TRACKING OPTIMAL BUCKING

by

Bryan D. Beemer

A PAPER

submitted to

Oregon State University

in partial fulfillment of
the requirement for the
degree of

Master of Forestry

Completed June 1991

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Recent developments in handheld computers now make it possible to improve log value recovery by bucking (cross cutting) a tree into log lengths that maximize its value. The use of a handheld computer allows these decisions to be made at the stump for each individual tree. One program developed for this use is BUCK (Sessions et al. 1988), a single tree value optimizing program that specifies the length of logs to manufacture and which mill the logs should be shipped to give the greatest return.

This study will determine if using BUCK has an impact on the time it takes to crosscut a tree. Previous studies using BUCK have not investigated this, they focused on determining the increase in time required to measure the tree. This will be accomplished by regression analysis on data from a detailed time study of a falling operation using BUCK.

Additionally, this is the first time that trees were cut using the BUCK recommended solution. Therefore, a quality "audit" on BUCK can be made in this study. A comparison will be made between values assigned to logs by BUCK and values assigned when scaled. From this a determination of the expected accuracy of BUCK can be estimated.

The final part of this study will be general observations from a implementation trial. BUCK will be used in a commercial operation by a commercial faller as if this was his normal method of operation. One goal is to discover how using the computer affects the faller. Another goal is to determine which areas of operation using BUCK need refinement.

BACKGROUND

The BUCK program determines a value for each possible combination of log length, diameter, and quality. These factors are used to determine the best destination for each hypothetical log. The program then recommends the highest valued log combination possible for a particular tree. Optimal solution values take into consideration mill-delivered prices, logging costs, hauling costs, volumes based on gross scale, and the tree's physical characteristics. Calculations take seconds and are done at the stump. Measurements of interest for each tree are length, inside bark diameters, and quality. They must be accurate or the resulting computer recommendation may not give the optimum value for the tree.

Oregon State University researchers have conducted several field studies using the BUCK program on felled trees ready to be cut into logs (Garland et al. 1989; Sessions et al. 1989; Sessions et al. 1989b). Results of these studies suggest that gains of ten percent or more in tree value may be obtained with computer aided bucking decisions. Real gains may be somewhat less than this for two reasons; first, the faller may require extra time to measure and buck a tree when he is using BUCK with the handheld computer. This increase in time is a cost that should be deducted from the gain in tree value. Second, log grades assigned by the scaler may be different than those assigned by BUCK. This could result in less/more value being received then was reported by BUCK. If the discrepancy can be determined then the estimated BUCK gains can be adjusted appropriately. This investigation may also uncover ways to improve BUCK's estimations.

Previous studies have shown that using a computer increased the total time for felling and bucking a tree by 33% (Table 1). This increase in production cost, along with increased harvesting cost, reduced the value gain obtained by the computer from 11.9% to 9.9%, for second growth trees.

Table 1

Time-study data for felling and bucking old-growth and second-growth Douglas-fir (Olsen, 1989)

Item	Old-growth	Second-growth
Number of trees	50	100
Percentage delay time	20%	30%
Time per computer entry	0.9 min.	0.8 min.
Time/tree Conventional procedure	19 min.	12 min.
Time/tree Computer procedure	25.3 min.	16 min.
Percentage increase	33%	33%

The process of harvesting a tree has several distinct steps:

(1) Walk to the next falling area and deposit equipment.

(2) Select the tree to be felled. Determine the desired falling direction. Clear brush from the base of the tree. Ensure escape

route is clear.

(3) Make a face cut on the selected tree.

(4) Make the back cut and fall the tree.

The first 4 steps are the same for both the traditional and the BUCK method. The following steps have a difference.

(5a) Measuring (traditional method): This step will be referred to as the delimbing or measuring phase of harvest. The faller attaches his tape to the butt of the tree. He delimbs the tree as he walks up the bole and makes scuff marks that correspond to preferred log lengths, usually every 41 feet. He also mentally notes surface quality characteristics and visually estimates the tree's diameter. At the top he makes the top cut. He mentally determines if any adjustments are needed from the crosscut locations he marked on the tree.

(5b) Measuring (BUCK method): This is referred to as the measuring phase of harvest. The faller measures the butt diameter. He attaches his tape to the butt. He walks up the tree. Periodically he measures the tree's diameter using calipers. These measurements along with the length at which they are taken are entered in the computer. The faller delimbs as necessary and makes the top cut at the top of the tree. The computer calculates crosscut locations.

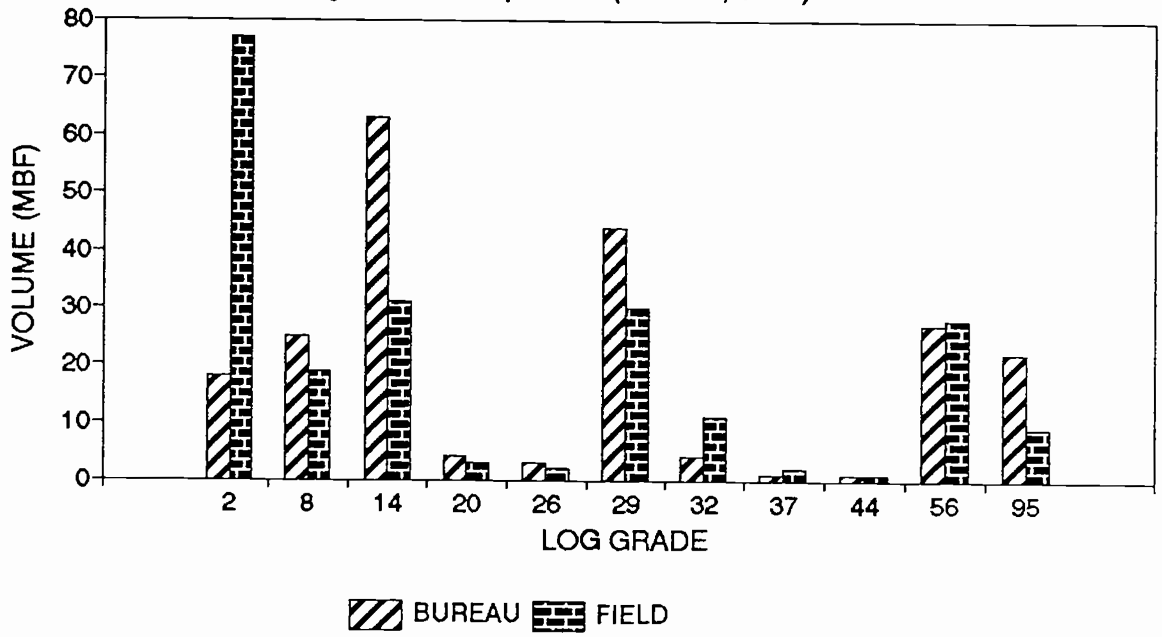
(6a) Crosscutting (traditional method): Making measurements from scuff mark locations for any desired adjustments the faller crosscuts the tree.

