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MAFES
MISSISSIPPI AGRICULTURAL &
FORESTRY EXPERIMENT STATION
James H. Anderson, Director
Mississippi State University, Mississippi State, MS 39762

By
James E Moak

MAN-POWER REQUIREMENTS FOR CONTINUOUS FOREST INVENTORY (CFI)

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ABSTRACT

During the establishment of a Continuous Forest Inventory system on the Mississippi ate University School Forest where a total of 324 circular plots 1/5 acre in size were stalled, a time study was made on 212 of the plots. Three different crew organizations re used. Crew A, where two men made one trip to the plot; Crew B, where two men cated and laid out the plot and three men returned later to make and record the asurements; and Crew C, where three men made two trips to the plot.

The weighted average of field time requirements, including travel time, was 7.42 an-hours per plot. It took 3.5 man-hours per plot for travel and off plot activities, and 93 man-hours per plot making the within plot measurements. The number of trees easured per plot was the most important factor determining time requirements within e plot. Crews A and B were equally efficient in number of trees measured per man-hour hile crew C was significantly slower.

Prediction equations for time requirements within the plot were developed for all ree crew organizations. Under existing conditions the organization of crew B, where o men make the first trip to the plot followed by three men on a second trip seemed to ve some advantages. Man-hour requirements for within the plot activities for crew B uld be estimated if number of trees to be measured on the plot and the sum of their ameters were known.

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INTRODUCTION

Continuous Forest Inventory or CFI s been used as a management tool by rest managers for over 30 years in the iited States and for about 20 years in e South. And in 1965[1] it was estimated at there were over 130,000 permanent ots being maintained on approximately ; million acres in this country. Stott deribes CFI as a proportional sampling stem based upon circular plots within hich all living trees above a specified b.h. are measured, described, recorded ı punch cards or tape, machine comled, and analyzed in whatever segreitions of the data are needed.[2] Recent :velopments since this definition by :ott have led to widespread use of varible radius plots.

During the field installation of a CFI 'stem on the Mississippi State University chool Forest, a time study was made to etermine man-hour requirements for varus activities involved in locating and esiblishing the plots.

PROCEDURE

The field establishment plan called for ie systematic location of two one-fifth cre circular plots within each 40-acre ompartment. Essentially the plot layout epresents a line plot grid with the lines paced 20 chains apart and the plots paced 10 chains apart along the line.

There are approximately 8 thousand

Figure 1. Driving a metal stake which designates the center of the permanent plot.

Figure 2. Measuring the tree heights with a Haga Altimeter.

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[1]Reported by Shain in 1965, "CFI in Amerian Forest Management," Quarterly Bulletin, 'ol. 47, No. 3, Michigan State Agric. Expt. Sta.

[2]Stott, Calvin B. 1968. "A short history of ontinuous forest inventory east of the Missisippi." Jour. For. Vol. 66, No. 11.


Figure 3. Establishing the plot radius with a 100 foot tape.

Figure 4. Numbering the tree with paint

aes in the School Forest, but due to sne open spaces and irregularities the tal number of plots established was :4. These were permanently marked th a center stake which was witnessed l two trees where possible. All live trees thin the plot 4-1/2 inches d.b.h. and lger were numbered, tagged, measured, d the data recorded on mark sense rds.

The time study covered 212 sample ots in 128 different 40 acre mpartments, 8 timber types, 4 density asses, 4 site classes, and a range in trees easured on an individual plot from 0 to '. The sample also included three differ-t crews. Crew A, with two men making e trip to the plot had 28 observations; ew B, with two men locating and laying t the plot and three men returning to ish the measuring had 125 observa-ns; and crew C, with 3 men taking two ps to the plot had 59 observations.

Distance traveled by pickup to the ots ranged from 10 to 18 miles, with an average of 14 miles. On 53 of the sample plots the researcher traveled with the crew and recorded the time for 7 distinct activities with a stop watch to the nearest 1/100 of a minute for everything except travel time which was recorded to the nearest minute. For the other 159 plots, the tallyman on the crew recorded the time for five distinct activities to the nearest minute. Data on a sub-sample of 22 plots were recorded by the researcher who did nothing but record the time on 10 distinct activities.

DISCUSSION OF RESULTS

Table 1 gives the number of plots and man-hours required for establishment by three different crew organizations. As shown in the table, crew C, the three-man crew making two trips to each plot spent significantly more man-hours per plot; however, this was due primarily to higher man-hour travel time. While off the plot time was only 34 percent of the total for crew A, it was 50 percent for crew C.

able 1. Man-hour requirements for CFI plot establishment by three different methods on the MSU School Forest.

Crew and Method	No. of Plots	Man-hours per plot		
		Total Time	Within Plot	Off Plot
A - 2 men, one trip	28	7.81	5.11	2.70
B - 2 men first trip, 3 men second trip	125	6.42	3.33	3.09
C - 3 men, two trips	59	9.37	4.64	4.73
Total Plots	212			
Weighted Average		7.43	3.93	3.50

Early in the study it was apparent, as one would suspect, that the number of trees which were measured on the plot had a significant effect on the time required for plot establishment. Therefore, a more meaningful comparison of the crews can be made by allowing for a difference in the number of trees measured on the plot.

