United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

P.O. Box 245
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Research Note
PSW-365

July 1984

Slash Prediction: a test in commercial thinnings in northeastern California

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Weatherspoon, C. Phillip; Fiddler, Gary O. *Slash prediction: a test in commercial thinnings in northeastern California.* Res. Note PSW-365. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture; 1984. 5 p.

Two slash prediction handbooks commonly used in California do not use data from California. To test predictions of the handbooks in northeastern California, logging residues from commercially thinned young-growth stands were surveyed. Measured residues were compared to handbook predictions. Species represented were ponderosa pine, California white fir, California red fir, and Douglas-fir. Only for the 3- to 6-inch (7.62- to 15.24-cm) residue size class in ponderosa pine was the mean difference between predicted and measured loadings significantly different from zero. For the forest types and stand conditions sampled, the handbooks appear to predict residue amounts reasonably well. Managers who require greater accuracy for particular applications may need to adjust these predictions to account for local stand conditions and harvest practices.

Retrieval Terms: forest residues, slash prediction, residue inventory, commercial thinnings, ponderosa pine, true firs, northern California

Commercial thinning to increase yields from young-growth timber stands is a practice that is gaining wider use throughout California. When harvested, young stands do not produce as much residue as older stands, but amounts generated and values at risk usually are sufficient to require some treatment. Residual crop trees often complicate residue management. If treatments—whether mechanical (including utilization) or prescribed fire—are improperly selected or applied, they can damage the stand unacceptably. Volume loss from decay associated with mechanical wounding—especially in true fir stands—is significant,[1] and bole wounds resulting from fire are apt to cause similar loss. But stands left untreated or inadequately treated could be lost to wildfire or pests. The forest manager, therefore, must decide on a residue treatment regime that is adequate, has minimal adverse effect on the stand, and is cost-effective.

Two handbooks for predicting quantities of residues that will be produced,[2,3] on the basis of species, size, and number of trees to be cut, provide a useful tool for improving residue management decisions. They include slash prediction tables that have been widely used in California. Neither handbook, however, uses data from California. And we know of no tests of these predictive tables under California conditions. A study designed to investigate several aspects of commerical thinning provided an opportunity to do such a test for selected young-growth stands.

This note reports a survey of logging residues from commercially thinned young-growth stands on two National Forests in northeastern California, and compares amounts of residue predicted by published handbooks with those measured. Results indicate that the handbooks provide reasonable estimates for the forest types and stand conditions sampled.

METHODS

Logging residues were surveyed in 13 cut blocks of commercially thinned young-growth stands on the Lassen and Shasta-Trinity National Forests in northeastern California from 1976 to 1980. Stands were naturally established and less than 100 years old. Four species were represented: ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), California red fir (*Abies magnifica* A. Murr.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). Individual blocks were composed primarily of a single species *(table 1)*.

The planar intersect technique[4] was used to inventory downed woody material before and after thinning on each cut block.[5] Different transects and sample planes were used on the two occasions. Fresh slash was not distinguished from older material in the postlogging inventory.[5] Size classes of woody material[4] sampled were: (a) 0 to 3 inches (7.62 cm), and 3 inches and

Table 1—*Block and species, average diameter-at-breast-height (d.b.h.), number, and volume of cut trees per acre on cut blocks in northeastern California*

Block and species		Average d.b.h. of cut trees	Cut trees per acre	Cut volume per acre
		inches		*MBF*
P1	Ponderosa pine	10	92	3.7
P2	Ponderosa pine	12	36	1.8
P3	Ponderosa pine	10	174	5.7
P4	Ponderosa pine	9	72	2.6
P5	Ponderosa pine	10	86	2.6
P6	Ponderosa pine	13	39	4.4
P7	Ponderosa pine	12	57	4.4
P8	Ponderosa pine	12	25	1.5
T1	True fir [1]	12	126	12.8
T2	True fir	13	125	14.2
T3	True fir	13	51	5.4
T4	True fir	12	80	6.7
D1	Douglas-fir	13	72	10.3

[1] True fir stands contained more than 90 percent California white fir, and the balance, California red fir.

larger in the true fir units; (b) 1 inch (2.54 cm) to 3 inches, and 3 inches and larger for the ponderosa pine units; and (c) 3 inches and larger for the single Douglas-fir unit. Procedures outlined by Brown[4] were used to calculate the amounts of residue in tons per acre for pre- and postlogging residues. The difference in these two values provided an estimate of the amount of residue produced by the logging. This difference is referred to hereafter as "measured" loading of residues.