(6b) Crosscutting (BUCK method): The faller attaches his tape at the top cut and measures to the next crosscut location. He pulls his tape free and then makes the crosscut. The faller repeats this until the last crosscut is made.

The measurement time is significantly longer when using the computer. This is the major component of the 33% increase in production time. However, change in crosscutting time when using the computer has not previously been studied. It may be quicker with the computer because the faller does not have to determine how he will cut the tree. On the other hand, if the computer averages more cuts per tree, or the faller is slowed down implementing the solution, it will take longer. Data from one of the field studies will be used for a comparison of the time it takes to make crosscuts. From this we will be able to determine if implementing BUCK has an impact on the duration of the crosscutting phase of harvest.

Another question of interest is: How do grades and volumes that the BUCK program determines for each log compare with actual values assigned by the scaling bureau? Scalers at a bureau scaling station usually see both ends of a log and most of its length; fallers on the other hand, make quality judgements based on the butt surface and the visible log exterior. Only one previous old growth study compared grades assigned by the computer from field data and grades assigned by the bureau scaler. Results from this study, shown in Figure 1, indicate that there can be a significant difference. The agreement of the BUCK program's recommendations when compared to all of the scaled values of logs cut when using this recommendation has not been determined.

Figure 1
Field Study Grade Comparison (Garland, 1989)



The log grades are defined as:

2 - 1 Peeler
8 - 2 Peeler
14 - 3 Peeler
20 - Special Mill
26 - 1 Sawmill
29 - 2 Sawmill
32 - 3 Sawmill
37 - Peelable Cull
44 - 4 Sawmill
56 - Special Peelable Cull
95 - Utility

A difference in log values between that determined using BUCK recommendations and actual values as assigned by the scaling bureaus could have a large impact on value gain attributed to use of the computer. A study was recently conducted by Oregon State

University to test a method of using optimal bucking procedures to aid in cruising and stand value appraisals (Olsen et al. 1991a). This study's well-documented data can be used to analyze several effects of using BUCK. The time it takes to implement the BUCK solution and a comparison between the computer and scaled values for each second growth log can be determined from this data. Any differences in value for logs that were cut properly indicates that either the measurements for the tree were incorrectly entered into the computer or that the program algorithms are not correct.

There has not been a full implementation of BUCK where company personnel performed all of the computer activities. On all of the previous studies, researchers operated the computer and did part of the measuring. Also the trees were never crosscut at the BUCK locations, only hypothetical results were calculated.

There are several questions that can be answered in an implementation study: How much training is needed before the operator can work independently? How does the operator react to using the computer on a daily basis? Are there any correctable problems with the current version of BUCK that would hinder its acceptance by a faller?

Finding the answer to these questions is the goal of the second part of this study. A single experienced faller was trained and monitored for three weeks. At the end of this period, a subjective evaluation of BUCK was made by the faller.

Improvements to BUCK from the information gained here will improve the usability of the program.

OBJECTIVES

1) Determine the time it takes to physically buck a tree using results from the BUCK program. This is the time it takes to complete crosscuts on a tree after the measurement phase has been completed. For the traditional method, the time the faller spends deliberating on where he will make crosscuts is considered to be a part of the delimbing/measuring phase.