Crew efficiency within the plot can be compared by the number of trees that were measured per man-hour. Table 2 shows a comparison on this basis. Here we find that crew B was the most efficient in terms of actual work performed. Statistically crew B was 19.6 percent more efficient at the .05 level of confidence than crew C, but not significantly more efficient than crew A. Neither was crew A significantly more efficient than crew C.

Off Plot Activities

Many specific tasks were performed while the crews were establishing the plots. Table 3 gives the mean time spent in each of the off plot activities.

A rather high percentage of the off plot time was taken up in driving from the campus to the forest, 44 percent. This was an average of about one and one-half man-hours per plot established. Travel was along improved roads and the average distance was 14 miles one way.

The compartmental boundary lines in the forest had been previously brushed out and painted; therefore, the crews chained down these to the mid-point of the compartment and designated and marked a tree as a "point of beginning" or PB. They then proceeded by compass and chaining in a cardinal direction for five chains to the plot center.

It took less than half as long to chain 10 chains along the compartment boundary than it did to chain 5 chains into the interior of the compartment. This was possible because the compartmental boundaries were well marked and brushed out while it was necessary to run a compass line and, in most cases, cut brush going into the interior.

Table 2. Trees measured per plot and per man-hour within the plot for CFI plot establishment on the MSU School Forest.

Crew and Method	No. of Plots	Trees measured per plot	Trees measured per man-hour
A - 2 men, one trip	28	33.4	6.54
B - 2 men first trip, 3 men second trip	125	24.9	7.48
C - 3 men, two trips	59	26.3	5.67
Total Plots	212		
Weighted Average		26.4	6.72

Table 3. Man-hours required for off plot activities while establishing CFI plots on the MSU School Forest.

Task	No. Obs.	Average Man-hours per Plot	Percent of Total Off Plot Time
iving to forest	55	1.54	44.10
aining from corner to PB[1]	51	0.16	4.48
rking PB[2]	51	0.13	3.77
aining from PB to plot[3]	58	0.45	12.84
xed (overlapping, not separate)[4]	58	1.22	34.81
Total		3.50	100.00

1/ Chaining from compartment corner 10 chains to a suitable tree to used as a PB.

2/ Marking a tree expected to remain several years with a large PB in int and attaching a metal tag for identification purposes, to be used as "point of beginning" from which to locate the plot for remeasurement.

3/ Chaining 5 chains in a cardinal direction inside the compartment establish the center of the plot.

4/ Other activities such as gathering up instruments and tools, arching for the compartment corner, and other miscellaneous preparation ior to leaving the vehicle.

On Plot Activities

After locating each plot center many pecific activities were necessary in completing the plot establishment. Many of hese were distinct enough so that the ime spent on each of them was recorded eparately. Table 4 shows the time breaklown within the plot.

The most time-consuming activity (47 percent) was taking the height measurenents of the trees. This involved four neasurements on the sawtimber trees and three on the pulpwood size ones.

Measuring Tree Heights

During the measuring of tree heights a stop watch was used to obtain time for individual measurements. The job was divided into five operations. Distances from the base of the trees were measured with a 100' tape, then from these points the height measurements using the Haga Altimeter were made for (1) total height of the tree, (2) pulpwood height, (3) sawtimber height, and (4) height to live crown.

Table 4. Man-hours required for within the plot activities while establishing CFI plots on the MSU School Forest.[1/]

Item	No. Obs.	No. Trees Measured on Plot (Average)	Average Man-hours per Plot	Percent of Tota[l] within Plot Time
Witness Plot Center	54	27.2	0.43	10.92
Number Trees	22	35.0	0.14	3.48
Tag Trees	27	34.6	0.26	6.63
Measure d.b.h.	31	31.5	0.42	10.77
Measure Tree Heights	54	31.4	1.85	47.10
Mixed (overlapping)[2/]	23	---	0.83	21.10
Total			3.93	100.00

1/ Two-man crew.

2/ Miscellaneous jobs such as getting plot density, type, reproduc[ti]on count, mark 4-1/2 foot point on trees, determine site and size class, smooth trees for marking, and lost time.

Table 5 shows the average time in minutes required for one man to measure individual trees. The person measuring the trees decided which base distance to use. Generally 100 feet was used only if the trees were over 75 feet tall. As one would expect, it took longer to measure out 100 feet and 50 feet than it did either 30 feet or 25 feet. However, it took longer on the average to measure out 25 feet than for 30 feet. This was probably due to the use of 25 feet only in case of thick briars or undergrowth.

In this particular study these five measurements for tree heights were needed to meet detailed information requirements. Many firms who use CFI would not take all of these measurements.

Table 6 has been prepared to illustrate how one might use Table 5 data in this event. In using the Haga Altimeter, distance must be measured in order to o[b]tain total height. Therefore cumulati[ve] times are presented for distance plus a[ny] additional measurements.

Figure 5 shows a comparison of t[he] time it took to measure the various heig[ht] components in pine type and in har[d]wood types. All of the measuremen[ts] took significantly more time in hardwo[od] types than in pine types except for tot[al] height (at the .05 level of significance).

One might suspect that this would [be] the case for the individual height me[a]surements. It is not much harder to dete[r]mine the top of hardwood trees than pi[ne] in order to sight with the Haga, but d[e]ciding the point of merchantability [in] hardwoods generally takes more tim[e] than for pines. And also picking out th[e] dead length or base of the live crow[n] tends to be harder on hardwood tree[s] than on pine.

