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Jeffrey T. Olson, Allen L. Lundgren, and Dietmar Rose

North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture

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North Central Forest Experiment Station
John H. Ohman, Director
Forest Service — U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108

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EQUATIONS FOR ESTIMATING STAND ESTABLISHMENT, RELEASE, AND THINNING COSTS IN THE LAKE STATES

Jeffrey T. Olson, *Forest Economist,*
Michigan Department of Natural Resources,
Lansing, Michigan,
Allen L. Lundgren, *Principal Economist,*
North Central Forest Experiment Station,
St. Paul, Minnesota,
and **Dietmar Rose,** *Associate Professor,*
University of Minnesota, St. Paul, Minnesota

Cost estimates are required as basic inputs when evaluating forest management projects, allocating funds, and planning programs. Forest managers often do not have the data necessary to relate project cost to resource and job factors. Cost estimates, applicable over a wide geographic area and a variety of forest conditions, would be useful in reviewing the potential benefit of forest treatments and in better understanding the costs of forest management.

The Lake States of Minnesota, Michigan, and Wisconsin have a wide diversity of forest conditions. Within this region, certain common treatments, such as site preparation and planting make up a significant share of the cost of forest management. Treatment costs vary widely from project to project, and much of the variation can be attributed to either resource or job conditions.

Wickstrom and Alley (1967) point out that due to the lack of uniformity from one job to the next, treatment costs must be modified by the effect of certain other factors such as: (1) size of area treated; (2) accessibility; (3) work done such as number of trees planted, size and number of trees felled, etc.; (4) work conditions such as brush cover, down material, slope, and soil type.

Yoho, Dutrow, and Moak (1969) presented average costs of treatments commonly carried out in the Southeast. Cost estimates were based on response of forest landowners to a questionnaire. Because such cost averages cannot account for a variety of forest or job conditions, they are limited in application.

Hillicker, Webster, and Tritch (1969) studied the cost of forest treatments in Wisconsin and found that certain factors could be used as primary cost determinants. Project costs were estimated in terms of hours rather than in their dollar equivalents; thus, the cost estimators were likely to be applicable to more cases and for a longer time since the cost was not affected by variations in wage rates, cost of materials, and inflation. The equations they developed are limited, however, by the small sample size and the time that has passed since their results were reported. As a result, new cost estimates are needed for the Lake States.

Conkin (1971) identified several factors that were expected to influence input times for forest treatments. However, because so few observations of costs were available, Conkin was able to develop only a few relations, and for some treatments could only report an average cost.

Although these studies provide suggestions as to factors affecting costs, the results reported are either too limited in scope or too outdated to be used directly in estimating current costs for forest treatments in the Lake States.

This paper presents the results of a study to develop more current estimates of the costs of silvicultural treatments in the Lake States.

PROCEDURES

Public and private forest landowners in the Lake States were contacted to obtain data for the study. One of the authors visited each landowner (either a public land management agency or a corporation) that indicated willingness to participate. After we reviewed their records we eliminated all but two of them. The two chosen, both public land managment agencies in Minnesota and Michigan, kept detailed records of each project undertaken, including:

(1) location and type of treatment project
(2) system used in carrying out the project
(3) size of the area treated
(4) factors that measure the amount of work done
(5) other factors that influence cost
(6) labor cost
(7) supervisory cost
(8) equipment cost
(9) cost of materials used
(10) total project cost in dollars.

The first five data categories in the list above were used as independent variables. Data were available to develop cost equations for six treatments: hand plant, machine site-preparation, aerial spray, prescribe burn, manual release, and thin.

Regressions were run of total project cost against the independent variables listed for each forest treatment. Variables to be included in each treatment equation were selected using Mallows' C_p statistic[1] as computed by an interactive computer program.[2] The program allows the user to select the best fitting model from the set of possible regressions. This is done through inspection of residuals and the behavior of the model over the range of the data. Only direct project costs were included wherever possible, although overhead costs may have been included as a part of the project cost when reports were prepared. No control over how the data was reported was possible. Data was taken for projects completed during January 1 to December 31, 1976.

It was theorized that the total cost of a treatment project could be expressed as an equation of the following form:

TPC = FC + VC

where:

TPC = total project cost

FC = fixed project costs

VC = variable project costs expressed as some function of independent variables

Regression analysis was used to fit an equation of the general form shown above to the samples for each specific treatment system and method. Functions to estimate the cost per acre of treatment projects were not developed directly since the variance in cost is greater for smaller projects than for larger projects, making it necessary to weight the samples by project size (Wickstrom and Alley 1967). Estimated cost per acre may be found by dividing the estimated cost of the total project by project acreage.