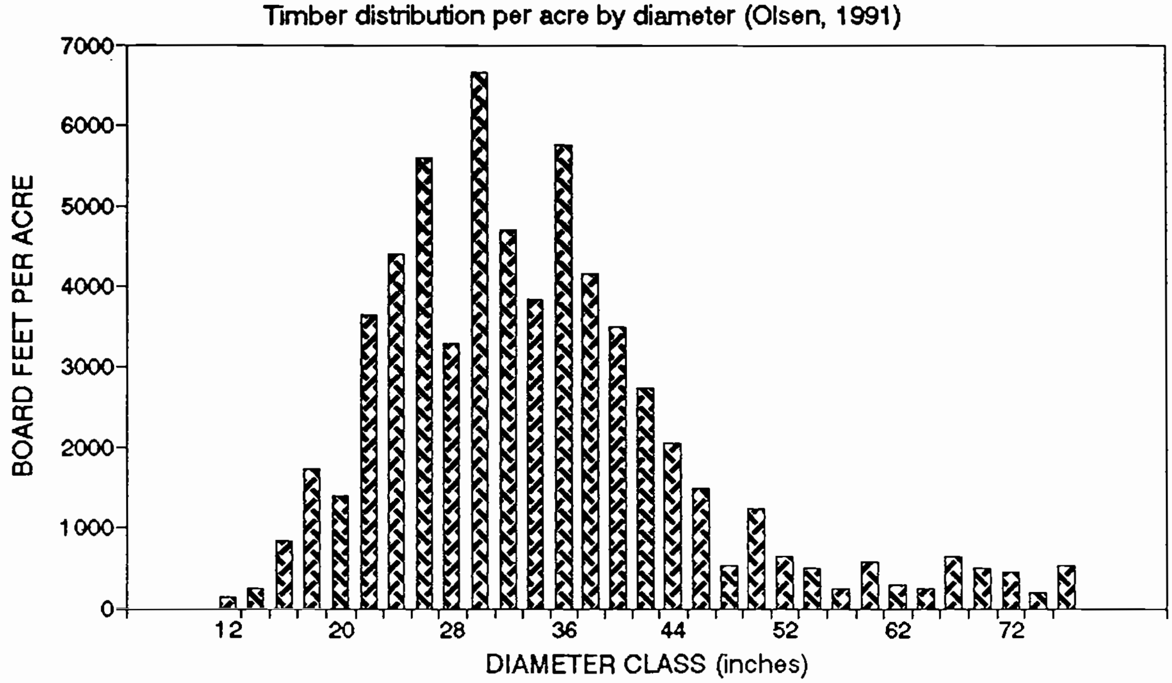
2) Compare the length, diameter, and grade for each log that was cut using the BUCK program with the log values as they were actually scaled. Compare the value of logs as determined by using the BUCK program with the actual amount paid. Attempt to reconcile the differences or to determine the cause of the differences.

3) Determine the requirements to fully implement computer bucking at the stump by a commercial operator.

STUDY SITES

This study was conducted on two sites. Objectives 1 and 2 were done on one site and objective 3 was accomplished later on a different site. The first part of the study was conducted in the Spring of 1989 on a 95-acre parcel of the Spaulding Tract, located on state owned land in the Coast Range near Corvallis, Oregon. The stand was high quality 120-year-old Douglas-fir with approximately 47 MBF per acre (gross), ranging from 8 to 76 inch dbh (Figure 2). The site was clearcut and cable yarded or ground skidded. Logs produced were of peeler, saw, and chip quality for both export and domestic markets, and were sold to five mills, requiring 8 sorts on the landing.

Figure 2
Timber distribution per acre by diameter (Olsen, 1991)



The implementation study (objective 3) was conducted on a commercial thinning operation on the OSU McDonald Forest in the early Fall of 1990. The area thinned was a 70 acre stand of Douglas-fir (90%) and grand fir (10%), with trees from 35 to 90 years of age. The thinning regime was based on crown spacing with a co-dominant/dominant residual.

STUDY DESIGN AND PROCEDURES

The Spaulding Tract had 19 pre-established permanent sample plots containing 151 trees. Trees within these plots were actually bucked using BUCK solutions. They will be referred to as "computer" trees in this report. Remaining trees on the tract were bucked without using BUCK. Twenty-eight of these trees, referred to as "non-computer" trees, were included in this study. Data was collected on three fallers. The faller would fell the tree and then move up the tree, measuring length, estimating diameters, and delimbing as he proceeded. At the top of the tree he would determine how to buck the tree, using his experience to intuitively decide log length. A two person time study crew was assigned to each faller to collect data. One person recorded times and independent variables on both computer and non-computer trees. His partner processed tree data using the BUCK program on computer trees. He also measured piece sizes when the faller had completed bucking the tree. For the computer trees, each piece was tagged when its measurements were taken. The scaling information for each of the tagged logs was recorded when the logs were scaled at a scaling station. The scalers were employees of the Columbia River and Pacific Log Scaling and Grading Bureaus.

The time spent on each tree during the crosscutting phase of the harvest was also determined. This was the time between giving the faller the BUCK results and completing the last crosscut on computer trees. On non-computer trees, the time started when the faller completed the measuring and delimbing phase. For the computer trees the faller would tell the researcher how he would have bucked the tree. For the non-computer trees he would immediately commence the bucking phase of harvest. For the computer trees the tree was measured by a researcher, who entered the data into the computer. The researcher would then run the BUCK program to determine the optimum cross-cut location. With the solution displayed on the screen, the researcher would hand the computer to the faller who would buck the tree according to this solution. The faller would make the crosscuts at the designated locations as he returned to the butt of the tree.

The tree input data and resulting BUCK recommendations were recorded in the handheld computer's memory. Upon return to the office from the field the memory was down-loaded to a personal computer.

OBJECTIVE 1

Regression equations were found using Statgraphics (version 4.0) a statistical graphics computer program developed by the Statistical Graphics Corporation (copyright 1989). Since we were interested in the time it takes to buck a tree, BUCKTIME was selected as the dependent variable. Independent variables that were considered are: an indicator variable for using the computer, number of cuts made on the tree, butt diameter of the tree, tree length, an indicator variable for two of the fallers, number of merchantable logs produced from the tree, and volume of the tree.

The dependent variable, BUCKTIME, describes a time period that started when the faller moved from the topcut to begin his crosscuts. The period ended when he left the tree after making the last crosscut. Bucktime was delay free but includes the time required to walk along a felled tree between the crosscuts. The butt diameter measurement is the value recorded by one of the researchers in the field. For oblong butts the diameter was taken as the average of the major and minor axis. The number of cuts is the total number of cross cuts made on a felled tree after the tree was topped, including cuts made to remove broken and/or cull sections. Tree length, for both computer and non-computer trees, is the sum of the lengths for the logs produced from that tree plus the lengths of any cutouts between these logs. The length of tree remaining above the top cut was not considered. The number of logs produced does not include any cull sections that were cut out; it is total number of merchantable logs produced for a particular tree. Tree volume was determined by summing the volume for each piece in the tree. Piece volume was calculated from the Scribner volume table using the piece's length and small end diameter as measured in the field by the OSU researcher. Tree volume is the sum of both the cull and merchantable log volumes.