We used cruise data on species and number of trees to be harvested by diameter-at-breast-height (d.b.h.) class to predict quantities of logging residue for the same 13 cut blocks, using handbooks by Brown and others[2] and Snell and Brown.[3] (For convenience, the handbook by Brown and others,[2] published by the Intermountain Forest and Range Experiment Station, will be referred to hereafter as "the INT handbook." The handbook by Snell and Brown,[3] published by the Pacific Northwest Forest and Range Experiment Station, will be called "the PNW handbook.") For stand conditions and logging methods in this study, residue from trampling or damage to trees not harvested was insignificant. For ponderosa pine stands, crown class data were used to make the recommended[2,3] adjustments of crown weights for shade-intolerant species. The California Region (USDA Forest Service) Timber Appraisal Cruise Report (TACR) provides predicted slash data for cruised timber sales. Its predictions are identical to those in the PNW handbook, so a separate test was not needed.

Current tools for predicting fire behavior[6] require loading estimates for fuels < 3 inches in diameter. Larger residues are also of interest for several reasons, including utilization potential and resistance to suppression. Therefore, we separately compared measured and predicted loadings for residues (a) <3 inches, (b) $\geq$3 inches, and (c) total.

To ensure valid comparisons of the same residue components, adjustments to both planar intersect data and predicted slash weight per tree were necessary. The following corrections were made:

- Because rotten material should not be a component of logging slash in these young stands, rotten material >3 inches was deleted from pre- and postlogging inventories to eliminate one source of sampling error.
- Since cull and breakage were virtually negligible in these stands, no cull and breakage component was added to the table predictions. Trees were utilized to a 6-inch (15.24-cm) top and slash prediction tables for a 6-inch top were used, so with no cull and breakage, material > 6 inches in diameter would not be a part of the predicted residue. Therefore, to reduce sampling error further, material > 6 inches was deleted from pre- and postlogging inventories.
- Predicted slash weight per tree was adjusted to eliminate foliage and to segregate woody residues into < 3-inch (0 to 3 inches for true fir, 1 to 3 inches for ponderosa pine) and 3- to 6-inch components. In the INT handbook, the adjustment was accomplished for each d.b.h. class by multiplying appropriate crown component fractions by crown weight per tree, and adding the proper tip weight components. In the PNW handbook, equations in Brown[7] were used to calculate the weight of foliage (and 0- to 1-inch woody material for ponderosa pine) to subtract from table values for 0- to 3-inch loadings. Predicted weights for > 3-inch residues were directly available as table values in the PNW handbook.

RESULTS AND DISCUSSION

Measured loadings of residues in each size class are plotted against those predicted in the two handbooks in *figure 1*. Numbers adjacent to data points correspond to block designations in *table 1*, and so permit comparisons of stand characteristics with slash production. Standard errors for measured loadings in the ponderosa pine units ranged from 0.5 to 1.5 tons per acre (1.1 to 3.4 t/ha) for the < 3-inch and 3- to 6-inch size classes, and from 0.8 to 2.1 tons per acre (1.8 to 4.7 t/ha) for the combined (< 6-inch) size class. Standard errors for the same size classes in the true fir units were higher—1.2 to 2.4 tons per acre (2.7 to 5.4 t/ha) for the < 3-inch and 3- to 6-inch size classes, and 1.6 to 3.7 tons per acre (3.6 to 8.3 t/ha) for the < 6-inch size class. The single Douglas-fir unit had a standard error of 1.4 tons per acre (3.1 t/ha) for the 3- to 6-inch size class. In most instances, these standard errors are substantially greater than 20 percent of the mean, the level of precision that many fuel managers accept as a nominal standard in residue inventories. The reasons are these: (a) Each measured value represents a difference between two independent (pre- and postlogging) inventories, so the measured mean is less than the postlogging value and, frequently, even less than the prelogging value. (b) The standard error of this difference incorporates the error of both inventories from which it is derived.