Table 5. Average time for one man to take height measurements on individual trees with the Haga Altimeter on CFI plots.

Distance from tree in feet	Item	Measurement					Sum of all measurements
		Distance	Total Ht.	Pulpwood Ht.	Sawtimber Ht.	Ht. to Live Crown	
100	minutes	0.89	0.36	0.26	0.34	0.23	2.07
	no. obs.	54	54	52	39	47	
50	minutes	0.85	0.32	0.31	0.27	0.27	2.02
	no. obs.	764	764	589	207	640	
30	minutes	0.34	0.29	0.20	0.21	0.20	1.23
	no. obs.	352	352	293	34	332	
25	minutes	0.60	0.29	0.13	---	0.13	1.15
	no. obs.	59	59	6	---	29	
Weighted Avg. Minutes		0.70	0.31	0.27	0.28	0.24	1.79
Total Observations		1229	1229	940	280	1048	---

Table 6. Cumulative time to measure various height measurement components in measuring individual trees on CFI plots.

Item	Distance from Tree				Weighted Average
	100	50	30	25	
	---------- Minutes for one man ------------				
Distance	0.89	0.85	0.34	0.60	0.70
Distance plus total height	1.25	1.17	0.63	0.88	1.01
Distance plus total height plus pulpwood height	1.51	1.48	0.83	1.02	1.27
Distance plus total height plus pulpwood height plus sawtimber height	1.84	1.75	1.04	---	1.55
Distance plus total height plus pulpwood height plus sawtimber height plus height to live crown	2.07	2.02	1.23	1.15	1.79

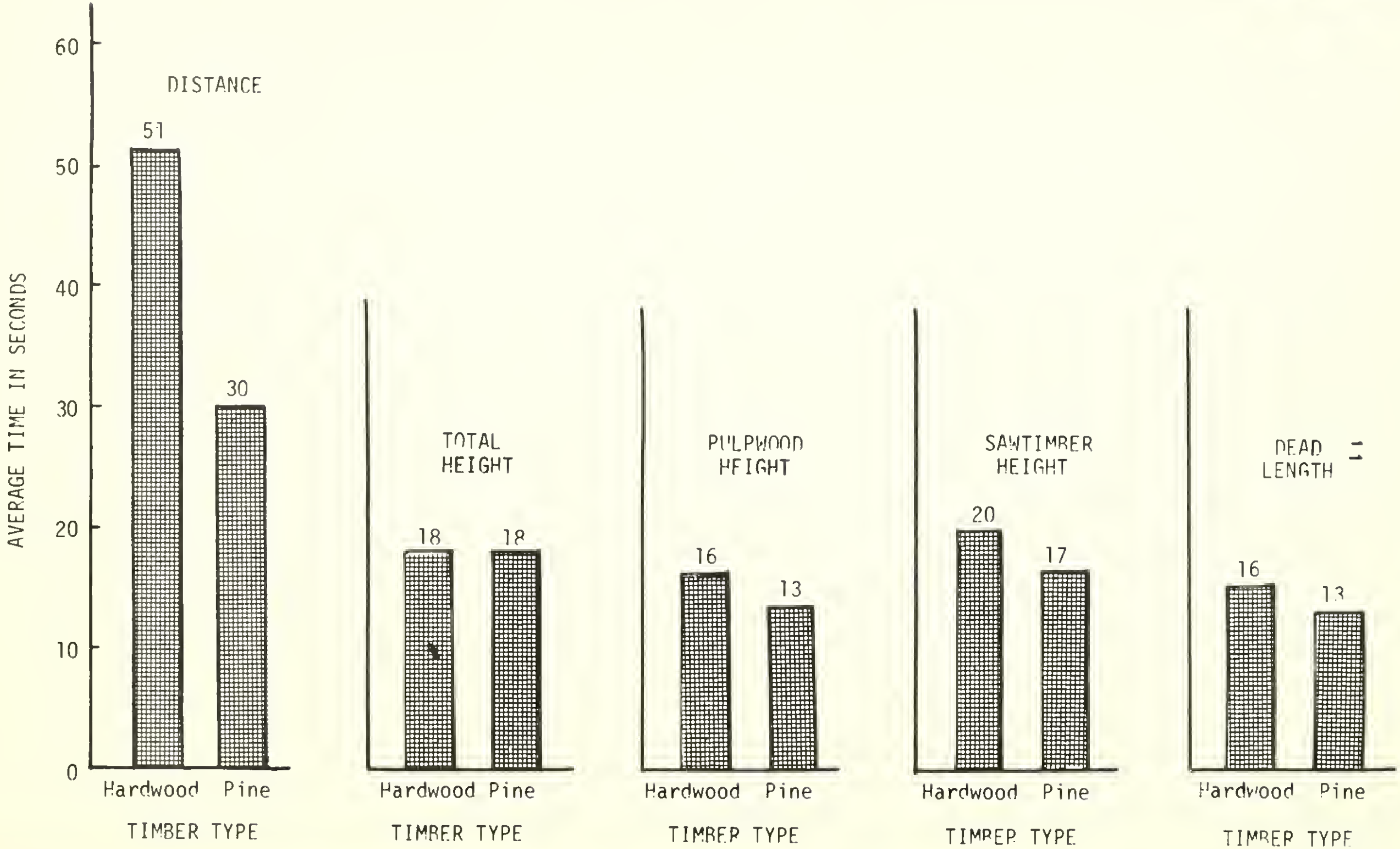


Figure 5. Average time to measure out from the tree and make tree height [illegible]
[illegible] types on CFI plots on the MSU School Forest.

