \right]$$

Equation 2 FIA Line Intersect equation for volume in ft³/acre (Smalians) for the piece (Y_{jmt})

$$\frac{(\pi/8)(DS_{jmr}^2 + DL_{jmr}^2)l_{jmr}}{144}$$