Total project acreage (AC) was expected to be important in all six treatment cost functions. In addition, trees planted per acre (TPA) was expected to be a consideration in planting, basal area removed (BAR) in thinning and manual release. Dummy values were assigned in estimating machine site preparation projects, separating type of operation (OP) into pulling (−1) and pushing (+1). Important independent variables, and their minimum, maximum, mean, and standard deviation values, are presented in table 1.

COST FUNCTIONS

For each treatment, cost functions are presented in the following discussion. The cost functions are compared with the data used in derivation. The residuals as a percent of the range in observed costs, standard errors of prediction, and equation R^2 values are presented for each equation discussed (table 2).

[1]*The C_p statistic is a measure of the sum of the squared biases plus the squared random errors for the proposed regression at all data points. For an equation with negligible bias the C_p value is equal to the number of terms in the equation (Daniel and Wood 1971).*

[2]*The interactive regression program used was MULTREG, developed at the University of Minnesota School of Applied Statistics by Asst. Prof. Sanford Weisberg.*

Table 1.— Description of basic data used in developing cost equations for six stand establishment, release, and thinning site treatment activities in the Lake States

Site treatment	Number of projects	Size of area Mini-mum	Maxi-mum	Mean	Standard deviation	Number of trees Mini-mum	Maxi-mum	Mean	Standard deviation	Basal area removed Mini-mum	Maxi-mum	Mean	Standard deviation
		(Acres)				(1000/acre)				(sq.ft./acre)			
Hand plant	43	2	50	10.5	9.4	0.47	1.5	0.94	0.17	–	–	–	–
Machine site-preparation	28	2	118	27.5	28.8	–	–	–	–	–	–	–	–
Aerial spray	36	4	276	53.0	63.9	–	–	–	–	–	–	–	–
Prescribe burn	25	3	140	20.4	22.4	–	–	–	–	–	–	–	–
Manual release	16	10	320	67.0	53.0	–	–	–	–	10	28	18.7	5.7
Thin	38	8	250	52.4	47.0	–	–	–	–	20	70	38.0	10.5

Table 2.— Summary of cost equation statistics

Site treatment	Residuals as percent of range in observed costs Minimum	Maximum	Average	Standard errors of pred. over range of observed cost Minimum	Maximum	Average	Square root of residual mean square	R^2
	(Percent)			(Dollars)				
Hand planting	0.13	12.0	3.0	232	278	237	229.10	0.93
Machine site preparation	0.26	16.0	4.0	269	304	276	262.16	.96
Aerial spray	0.07	12.0	3.0	116	135	118	124.58	.95
Prescribed burning	0.32	40.0	9.0	105	136	110	102.05	.79
Manual release	3.70	33.0	12.0	427	474	438	415.35	.87
Thinning	0.62	7.0	3.0	191	209	194	188.50	.82

1. Hand planting

$$Y = 43.82 + [41.298 + 0.050894(TPA)] AC$$

Costs included are labor, supervision, planting stock, and transportation. The range in observed costs was \$4860, with a minimum observation of \$140 and a maximum of \$5000. The maximum residual (observed minus predicted) was within 12 percent of the range in cost. Standard errors of prediction averaged \$237 over the observed range in cost, ranging from \$232 to \$278. Using two standard errors as a guide to confidence, on the average, the cost function can be expected to estimate true project cost within \$474. Data was taken from 43 projects carried out in Minnesota. Fixed charges are \$44 per project. Variable costs are \$41 per acre and \$51 per thousand trees planted per acre. Equation R^2 is 0.93. To better illustrate the range of costs, total costs and cost per acre for various sized projects have been graphed from this equation for planting 500 and 1,000 trees per acre (fig. 1). These indicate that costs per acre for hand planting are relatively constant for areas larger than 10 to 20 acres in size.

2. Machine site preparation.

$$Y = 86.50 + [33.910 - 7.068(OP)] AC$$

Costs included are labor, supervision, transportation, fuel and associated equipment operation costs directly attributable to the project. The range in observed costs was \$4,650 with a minimum cost of \$47 and a maximum of \$4,701. The maximum residual was within 16 percent of the range in cost. Standard errors of prediction averaged \$276 over the range in observed costs, ranging from \$232 to \$278. The cost function on the average, can be expected to estimate project cost within \$552. Data was taken from 28 projects in Minnesota. Fixed charges are \$86 per project. Variable costs are \$34 per acre ±\$7 per acre depending on whether it is a machine pushing (−\$7) or machine pulling (+\$7) operation. Use of this term (OP) serves to distinguish between the differences in work the machine must perform. Equation R^2 is 0.96. The predicted cost per acre increased sharply for projects less than 20 acres in size (fig. 2).