Using Statgraphics a math model can be tested. By using stepwise variable selection, the independent variables that relate to the dependent variable (bucktime) are determined. A confidence level of 95% was required. This method expresses the dependent variable as a linear function of the independent variables. In each step of the procedure, variables are entered or removed with the goal of obtaining a model with a small set of significant variables. The regression uses least squares to estimate the regression model. Values for the dependent variable are screened against the resulting model for outliers. The outliers are removed and the regression model is recalculated.

For this objective the math model used was:

$$\hat{y} = b_0 + b_1(\text{BUTTDIA}) + b_2(\#\text{CUTS}) + b_3(\text{I1}) + b_4(\text{I2}) + b_5(\text{LENGTH}) + b_6(\#\text{LOGS}) + b_7(\text{VOLUME}) + b_8(\text{COMPUTER})$$

$\hat{y}$ = bucktime in minutes. This is the time it takes to complete the bucking phase on a felled tree.

BUTTDIA = The butt diameter of the felled tree in inches.

#CUTS = total number of crosscuts made on the tree.

I1 = tree was cut by individual identified as I1.

I2 = tree was cut by individual identified as I2.

LENGTH = length of tree from butt to top cut in feet.

#LOGS = the number of marketable logs.

VOLUME = gross scribner volume (board feet) of the tree as cut.

The coefficient b_0 represents the intercept with the y axis. The coefficient b_1 shows the effect that BUTTDIA has on the bucking time. The coefficient b_2 shows how the number of cuts made on a tree affects the bucking time. Since three faller were studied, one was selected as the reference faller and the other two fallers were assigned indicator variables. The coefficient b_3 indicates the difference in bucking time between faller I1 and the reference faller. The coefficient b_4 indicates the difference in bucking time between faller I2 and the reference faller. The coefficient b_5 shows the effect that LENGTH has on the bucking time. The coefficient b_6 shows the effect that the #LOGS has on the bucking time. The coefficient b_7 shows how the tree volume effects the bucking time. The coefficient b_8 indicates the difference in time between using the computer and not using the computer.

An expression for the time it took to buck a tree with a dependent variable that has a measure of volume in it was also desired. To get a dependent variable to use in the regression equation, the recorded bucktime (minutes) was divided by the volume of the tree (board feet). The previous math model was used with the following changes; $b_7 = 0$ and $\hat{y}$ = time/volume in minutes per board foot. The other independent variables and coefficients were not changed.

OBJECTIVE 2

After a tree was bucked the logs were tagged and measured by

OSU researchers. Measurements from the scaling station for tagged logs were obtained, allowing a comparison between the scaled (or actual) values with those calculated by BUCK. This comparison was done on logs that were cut correctly when using the BUCK recommendation, logs that were not cut according to BUCK were not studied. Logs were numbered sequentially. To determine if a tree was correctly bucked the measured log lengths for that tree were compared to BUCK recommended log lengths. A length difference of one foot or more was considered to be an incorrectly bucked log. Since two researchers measured and evaluated trees for BUCK input data, comparisons were made for each researcher. The first researcher will be designated as Alpha and the second as Beta. Alpha is a research assistant at OSU. He has participated in several previous studies conducted on optimal bucking. He was the field supervisor for data gathering in this study. Beta is also a research assistant at OSU. He did not have any prior exposure to BUCK. Researcher Alpha taught researcher Beta how to use the computer and how to measure and evaluate pertinent tree characteristics.

The desire was to find out if the actual value received for logs differed from the value estimated by BUCK. This was determined by comparing diameter and grade measurements made by the scaler with that calculated by BUCK.

DIAMETER

The diameter of interest is at the small end of a log, which is the diameter used to determine Scribner volume, the basis mills use to pay log owners.

The researcher estimates the inside bark diameter of the felled tree at several points along the length of the tree. Diameter input was determined by measuring the felled tress with calipers and then subtracting the expected bark thickness. This measurement and corresponding length (distance from the butt) is entered into the computer. From this the computer calculates the diameter by interpolation at locations between measurement points. BUCK calculates the diameter for a location between these points linearly, assuming that a tree smoothly tapers between these points. For this reason the researchers attempted to make a measurement every 30 feet and at points where there was a visual change in taper. Based on log diameter and researcher, logs were divided into 5 inch diameter groups and comparison was made between the value obtained from the scaling station and that calculated by BUCK.

GRADE

The BUCK program does not assign a grade to the log, it finds the best combination of logs that it can sell using length, diameter, and quality information. Mill destination for each log is also assigned by BUCK. Using this information a log grade correlating to the BUCK recommendation was calculated for each log. To allow a comparison to be made the BUCK logs were assigned the highest possible grade for values attributed to them by the program. The grade was assigned using the official Log Scaling and Grading Rules for the Columbia River Log Scaling and

Grading Bureau.

The mills pay for logs using net volume. Value assigned to a log for comparison purposes was based on gross volume as determined by the scaler, not net volume. Net volume was not used as this is influenced by internal defects. A faller is not able to determine internal defects prior to making crosscuts. A scaler may also reduce the volume assigned to a log because of damage incurred during yarding and loading operations. The "actual" value obtained for a log was calculated by using the bid price for the mill receiving the log and the grade assigned to the log by the scaler.

OBJECTIVE 3

There are two distinct work environments that are affected by the implementation of BUCK. Management must take an active part by developing the data tables used by BUCK, which is best done in an office. The faller is also impacted; he is now required to use a computer in the field.