Stand Conditions

All of the plots were not located in the same stand and site conditions; therefore, it seemed desirable to see whether stand conditions affected performance. Apparently it made no difference in performance between establishing plots in the bottomlands and the uplands, since all of the crews performed just as well in one as the other. However, the density of the stand in which the plots were established did make a difference. Crew C did much better in high density bottomland stands, those which had 70 percent and over crown closure, than in low density bottomlands. And in the uplands, all crews showed significantly better performance in high density stands than they did in low. Table 7 shows this comparison.

Table 7. Trees measured per man-hour within the CFI plot in uplands on the MSU School Forest.

Crew	High Density 70% and over crown closure		Low Density Under 70% crown closure	
	No. Obs.	Trees per Man-hour	No. Obs.	Trees per Man-hour
A	7	7.7	8	4.1
B	87	7.3	22	5.6
C	25	6.3	15	3.8
Average All Crews		7.1		4.5

When looking at the average of all crews, we find that performance in the stand types was 51 percent better in high density stands than in low density stands. This can probably be explained by two factors. In low density stands more time would be lost in going from tree to tree and with a sparse overstory more brush and low brush would be present.

As previously stated covering all plots established, crew B performed much better than crew C while within the plot. After further analysis it was found that crew B's performance was not significantly better than C's in high density stands, but was 30 percent better in low density stands. Therefore, it is concluded that since crew C had 3 men performing all within plot measurements while crew B had only 2 for many of them, dense stands could keep 3 men busy and thin stands could not.

Another point must be considered, however. Almost half of the within plot time was spent in measuring the tree heights. Table 8 shows crew B was 46 percent faster in measuring tree heights than crew C in low density stands, even though the tree heights were measured during the time when each crew had 3 men participating. Thus it appears that part of the difference in performance is a difference

Table 8. Trees measured per man-hour for height measurements by crews nd plot density on CFI plots on the MSU School Forest.

Crew	High Density 70% and over crown closure		Low Density Under 70% crown closu	
	No. Obs.	Trees per Man-hour	No. Obs.	Trees per Man-hour
A	19	7.0	9	4.1
B	103	7.3	22	5.6
C	41	6.7	18	3.8
Average All Crews		7.1		4.7

in crew capability. Crew B was not significantly faster in measuring tree heights in low density stands than crew A.

In addition to different densities, the plots fell in different timber size classes. Three classes have been recognized for this analysis. Seedling-sapling stands, where at least 2/3 of the trees were below 3.5 inches d.b.h.; poletimber stands, where at least 2/3 of the trees fell between 4" and 12" d.b.h.; and sawtimber stands, where at least 2/3 of the t[illegible]s were 12" d.b.h. and above. Table 9 sh[illegible]s performance by each of the crews witn each of these stand classifications. Th e was no significant difference between p[illegible]formance of the crews in the seedl[illegible]sapling stands, but crew B performed [illegible]0 percent better in the poletimber sta[illegible]s than crew C and 54 percent better in s[illegible]timber stands than crew A. The ab[illegible]e holds when we consider all within p[illegible] activities.

Table 9. Trees measured per man-hour within the CFI plots by crews and size classes on the MSU School Forest.

Crew	Size Class of Plot: Seedling-sapling		Poletimber 4"-12" dbh		Sawtimber 12" dbh and p	
	No. Obs.	No. Trees	No. Obs.	No. Trees	No. Obs.	No. Trees
A	5	4.6	17	7.2	6	4.0
B	16	4.6	61	8.3	48	6.2
C	7	3.0	24	6.9	28	5.6
Average All Crews		4.1		7.5		5.3

It is also of interest to see how all crews combined performed within different size classes. For all within the plot activities as judged by trees measured per man-hour, all crews performed much better in poletimber stands than in either the seedling-sapling or the sawtimber stands. Crew A performed 80 percent better in poletimber stands than in sawtimber and 57 percent better than in seedling-sapling stands. Crew B was 80 percent faster in poletimber stands than in seedling-sapling ones and 34 percent faster than in the sawtimber stands. Crew C was more than twice as fast in poletimber stands than in seedling-sapling stands and [illegible] percent faster than in sawtimber stands. Crew C was also 85 percent faster in sawtimber stands than in seedling-sapling stands.

Table 10 shows performance of each of the crews within these stand size classifications in measuring the tree heights. Again there was no significant difference in performance between the crews in the seedling-sapling stands. However, in the poletimber stands crew B was 26 percent faster than crew C and 21 percent faster than crew A. In sawtimber stands crew B performed 36 percent better than crew A.

All three crews measured tree heights faster in poletimber stands than in sawtimber stands. However, only crew B measured faster in poletimber than in seedling-sapling stands.

Crew A was 49 percent faster in poletimber than in sawtimber stands, while crews B and C were 32 percent and 33 percent faster respectively. Crew B was also 30 percent faster in poletimber stands than in seedling-sapling stands.

Crew A

A sub-sample of 20 plots which were established by crew A were used for a very detailed time study. This crew made only one trip to the plot and completed all measurements before leaving, except in a few cases when they were unable to finish on a given day and had to return the following day to complete the job.