The variability associated with estimating logging slash as a difference between two inventories probably accounts for much of the scatter of points (including a few negative values) around the 45-degree line in *figure 1.* Also, this source of variability is apt to be relatively more significant for commercial thinnings, with their moderate slash production, than for heavier volume cuts. (A single postlogging inventory of fresh slash could have produced more precise estimates, although dead branchwood is difficult to assess by that method.)

Other sources of error include the slash prediction algorithms used in the two handbooks, and the logging and stand condition variables discussed on page 35 of the PNW handbook. These errors are complex, and an estimate of their size was not attempted. Their approximate magnitude, however, may be inferred from the statement in the INT handbook that standard errors for equations to predict one slash component—live crown weight—range from 30 to 64 percent of mean values, and that predictions for stands should be more accurate than those for individual trees.

With all these sources of variability considered, overall agreement of predicted and measured loadings probably is reasonable. Agreement apparently is better than that reported in a similar test in an old-growth Douglas-fir–western hemlock stand in Oregon.[3]

We used a series of paired t-tests to determine if predicted and measured loadings differed significantly. Only for the 3- to 6-inch residue size class in ponderosa pine was the mean difference between predicted and measured loadings significantly different from zero *(table 2).* Predictions from both handbooks exceeded measured values

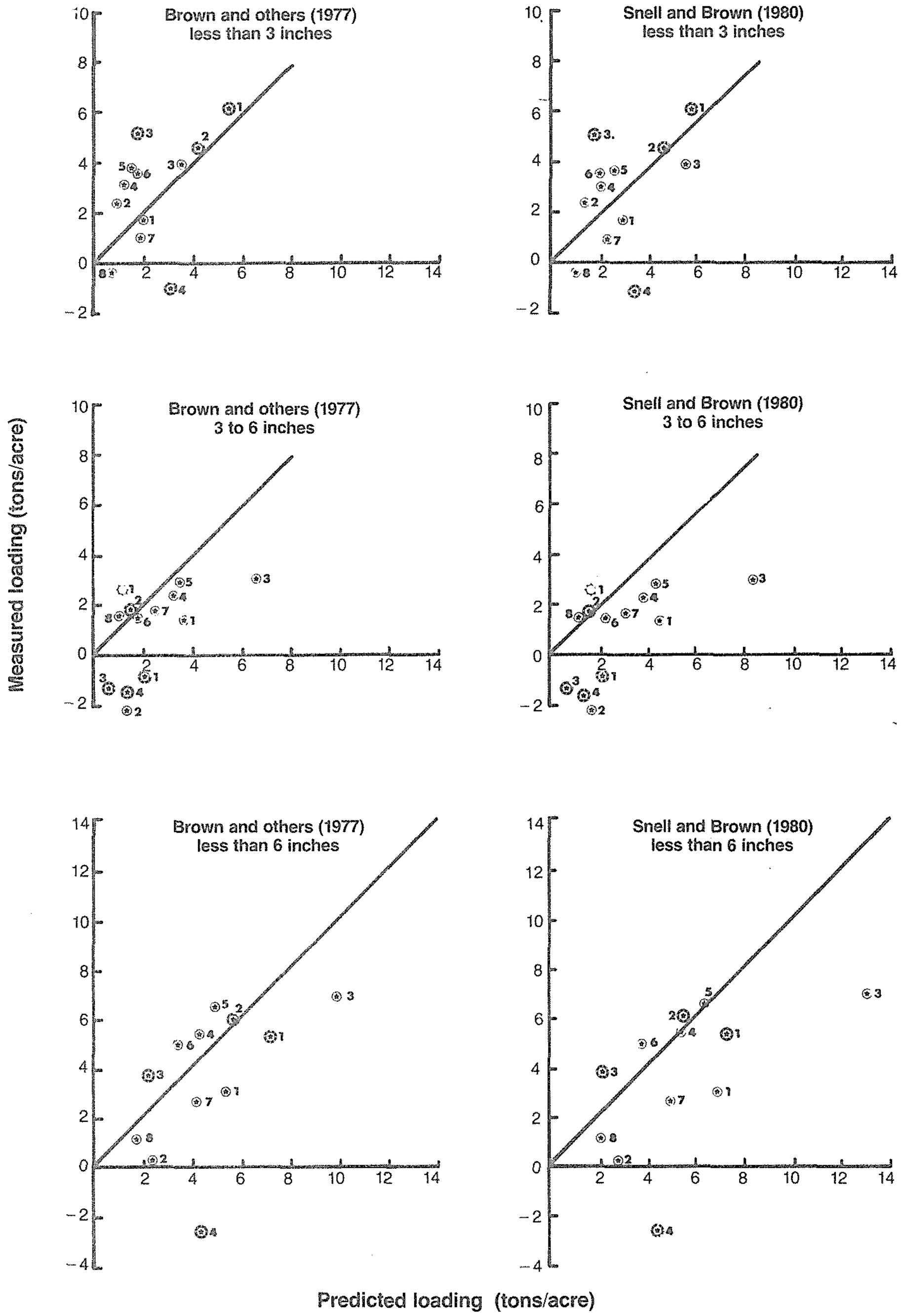

Figure 1—Measured and predicted loadings for three size classes of residue. Statistically significant differences between measured and predicted loadings were found only for ponderosa pine in the 3- to 6-inch size class.

⊙ Ponderosa Pine
⊛ True Fir
○ Douglas-fir

in this size class. For all other residue categories, the two handbooks appeared to give unbiased predictions of measured slash loadings. Possibly we could not detect real differences between predicted and measured loadings because of the substantial variability and associated broad confidence limits for some categories in *table 2.* Even if variability masked real differences, however, all mean differences were less than 2 tons per acre (4.5 t/ha)—probably close enough for most purposes for which slash predictions are needed. Significantly greater accuracy probably cannot be expected from the two handbooks except by developing local adjustments or cali-

Table 2—*Mean difference between predicted and measured loadings, by size class of residue, species, and slash prediction handbook*