OFFICE PREPARATION

Prior to using the computer in the field several data tables must be developed. These tables determine the size and quality of the logs the BUCK program will consider. Several costs associated with harvesting are also needed for use with this program. Among these are the logging and hauling costs, which for this project were obtained from the OSU Research Forest Manager. Two types of tables had to be created, a grade table and a price table for each mill, an example of each can be found in OSU Forest Research Laboratory's Research Bulletin 71 (Olsen et al. 1991b). The grade table is created using the appropriate grading rules that apply to the trees of interest, in our case the Columbia River Grading and Scaling Rules for Douglas fir. Using contracts from successful bidders, a price table is constructed for each mill.

Prior to constructing the price table, the mill's buyer must be contacted to get any information needed that is not on the contract. This information may include: desired log lengths, percent of volume in required lengths, non acceptable lengths, diameter limits, and any other log specifications the mill may have, but not specifically stated on the bid sheet.

In the price table, each log that can be sent to a mill must be represented, along with the price that the mill will pay for it. Once this is complete, some prices are adjusted to get desired log length preferences. This is typically accomplished by increasing the value paid for logs in the preferred lengths. Care must be taken to insure that increasing the price paid for preferred lengths of lower quality logs does not become higher than the price paid for non-preferred logs of higher quality, if, in actuality, these logs are in actuality worth less. Effectively, you must ensure that adjusting the log prices for preferred length logs does not result in a lower price log "stealing" wood from a higher price log.

Once the price tables for all of the mills are completed a trial solution is run. This involves using a representative (fabricated or actual) tree and bucking it with the new price and grade tables. The first tree is useful in checking for gross error, i.e. does it result in a ridiculous bucking pattern or value amount? Next, run the new tables against a batch of trees. Trees in the batch should be similar to those that will be at the harvesting site. Save the log files created by BUCK and then transfer a copy to a spreadsheet. Sort the log data base as necessary to determine if all of the mill requirements have been met. If the requirements have not been met, then the preferred length prices in the price table must be adjusted. It is best to make a copy of the price table for reference before making any changes. Run the same batch of trees again, using the newly adjusted price tables. Repeat above, making adjustments in the price tables until the mill requirements are met. The batch of trees should be large enough to confidently represent the output from the harvest site.

For this sale the primary mill was paying a camprun price which simplified the price and grade tables significantly, as fewer quality codes were necessary. Logs not sent to this mill went to one of two other mills. Price tables were made for these mills also. The batch used for this study had 100 trees in it that were consistent with the trees on the thinning site. The BUCK program in its current stage of development can only be used on one tree species per computer.

FIELD OPERATIONS

Because thinning had started prior to completing the new price tables, all operator training occurred in the field. The faller used for this study is probably above average for several reasons. He has a degree in Forest Engineering, which included the use of computers. He has experience in all harvesting activities and is commonly used as a utility man by the logging contractor.

After an initial training period with OSU researchers, the faller used the computer on a daily basis. Twice a week a researcher would meet the faller. He would get feedback and download a copy of the BUCK solutions to a portable personal computer. The faller saved each BUCK solution used in the handheld computer's memory. The final day was spent making a video of the faller in action.

The faller answered questions from OSU researchers and provided a summary about how using the computer impacted his operation in the field.

DATA ANALYSIS / RESULTS

OBJECTIVE 1

A regression equation was obtained using Statgraphics. A constant value was selected to allow for a non-zero intercept point. A confidence level of 95% was required. The resulting equation had an R-squared value of 0.70. Sample size was 155 trees. Twenty-eight of these trees did not use BUCK. T-values and ranges for the independent variables are listed in Table 2. The equation is:

BUCKTIME (minutes) = -5.66 + (.21)(BUTTDIA) + (.93)(#LOGS) - (.94)(I1) - (.87)(I2) + (.79)(COMPUTER)

CONSTANT = -5.66

BUCKTIME = time it takes to crosscut the tree

BUTTDIA = tree butt diameter in inches

#LOGS = total number of merchantable logs produced

I1 = tree was cut by faller identified as I1

I2 = tree was cut by faller identified as I2

COMPUTER = computer solution was used to crosscut the tree.

From this equation, it can be seen, that using the handheld computer added approximately 0.79 minutes to the time it takes to buck a tree. Again, this is the additional time it takes to complete bucking cuts on a tree when using the computer solution.

Table 2

Variables used to estimate BUCKTIME

Independent Variable	Coefficient (minutes)	T-value	Range
CONSTANT	-5.66	-8.75	-
BUTTDIA	0.21	12.87	16" to 51"
LOGS	0.93	6.69	3 to 6
I1 (Faller)	-0.94	-3.36	yes(1) or no(0)
I2 (Faller)	-0.87	-3.23	yes(1) or no(0)
COMPUTER	0.79	2.70	yes(1) or no(0)

R-squared = 0.70 Sample Size = 155 Confidence Level = 95%

Additional analysis using Statgraphics showed a component of this computer time is due to trees which have a must or can't buck entry. A must buck entry is made when the faller requires a crosscut within a zone on a tree. This might be required for a tree with sweep. A can't buck zone indicates an area on the tree that can not be crosscut. An area where it would be unsafe for a faller to make a crosscut would be indicated using a can't buck entry. An indicator variable was assigned to trees that had either a must or can't buck entry. This variable, called ADDBUCK, when used in the regression equation in place of the COMPUTER indicator variable had a coefficient equal to 0.40 minutes. The R-squared value was also 0.70. T-values are shown in Table 3.

Table 3

When ADDBUCK is used to estimate BUCKTIME

Independent Variable	Coefficient (minutes)	T-value	Significance level
CONSTANT	-5.17	-8.25	0.000
BUTTDIA	0.21	12.88	0.000
LOGS	0.94	6.80	0.000
I1 (Faller)	-1.00	-3.55	0.001
I2 (Faller)	-0.90	-3.35	0.001
ADDBUCK	0.40	2.79	0.006

R-squared = 0.70 Sample Size = 155

Additionally an equation was obtained with a new sample of trees. For this sample, trees that had either a must or can't buck entry were removed. This reduced sample size to 69 trees. The resulting equation showed the COMPUTER variable had a weaker correlation to BUCKTIME. The assigned coefficient was 0.53 minutes. T-values are shown in Table 4.