It was believed that with accurate measurements of stand conditions and other

Table 10. Trees measured per man-hour for height measurements by crews and size classes on CFI plots on the MSU School Forest.

Crew	Size Class of Plot					
	Seedling-sapling		Poletimber 4"-12" dbh		Sawtimber 12" dbh and up	
	No. Obs.	No. Trees	No. Obs.	No. Trees	No. Obs.	No. Trees
A	5	10.6	17	15.8	6	10.6
B	16	14.7	61	19.0	48	14.5
C	7	12.6	24	15.1	28	11.4
Average All Crews		14.5		17.6		13.1

variables it should be possible to predict man-hour requirements for future plot establishment under similar conditions. Therefore a multiple regression was computed with man-hours within the plot as the dependent variable and independent variables of (1) number of measured trees, (2) plots previously established, (3) density (percent crown coverage), (4) number of understory stems, and (5) time of day at mid-point of plot establishment. Only two of these variables, number of measured trees and number of plots previously established, were significantly associated with the man-hour requirements within the plot.

An equation was fitted which included only these two independent variables and is:

$$\hat{Y} = 4.00 + 0.089\, X_1 - 0.096\, X_2$$

$$n = 20 \quad R^2 = 0.90$$

where Y = man-hours spent within the plot

X_1 = number of trees measured on the plot

X_2 = number of plots previously established by the crew

n = number of observations

R^2 = coefficient of multiple determination

Figure 6 shows regression lines for the two independent variables which were computed from the equation. As the number of measured trees increased on the plot a steep increase in man-hours was required, and with an increase in crew experience as measured by number of plots established, we find a strong decrease in man-hour requirements. A word of caution is in order here about extending this formula beyond the data. Obviously the crew could not increase in efficiency indefinitely. In fact, it appeared to be in leveling off at around 30 plots. Therefore it is suggested that the formula not be used beyond 30 plots.

Table 11 shows the mean values of the dependent and the independent variables, along with their ranges.

The consideration of these indepn-

Table 11. Mean values and ranges of variables measured in CFI plot establishment on the MSU School Forest with a two man crew (crew A).

Variable	Mean Value	Range of Values
(Dependent) Man-hours within the plot	4.98	1.6-10.8
Independent		
Numberof trees measured on the plot**	35.8	6-78
Number of plots previously measured*	22	9-34
Percent crown coverage	52	5-100
Number of understory stems on the plot	624	10-2010
Time of day	1230	0820-1642

**Significantly associated at 1% level

*Significantly associated at 5% level

dıt variables was based on observation c the crew's performance in the initial pases of the study. Plots which had dense underbrush did tend to impede the activities of the crew, but turned out to be insignificant in this case.

Since almost one-half of the within plot time was consumed while measuring tree heights, a similar regression was computed using as the dependent variable man-hours expended while measuring tree heights and the same set of independent

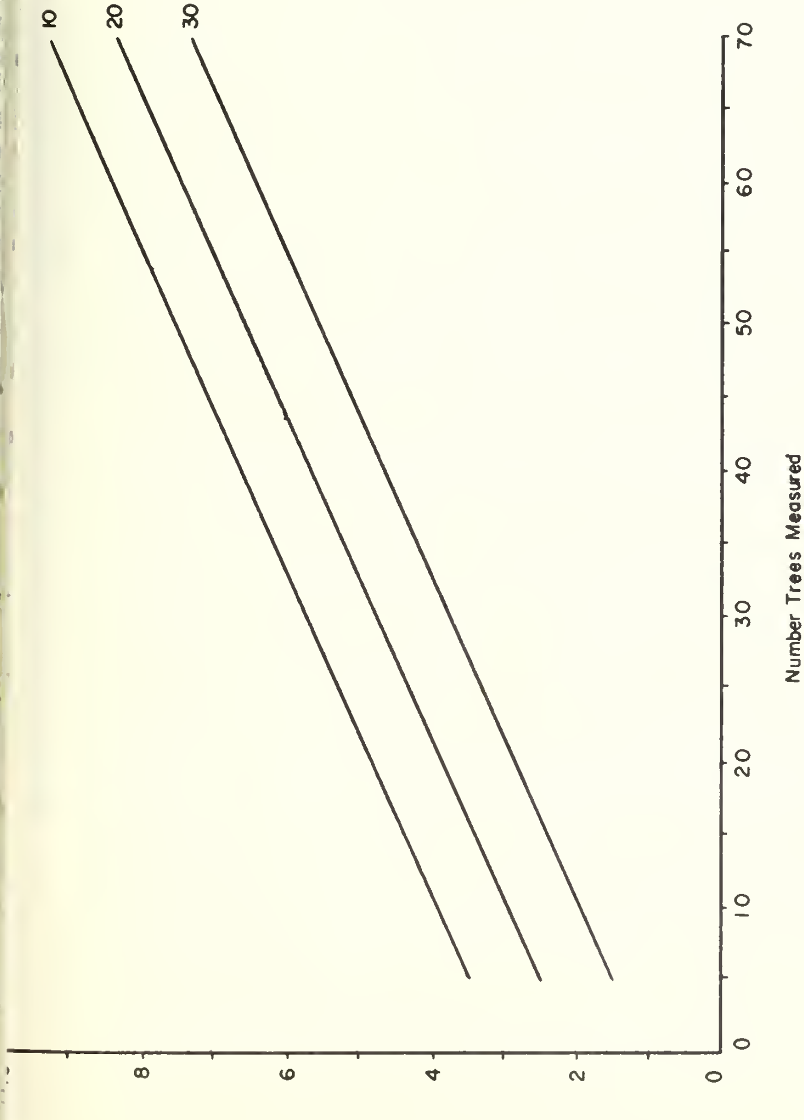


Figure 6. Relation of man-hours within plot to number of trees measured and crew experience.