Residue size class (inches)	Predicted minus measured loading (tons per acre) [1]					
	Ponderosa pine (n=8)		True fir (n=4)		Douglas-fir (n=1)	
	INT handbook [2]	PNW handbook [3]	INT handbook [2]	PNW handbook [3]	INT handbook [2]	PNW handbook [3]
[4] <3	−0.70 ±1.10	−0.07 ±1.17	−0.10 ±4.97	−0.06 ±5.11		
3 to 6	1.34 ±1.26*	1.87 ±1.45*	1.81 ±2.19	1.78 ±2.19	−1.45	−1.10
[5] <6	0.63 ±1.56	1.80 ±2.01	1.71 ±5.93	1.71 ±6.09		

[1] Confidence limits are for 95 percent probability level. Asterisk indicates significant (5 pct level) mean difference between predicted and measured loadings on the basis of paired t-test. No t-test was possible for the single Douglas-fir stand.

[2] See item 2 in Notes section.

[3] See item 3 in Notes section.

[4] 1 to 3 inches for ponderosa pine, 0 to 3 inches for true fir.

[5] 1 to 6 inches for ponderosa pine, 0 to 6 inches for true fir.

brations, in which situation handbook predictions would provide a good first approximation.

For ponderosa pine, the PNW handbook provided consistently higher predictions than the INT handbook. This difference resulted in predictions closer to measured loadings for 1- to 3-inch residues from the PNW handbook, and for 3- to 6-inch and 1- to 6-inch residues from the INT handbook. The 1- to 6-inch grouping is relatively less subject to sampling error than are its component parts and, therefore, is probably a better measure of overall comparative suitability of the predictive algorithms. The closer fit by the INT handbook in the 1- to 6-inch residue size range tends to confirm the advice of Snell and Brown[3] to confine use of the PNW handbook to stands west of the summit of the Cascade Range, and to use the INT handbook for predictions east of the Cascades. The pine stands in our study are typical eastside pine.

The two handbooks gave virtually identical residue predictions for the true fir stands. As with ponderosa pine, predictions tended to differ most from measured loadings in the 3- to 6-inch size class, although these differences were not statistically significant at the 5 percent level. For the true fir stands, however, most of the differences may be attributable to sources of error associated with determining measured loadings, because three of the four stands showed negative slash production in the 3- to 6-inch size class. Chance relationships of sampling lines to skid trails or other logging patterns may have resulted in greater than normal sampling error. Other possible reasons include crushing of considerable 3- to 6-inch material by tracked skidders, thereby reducing it to smaller size classes, and removal of more upper bole than was required by the 6-inch utilization standard.