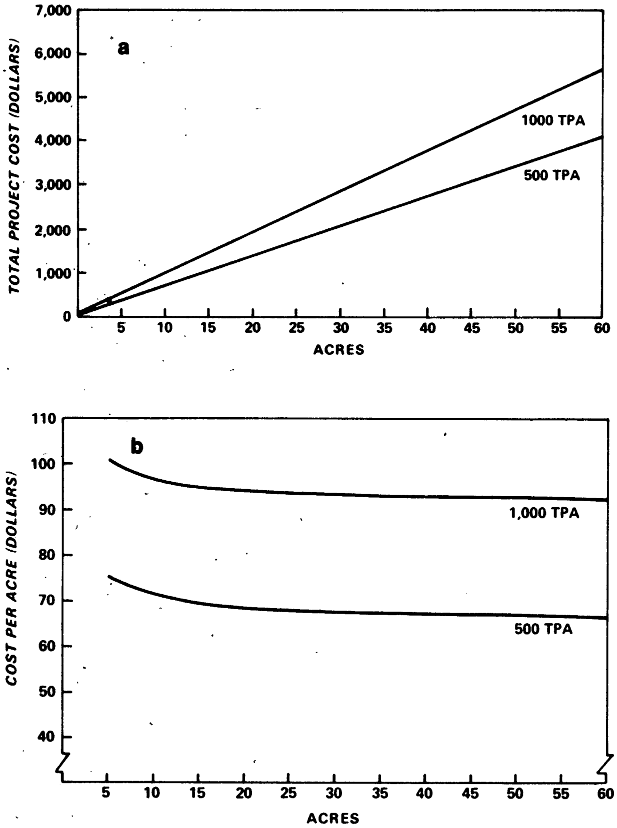

Figure 1.— *Cost of hand planting in the Lake States by size of planting area, 1976.*

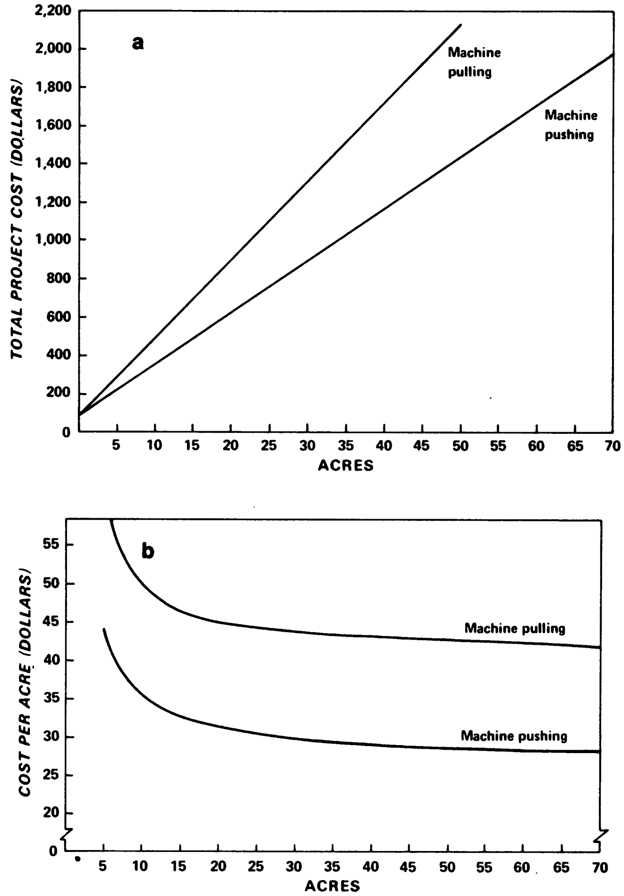

Figure 2.— *Cost of machine site preparation in the Lake States by pushing and pulling operations by size of project areas, 1976.*

3. Aerial spray.

$$Y = 3.43 + 8.734\ (AC)$$

Costs included are supervision, labor, chemical cost, fuel cost, aircraft rental, and the cost of a pilot. The range in observed cost was $2,573, with a minimum observation of $74 and a maximum of $2,647. The maximum residual was within 12 percent of the range in cost. Standard errors of prediction averaged $118 over the range in observed costs, ranging from $116 to $135. The cost function, on the average, can be expected to estimate true project cost within $236. Data was taken from 36 projects in Minnesota. Fixed charges are $3 per project and variable costs are $9 per acre. Equation R^2 is 0.95. The predicted cost per acre increases sharply for projects less than about 40 acres in size (fig. 3).