Equation: $\hat{Y} = 3.999 + 0.0890X_1 - 0.0960X_2$ $R^2 = 0.90$ n = 20

3/ Where clover disappears in the grass-clover mixtures apply 60 lbs. N in the fall.

variables. The mean value of this dependent variable was 2.25 and the range was from 0.33 to 6.30 man-hours. Again the only independent variables which showed significance were the number of trees measured on the plot and the number of plots previously established.

A regression was computed using only these two independent variables and the following equation was fitted.

$$\hat{Y} = 1.109 + 0.0629X_1 - 0.0452X_2$$
$$n = 28 \qquad R^2 = 0.75$$

where Y = man-hours per plot measuring tree heights

X_1 = number of trees measured on the plot

X_2 = number of plots previously established by the crew

n = number of observations

R^2 = coefficient of multiple determination

The regression was highly significant and accounts for 75 percent of the variation in man-hours required in making height measurements. And again we find that as the number of trees measured increases it takes more time, and efficiency increases significantly as the crew gains experience. The experience factor should not be assumed to maintain this effect beyond 30 plots.

Seasonal Comparisons

One would suspect that general weather conditions might influence work performance. And in this case crew A was significantly faster in completing within the plot activities in January than either October, November, or December. The crew was also significantly faster in November than in October, but not significantly faster in November than December. Neither was the difference between December and October significant.

Performance was best during the month of January while they were working in dense stands. Although the weather was cool and sunny during the October working period, it is believed that lack of experience for the crew caused poorer performance than otherwise would have been the case. The weather during January was cold and cloudy and generally disagreeable; however, it was observed that the men worked faster in order to counteract the cold. Also in January this crew had gained over 25 plots of experience.

Crew B

Data was collected on 125 sample plots that were established by Crew B. This crew consisted of two men who located the plot, witnessed the plot center, tagged the trees 3.5" d.b.h. and up, and numbered these trees. They then proceeded on to the next plot, performing the same activities. Later a third man would accompany them back to these plots and complete the measurements on the trees.

A series of regressions were computed on data collected from these plots. The first one had as the dependent variable man-hours required to perform within the plot activities and independent variables of (1) number of trees measured on the plot, (2) percent crown coverage, (3) sum of diameters of the measured trees, (4) number of sawtimber trees measured, and (5) percentage of the measured trees that were of pulpwood size. Another was run using the same independent variables but using man-hours measuring tree heights as the dependent variable.

Table 12 shows the mean values and the ranges of the variables. The only independent variables which showed a significant association with total man-hours required within the plot were the number of trees measured and the sum of diameters.

Since crew B visited each plot twice and measured parts of plots on each visit, it was not possible to evaluate the experience factor.

Man-hours per plot within the plot could be estimated from an equation which was fitted using only number of trees measured on the plot and the sum of their diameters. This equation shown below, accounts for 82 percent of the variation in man-hour requirements within the plot and was highly significant. Figure 7 was prepared from this equation.

$$\hat{Y} = 1.02 + 0.0465X_1 + 0.00538X_2$$

$$n = 125 \qquad R^2 = 0.82$$

where Y = man-hours spent within the plot

X_1 = number of trees measured on the plot

X_2 = sum of diameters of the measured trees

n = number of observations s

R^2 = coefficient of multiple determination

The number of trees measured on the plot has such an important influence on the time it takes to establish the plot that a simple regression using number of trees measured on the plot as the only independent variable gives a highly significant regression and accounts for 79 percent of the variation. An equation for this simple regression is shown below, and might be useful in approximating the man-hour requirements.

$$Y = 1.244 + 0.834X$$

$$n = 125 \qquad r^2 = 0.79$$

where Y = man-hours required within the plot

X = number of trees measured on the plot

n = number of observations

r^2 = coefficient of determination

Since about one-half of the time spent on the plot was in making the tree height measurements, again a regression was computed using man-hours measuring tree heights as the dependent variable and

Table 12. Mean values and ranges of variables measured in CFI plot establishment on the MSU School Forest with a two and three man mixed crew (crew B).