Less slash was predicted than was measured in the single Douglas-fir stand. On the basis of the standard error of the measured loading, the difference was not statistically significant at the 5 percent level.

We believe the data in *table 3* may be useful to fuel managers planning residue inventories[4] in young-growth eastside pine and true fir stands in northern California.[8] The values for coefficient of variation provided in the table can be used to estimate the number of sample points needed for a given inventory.[9] The values also reflect homogeneity of the various fuelbed components. The true fir fuelbeds sampled were substantially more uniform than those of the ponderosa pine stands. Fuelbed homogeneity, however, increased after harvesting in pine, but decreased after harvesting in true fir. The consistently higher coefficient of variation in the 3- to 6-inch size class suggests the need for longer total sample plane lengths for > 3-inch material in these residue complexes if precision comparable to that for other size classes is desired.

CONCLUSIONS

The slash prediction test described cannot be considered conclusive be-

Table 3—*Mean coefficient of variation of loading estimates from individual sample points,[1] using Brown's[4] technique for inventorying downed woody material*

Residue size class (inches)	Coefficient of variation (pct)				
	Ponderosa pine		True fir		Douglas-fir
	Preharvest	Postharvest	Preharvest	Postharvest	Postharvest
[2] < 3	130	86	31	41	
3 to 6	277	110	79	121	94
[3] < 6	121	70	36	44	

[1] Based on sample plane lengths of 6 ft for 0- to 1-inch residue, 12 ft for 1- to 3-inch residue, and 50 ft for > 3-inch residue.

[2] 1 to 3 inches for ponderosa pine, 0 to 3 inches for true fir.

[3] 1 to 6 inches for ponderosa pine, 0 to 6 inches for true fir.

[4] See item 4 in Notes section.

cause of the relatively high variability of the results. This problem of high variability is probably inherent in such a comparison. We believe, however, that for the forest types and stand conditions sampled, the appropriate handbook (or algorithms on which its tables are based) provides slash predictions that are satisfactory for most residue management decisionmaking. For applications requiring greater accuracy, such as biomass utilization contracts, managers may need to use local inventory data to adjust or calibrate predictions to account for local stand conditions and harvest practices. Results of this paper should not be used for such calibrations. Predictions of total slash production are likely to be more reliable than those of component size classes. We recommend use of the INT handbook for predicting slash in the California eastside pine type.

NOTES

[1] Aho, Paul E.; Fiddler, Gary; Srago, Mike. *Logging damage in thinned young-growth true fir stands in California and recommendations for prevention.* Res. Paper PNW-304. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1983. 8 p.

[2] Brown, James K.; Snell, J. A. Kendall; Bunnell, David L. *Handbook for predicting slash weight of western conifers.* Gen. Tech. Rep. INT-37. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1977. 35 p.

[3] Snell, J. A. Kendall; Brown, James K. *Handbook for predicting residue weights of Pacific Northwest conifers.* Gen. Tech. Rep. PNW-103. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980. 44 p.

[4] Brown, James K. *Handbook for inventorying downed woody material.* Gen. Tech. Rep. INT-16. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1974. 24 p.

[5] The single exception was the Douglas-fir block, in which new 3- to 6-inch slash was inventoried only after logging.

[6] Puckett, John V.; Johnston, Cameron M.; Albini, Frank A.; Brown, James K.; Bunnell, David L.; Fischer, William C.; Snell, J. A. Kendall. *Users' guide to debris prediction and hazard appraisal.* Missoula, MT: Northern Region, Forest Service, U.S. Department of Agriculture; 1979. 37 p.

[7] Brown, James K. *Weight and density of crowns of Rocky Mountain conifers.* Res. Paper INT-197. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1978. 56 p.

[8] The single number for Douglas-fir, based on only one stand and one residue size class, may be of limited value.

[9] $$n = \left(\frac{CV}{PE}\right)^2$$

in which

n = number of sample points
CV = coefficient of variation (in percent)
PE = specified percent error (in percent)

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