4. Prescribed burning

$$Y = 0.69 + [23.824 - 0.499(AC) + 0.0038(AC^2)]\ AC$$

Costs included are supervision, labor, fuel, equipment and machine charges directly attributable to the project, and transportation. The range in observed costs was $703, with a minimum of $67, and a maximum of $770. The largest residual fell within 40 percent of the range in costs. Standard errors of prediction averaged $110 over the observed range in cost, ranging from $105 to $136. The cost function, on the average, can be expected to estimate true project cost within $220. Fixed charges of −$.69 would indicate that no fixed costs were included in the sample. As burning projects were carried out by agency personnel instead of contractors, the lack of a fixed charge per project

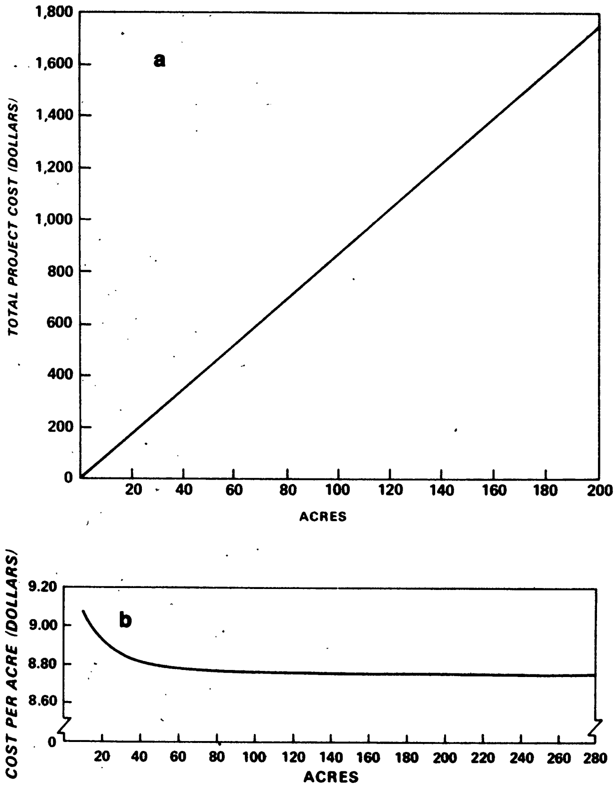

Figure 3.— *Cost of aerial spraying in the Lake States by size of project area, 1976.*

seems plausible. Variable costs are $24 per acre, with an additional charge of −$.50 per square of project size, and $.004 per cube of project size. Equation R^2 is 0.79. The data indicate that cost per acre for prescribed burning is strongly affected by size of project area, and is lowest when the area to be burned is about 60 acres (fig. 4).

5. Manual release

$$Y = 73.36 + [.948(BAR)] AC$$

Costs included are supervision, labor, chemicals, and transportation. The range in observed costs was $2,660, with a minimum of $274 and a maximum of $2,932. The largest residual fell within 33 percent of this range. Standard errors of prediction averaged $438, ranging from $427 to $474. On the average, the cost function can be expected to estimate true project cost within $876. Fixed charges are $74 and variable costs are $.95 per square foot of basal area removed per acre. Equation R^2 is 0.87. Costs per acre for manual release increase rapidly for areas less than about 20 acres in size (fig. 5).