Table 4

Estimate for BUCKTIME using the small size sample

Independent Variable	Coefficient (minutes)	T-value	Significance level
CONSTANT	-5.45	-5.93	0.000
BUTTDIA	0.18	7.29	0.000
LOGS	1.10	5.57	0.000
I1 (Faller)	-0.988	-2.26	0.028
I2 (Faller)	-1.07	-2.69	0.009
COMPUTER	0.53	1.53	0.130

R-squared = 0.72 Sample Size = 69

A correlation matrix was calculated for variables used. This indicated which variables could be correlated to each other. When regression equations were determined, multicolinear variables were not analyzed together. Variables that correlated were swapped during the analysis. The combination of variables with the highest R-squared values was selected.

Fallers averaged 5.3 crosscuts per tree on those trees that were bucked using the BUCK recommendation and 4.7 crosscuts per tree using traditional methods.

The regression equation also indicates that the baseline cutter is slower than cutters I1 and I2 as shown by their negative coefficients. Both cutters I1 and I2 can finish bucking a tree by almost a minute faster then the baseline cutter. How using the computer's solution affected each cutter and whether it had an impact on the resulting differences in time was not determined. There is the possibility that use of the computer slows down some cutters more than others.

One physical aspect of the tree was determined to have an impact on bucking time, this was the butt diameter.

Residual plots against predicted values showed no obvious trends.

When using a dependent variable which includes a volume component in it, the resulting regression equation is:

TIMEVOL = 3.83 + (0.33)(#LOGS) - (0.09)(BUTTDIA) -

(0.57)(I1) - (0.66)(I2) + (0.71)(COMPUTER)

TIMEVOL = minutes/MBF to crosscut a tree

#LOGS = number of merchantable logs produced

BUTTDIA = the diameter of the log at the butt

I1 = indicator variable for faller I1

I2 = indicator variable for faller I2

COMPUTER = indicator variable for trees that used BUCK

The equation had a R-squared value of 0.42. T-values are listed in Table 5. This equation ended up with the same variables that were selected for the previous regression equation. Selection of the COMPUTER variable indicates that using BUCK has an impact on time to crosscut a tree on a volume basis. The coefficient for using the computer is 0.71

minutes/MBF. Both faller I1 and I2 have a faster production rate then the baseline faller as indicated by negative coefficients.

Table 5

Variables used to estimate TIMEVOL

Independent Variable	Coefficient (minute/MBF)	T-value	Range
CONSTANT	3.83	9.07	-
BUTTDIA	-0.09	-8.48	16" to 51"
LOGS	0.33	3.68	3 to 6
I1 (Faller)	-0.57	-3.12	yes(1) or no(0)
I2 (Faller)	-0.66	-3.76	yes(1) or no(0)
COMPUTER	0.71	3.76	yes(1) or no(0)

R-squared = 0.42   Sample Size = 152   Confidence Level = 95%

Additional analysis was conducted on trees that had a must or can't buck entry. When the variable ADDBUCK was used in place of the variable COMPUTER the regression equation had a slightly lower R-squared value. Another run was made with the sample that had trees with either a must or can't buck entry removed. The regression equation selected the same variables with this smaller sample size. The R-squared value was 0.50. The coefficient for COMPUTER was now 0.52 minutes/MBF with the difference made up in the constant.