Variable	Mean Value	Range of Values
Dependent:		
Man-hours within the plot	3.33	0.47-9.19
Independent:		
Number of trees measured on plot	24.9**	0-60
Percent crown coverage	75	5-100
Sum of diameters of measured trees (inches)	217*	0-556
Number of sawtimber trees	6.6	0-24
Percent of measured trees that were pulpwood size	65.6	0-100

**Significantly associated at the 1% level

*Significantly associated at the 5% level cance was the sum of diameters of the measured trees. Therefore, a simple regression was fitted with man-hours measuring tree heights as the dependent variable and sum of diameters of the measured trees as the independent variable. This regression accounted for 88 percent the same independent variables as before (see Table 12). The mean value of man-hours measuring tree-heights was 1.56 with a range from 0.0 to 5.80. In this case the only variable which showed significance of the variation and was highly significant. The simple regression is presented below:

$$\hat{Y} = 0.00729X$$

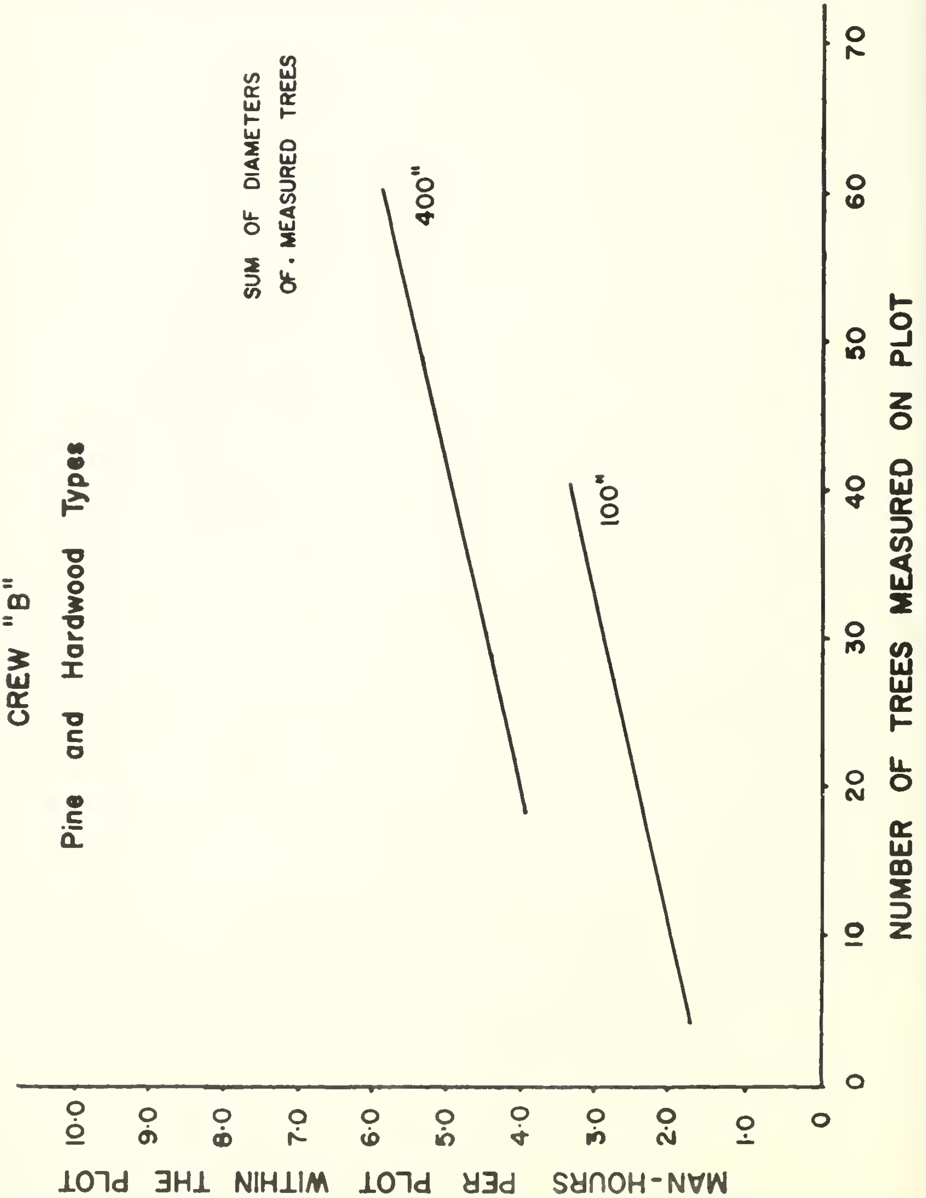
$$n = 125 \quad r^2 = 0.88$$

where Y = man-hours required in measuring tree heights

X = sum of diameters of measured trees

n = number of observations

r^2 = coefficient of determination



Crew C

During the establishment of the CFI ots a third crew was used and time data re collected for 59 plots. This was a ree man crew which made two trips to ch plot. On the first trip they located e plot, witnessed the plot center, mar-d, and tagged the trees that were 3.5" o.h. and above. They then proceeded to e next plot and performed the same sks. Several days later they returned d completed the measurements, de-riptions, and recorded data on the mark nse cards.

The analysis of data collected from ese plots was similar to that for crew B. series of regressions was computed with e first having as the dependent variable, an-hours required within the plot and e same five independent variables as re used in the crew B analyses. A sec-id regression was computed using man-hours while measuring tree heights as the dependent variable. Table 13 shows the mean values and the ranges of the values for the variables.

In the first regression only the sum of diameters and the number of sawtimber trees measured were significant. The regression was highly significant with a coefficient of determination (R^2) of 0.78.

A regression was fitted using these two variables and the equation is shown below.

$$\hat{Y} = 1.455 + 0.0163X_1 - 0.132X_2$$

$$n = 59 \qquad R^2 = 0.77$$

where Y = man-hours required within the plot

X_1 = sum of diameters of the measured trees in inches

X_2 = number of sawtimber trees measured

n = number of observations

R^2 = coefficient of multiple determination

ble 13. Mean values and ranges of variables measured in CFI plot establishment on the MSU School Forest with a three man crew (crew C).