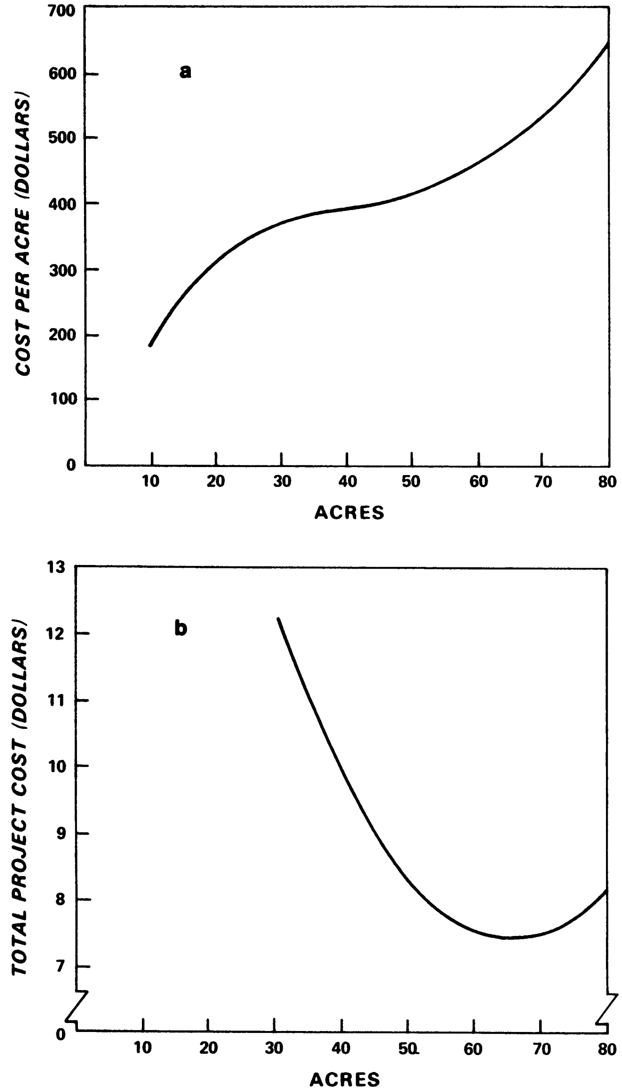

Figure 4.— *Cost of prescribed burning on level ground in the Lake States by size of project area, 1976.*

6. Thinning

$$Y = 120.29 + [0.418(BAR)] AC$$

Costs included are supervision, labor, transportation, and fuel and oil for chainsaws. The range in observed costs was $5,258. The largest residual was within 7 percent of the range in costs. Standard errors of prediction averaged $202 over the range in observed costs, varying from $191 to $209. Most of the time, cost estimates derived from this function can be expected to be within $404 of the true project cost. Fixed charges are $120, and variable charges per acre are $.42 per square foot

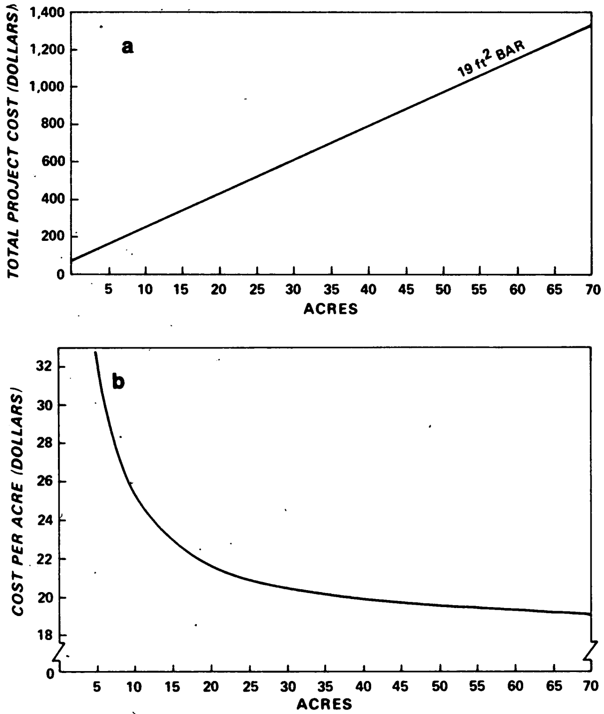

Figure 5.— *Cost of manual release in the Lake States for 19 square feet of basal area removed per acre (the mean for the observations) by size of project area, 1976.*