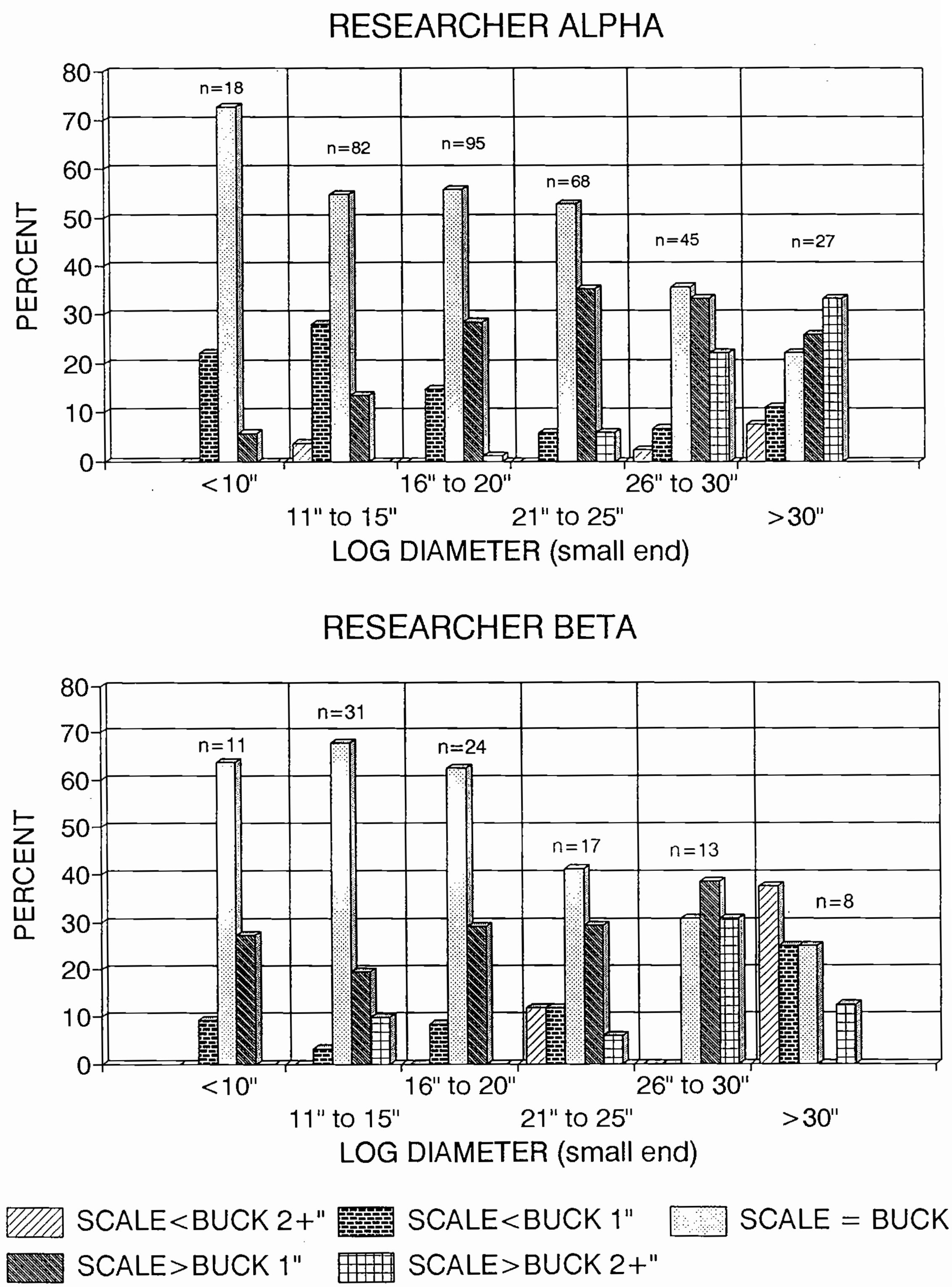
OBJECTIVE 2

DIAMETER COMPARISON

Slightly under 50% of the logs had a difference in log diameter between that predicted by BUCK and actual scaled. Which means that either bark thickness was improperly determined or the BUCK algorithm did not work for these trees. Most of the diameter changes were within one inch.

Figure 3 shows a diameter comparison of scaled diameters verse BUCK diameters for logs in 5 inch groups for each researcher. Accuracy decreased with increasing log diameter. Researcher Alpha was fairly accurate for smaller sized logs and tended to be conservative for larger log sizes. For trees that are less then 30 inches, researcher Beta shows a tendency to be conservative when measuring tree diameter. Beta's sample size for trees greater then 30 inches is too small to predict any trends.

Figure 3
Diameter Comparisons



GRADE COMPARISON

I. RESEARCHER ALPHA

Alpha had the largest sample, with 335 logs studied. When comparing buck grade with scale grade, 34% of the logs had a grade difference. These differences were divided into six categories, summarized in Table 6.

Table 6

Summary of misgraded logs

Log Misgrade Category	Alpha (# of logs)	Alpha (%)	Beta (# of logs)	Beta (%)
Log sample size	335	-	103	-
Grade overcalls	57	17.0	4	3.9
a) with deductions b) w/out deductions	26 31	- -	2 2	- -
Grade undercalls	35	10.4	24	23.3
Due to Volume Restrictions	9	2.7	5	4.8
Due to change in Diameter	5	1.5	0	0
Unknown	10	3.0	1	1.0
Total	116	34.6	34	33.0

The largest category was logs that received a lower grade from the scaler then assigned by BUCK. There were a total of 57 logs in this category, called "grade over calls". Twenty-six of these logs formed a subset receiving a length or diameter deduction from the gross measurements at the scaling station. Deductions at the scaling station are made for defects found in the log. Many of these log defects are internal and not visible on the log's surface. Also, there are internal requirements for log grades, not observable on the log's surface, that can prevent a log from getting as high a grade as would be expected. A couple of these requirements are annual ring count minimums and slope of grain maximums. For this reason grade overcalls with deductions were separated from grade overcalls with no deductions. Deductions indicate a defect in the log that may have resulted in the scaler assigning a lower grade to the log than that assigned by BUCK.

The next largest area of difference for Alpha was in logs that, due to surface quality input, were assigned a lower grade by BUCK than they actually received at the scaling station. These are referred to as "grade under calls". There were 35 logs that were in this category.

A restriction on a log's grade that is not a part of BUCK's algorithm, is minimum volume. Nine trees ended up with a lower scaler grade due to this requirement. A No. 2 Sawmill log has to have a minimum volume of 60 board feet Net scale and a No. 3 Sawmill log has to have a minimum volume of 50 board feet Net scale.

Five of Alpha's logs ended up with lower scaled grades than the grade assigned by BUCK because of diameter measurements. This occurred when the scaler's diameter measurement was smaller than BUCK's and the reduction in diameter moved the log into a lower grade. In all of these cases it was a reduction in grade from a No. 2 Sawmill log to a No. 3 Sawmill log. No logs improved in grade due to a change in diameter. This is due to the price break between grades. BUCK will recommend a shorter log with a 12 inch top to get the No. 2 Sawmill grade with its higher price versus a longer log with a 11 inch top. Therefore, the probability of a grade improvement due to a diameter change is very small.

There were 10 logs that were scaled differently; the information available did not show why. Surface quality inputs assigned would be acceptable for both scaled and BUCK grades. These logs were all either a No. 3 Sawlog or a No. 3 Special Mill log, the difference when making grade assignments for BUCK was that logs with greater than an 8 inch diameter were No. 3 Special Mill logs and those smaller were No. 3 Sawlogs. Yet when logs were scaled it seems that this was not the main consideration used by scalers and there is no indication of what the deciding factor was when these grade assignments were made. The No. 3 Special Mill grade is a "special services" grade which may not have been in effect at the scaling station.