Variable	Mean Value	Range of Values
pendent:		
Man-hours within the plot	4.19	1.15-11.7
ndependent:		
Number of trees measured on plot	26.3	1-66
Percent crown coverage	68	5-85
Sum of diameters of measured trees (inches)	212*	6-420
Number of sawtimber trees	5.4*	0-18
Percent of measured trees that were pulpwood size	74.6	0-100

*Significantly associated at the 5% level

Crew performance again was influenced by the number and size of trees which had to be measured on the plot. However, this crew was significantly influenced by a factor not influencing crew B. As the number of sawtimber sized trees increased on the plot, while holding the other factors constant crew C's performance increased. They were able to work faster with large trees than with small ones.

Another multiple regression was computed to find out which stand characteristics influenced the time in measuring tree heights. In this case only the sum of diameters of the measured trees had a significant influence. The regression accounted for 67 percent of the variation, and after further analysis it was found that a simple regression with sum of diameters of the measured trees as the independent variable was highly significant and accounted for 63 percent of the variation in man-hours while measuring tree heights. This regression equation is presented below.

$$\hat{Y} = 0.01 X$$

$$n = 59 \quad r^2 = 0.63$$

where Y = man-hours required while measuring tree heights

X = sum of diameters of measured trees in inches

n = number of observations

r^2 = coefficient of determination

As a rule of thumb, one could get the approximate man-hours required to measure tree heights by pointing off two places in the sum of diameters of trees to be measured on the plot.

SUMMARY AND CONCLUSIONS

A detailed time study was made during the establishment of a CFI system on the MSU School Forest. A total of 324 circular plots 1/5 acre in size was established and a time study was made on 212 of the plots. These study plots were locate in 128 different 40 acre compartment 8 timber types, 4 density classes, 4 te classes, and covered a range of trees r a- sured on an individual plot from 0 to).

Three different crews took part in e plot establishment and time data we collected from each crew's work. On 3 of the study plots the researcher trav d with the crew and recorded time o 7 distinct activities with a stop watch. n the other 159 plots, five activities we timed and recorded by the tallyman.

The weighted average of man-hour - quirements per plot was 7.42. This ered all 212 samples established by a 3 crews. Within the plot time was 33 man-hours and off the plot activities c sumed 3.50 man-hours per plot.

On the basis of work performed wit n the plot, crew B was over 19 perc t more efficient than crew C, but not nificantly more efficient than crew . Thus the crew organization and techni of crew B, which was two men locat the plot and marking the trees, then th men returning to make the tree meas ments, was superior to crew C, which l three men taking two trips. However, two man crew making only one trip m sured only one less tree per man-ho , which was not significantly slower.

Driving to the forest, which averag l 14 miles one way required 44 percent f the man-hours consumed off the pl . After the crews were in the woods it to on the average 2.04 man-hours per plot mark a reference starting point and ch to the plot location.

While within the plot, the most ti consuming activity was measuring t tree heights which took 47 percent of t time for the two man crew. It took l than 1/4 of this time to make the d.b. measurements.

All crews performed within plot acti ties just as well in bottomlands as in u lands; however, on the average they co ted measurements and descriptions on percent more trees per man-hour in h density uplands than in low density lands. Also performance was signifi- tly higher in poletimber stands than in vtimber or unmerchantable stands, 42 rcent more trees measured per man- ur in poletimber stands than sawtimber nds.

Performance for the two man crew ich made one trip to the plot was in- ienced primarily by number of trees at had to be measured on the plot and w experience. However, performance s also higher in January than either tober, November, or December.

The crew which had two men on the st trip to the plot and three on the next p had performance affected primarily number of trees measured per plot and e sum of the tree diameters. These were o the most important factors influenc- g performance of the three man crew ich made two trips to the plot.

For someone planning to establish a I system both the two man crew mak- g only one trip to the plot and the crew here two men make the first trip and ree men follow later and finish the ork should be considered. If the plots e widely spaced and travel time is great, en two men making only one trip ould probably be preferable.

Under existing conditions the crew here two men made the first trip to the ot followed by three men on a second ip had some advantages.

Having to carry only part of the equip- ent in each of two trips rather than all f it on one trip made the job much more onvenient. Also by completing only about half of the activities on the first trip a more efficient routine was established, and separating the critical measurements of the trees from the other activities allowed the use of less experienced personnel on the first trip.

In this type of crew organization, two men locate the plot center, witness the plot center, tag and number the trees, then proceed on to the next plot. Later a three man crew would return to the plot; record and measure the individual trees along with recording the plot data including type, density, site, size class and reproduction count.

An estimate of man-hours required per plot while within the plot for the above crew organization is illustrated below.

From forest inventory information, estimate the average number of trees that would be measured on the plot and the sum of their diameters.

Average number of trees per plot to be measured	20 inches
Sum of diameters	200

Then from the formula on page 19 substitute this data:

Man-hours per plot = 1.02 + 0.0465 (20) + 0.00538 (200) = 3.02

Then if a total of 200 plots were needed, 604 man-hours would be required for within the plot activities (200 x 3.02).

Since travel time and off the plot activities time would vary greatly from one property to another depending on spacing of the plots and distance the crew had to travel, each firm would need to make an individual estimate of them.

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