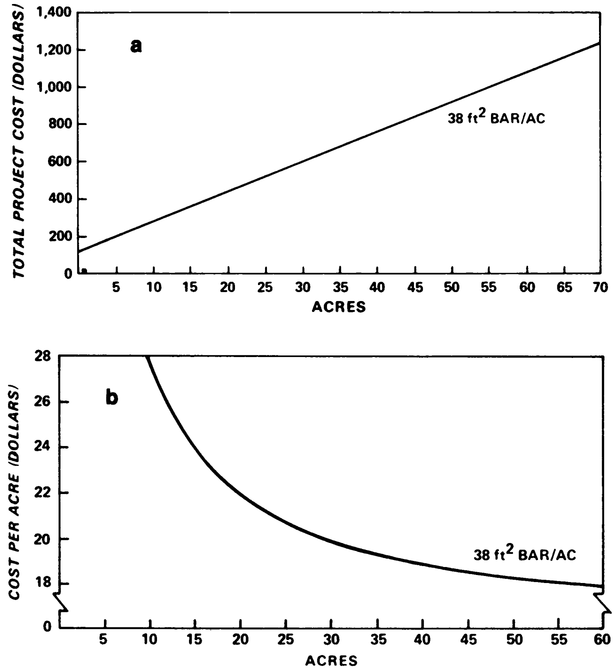

Figure 6.— *Cost of manual thinning in the Lake States for 38 square feet of basal area removed per acre (the mean for the observations) by size of project area, 1976.*

of basal area removed. Equation R^2 is 0.82. Figure 6 presents a plot of the predicted values over the range of data.

DISCUSSION

Cost equations that may be used to estimate costs of proposed forest treatment projects have been developed from records of actual projects. To illustrate, assume a hand planting project is proposed. Seven-hundred fifty trees per acre will be planted on 40 acres. The equation is:

$$Y = 43.82 + [41.298 + 0.050894(TPA)]\ AC$$

Putting in the trees per acre and number of acres to plant, the cost is:

$$Y = 43.82 + [41.298 + 0.050894(750)]\ 40$$
$$Y = \$3223$$

Dividing the estimated total project cost of $3,223 by the number of acres in the project (40) gives a per acre cost of $80.56. The true project cost, however, may differ to some extent from the estimate. Based on the average standard error of prediction, the true project cost most of the time will not differ from the estimate by more than $474, or 15 percent of the estimated cost.

The cost estimators were derived from records of projects conducted during 1976; the predicted costs then, are in terms of 1976 dollars. As time proceeds, the estimates from these equations must be adjusted to account for the effect of inflation. This adjustment is most easily achieved by substituting the estimated project cost into the compounded single payment formula, using the inflation rate as i, as shown below:

$$V_n = V_o\ (1 + i)^n$$

where:

V_n = future value

V_o = value estimated from 1976 cost function

i = inflation rate as a decimal

n = numbers of years since 1976

Unless technological changes occur that alter the type of systems used and the relation between cost and the independent variables presented earlier, the above adjustment provides a simple means of determining the future costs of projects.

CONCLUSIONS

Six equations were derived from existing project records. The equations allow estimation of total project cost for certain forest treatments. Confidence in estimates obtained from the equations is limited to two prediction standard errors. High R^2 values were obtained for each equation presented, indicating that the independent variables included in an equation are useful predictors of total project cost. The order of R^2 values was logical, with the highest R^2 terms being obtained for the most highly mechanized projects. The more labor-intensive projects were found to have lower R^2 terms. Fixed and variable costs could be identified from the equations. The equations presented appear to be reasonable predictors of cost for the Lake States.

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OXFORD: 651.6:681. KEY WORDS: Cost equations, site preparation, planting, prescribed burning, release, thinning.

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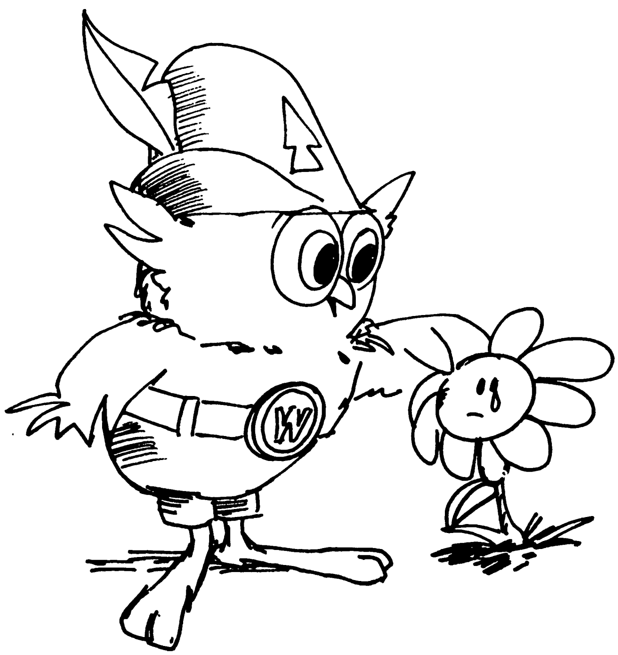

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