II. RESEARCHER BETA

Researcher Beta had a sample of 103 logs. A total of 33% of Beta's logs had a grade change when sent to the scaler. A summary of his grade changes are in Table 6. The largest error was in under calling log quality, as 24 out of 34 misgraded logs were in this category. He only over graded four logs, 2 of which had deductions for defects that may not have been visible from the log's surface. Five logs were reduced in grade by not having sufficient volume for the grade assigned by BUCK. There was one tree where the reason for the grade change was not determined. There were no grade changes made due to a difference in log diameters.

SORTING AFFECTS

Because logs were not tagged for a destination mill when bucked, they were sorted on the landing by the loader. When the study's data was analyzed it was noted that 37% of the logs were sent to a different mill than recommended by BUCK. Less than half of these logs had a grade change associated with them, which means many of the logs that were properly cut were sent to the wrong mill. Of the logs that had been misgraded by BUCK, several were sent to the mills that BUCK would have selected if the tree had been correctly graded. It was also noted that about 10% of the logs that were correctly cut and graded had been sent to mills that paid more for logs than the mill BUCK sent them to. These were logs that did not meet log length and/or diameter requirements that were given and used by BUCK to determine which mill would buy the logs. If the log had met the mill requirements, BUCK would have sent the log to the higher paying mill. As mills accepted these logs and paid the higher price for them, this would have to be looked upon as a favorable error. The loader did make some mistakes in the opposite direction too, once sending a No. 2 Peeler to a No. 3 Sawlog mill with a resulting loss in profit for that log. Most of the mill missorts by the loader involved No. 2 and No. 3 Sawlogs. For this study the loader sent 59% of the logs with a change in grade to the same mill that was originally recommended by BUCK.

PROFIT

A value for a log was calculated by using the original grade assigned by BUCK and gross volume determined by the scaler. This is referred to as the "base" value in the following comparisons. The "actual" value obtained for a log was determined by using grade assigned by the scaler and mill delivered price. Table 7 summarizes value comparisons.

Table 7

Comparison to BUCK "base" value*
(differences by percent)

RESEARCHER	ALPHA	BETA
ACTUAL**	-5.7	7.7
DIAMETER ALONE	3.4	2.2
GRADE ALT. #1 (BUCK MILL)	-5.4	1.3
GRADE ALT. #2 (BEST MILL)	-3.3	8.0

*value calculated by BUCK
**based on gross volume

The effect of diameter differences on change in profit was smaller than that due to grade changes. Value for a log with a diameter change was first calculated by using the scaler's measured log length and diameter. The value was then recalculated using scalers measured log length and the diameter assigned by BUCK. The volume difference was then multiplied by the mill price assigned to the log by BUCK. Because volume is calculated from diameter and length, the resulting change in volume is larger for longer logs. The net result for both researchers was a small increase in value. One researcher had a 2.2% increase and the other had a 3.4% increase over "base" value. Overall, diameter changes resulted in an increase in total log volume, this accounts for the increase in profit due to diameter changes.

Scaler gross volume was used to compare the value differences on logs which had grade changes. The effect of the grade changes, on the expected (BUCK) price was estimated in two ways. In alternative 1, all of the logs are sent to the mill originally designated by the BUCK program, regardless of the scaler's grade. This would show the change in profit from base value that could be expected if the faller marked each log with the BUCK designated mill. This assumes that no additional sorting takes place on the landing. For alternative 2, logs will be sent to the mill that would pay the highest net price as graded. This assumes a perfect sort is made on the landings. This method shows the maximum profit (best case) that can be made for a log. A log had to met the length and diameter requirements of the mill's contract to be assigned to a mill.

For researcher Alpha, when all of the logs go to the mill designated by BUCK, regardless of their scaled grade, there is a 5.4% decrease in profit when compared to the "base" value. This means that the return received for the logs would have been 5.4%

less than the sum of the values assigned to the logs by BUCK.

For the best case alternative (2), with misgraded logs being correctly sent to the mill that would pay the most for them, the result is the highest possible profit for the sale. However, due to the number of logs having a lower scaler grade, there is a 3.3% decrease in total log value when compared to the "base" value. This indicates that researcher Alpha's assessment of tree surface qualities were overly optimistic.

Results for researcher Beta using alternative 1, with the destination mill assigned by BUCK, show an increase in value of 1.3% above the "base" value. For alternative 2, sending misgraded logs to the mill that will result in the largest profit, there is an increase in value of 8.0% above "base" value. A couple of logs that were listed as culls by BUCK were graded as merchantable logs and accounted for 25% of the increase in value. Researcher Beta's tree surface qualities assessments were conservative, resulting in a larger profit than calculated by BUCK.

NET VOLUME

When a log has an internal defect, a volume deduction is made for this defect during scaling. The resulting lower volume is called net volume. Mills make their payments based on the net volume of each log. BUCK uses gross volume when determining value for a log. In all of the previous comparisons, gross volume was used for log volume. Therefore, even if each log was correctly graded by BUCK and was sent to the BUCK mill, there would still be a difference between BUCK predicted value and actual value received. The effect of these volume deductions are shown in Table 8.

Table 8

Comparison of net and gross volume

Researcher	Alpha	Beta
Gross Log Volume	204.8 MBF	49.6 MBF
Net Log Volume	187.3 MBF	44.1 MBF
Volume Lost to Defects	8.6 %	11.1 %
Mill Value from Gross Volume	63,303 $	15,451 $
Mill Value from Net Volume	58,249 $	14,005 $
Value Lost to Defects	7.6 %	9.4 %

OBJECTIVE 3

Researchers assisted the faller for the first three days using the computer. After the second day it was determined that the price tables needed to be adjusted. Too many logs of an undesirable length were being produced. This was done that night and the computer was returned to the faller for use the next day. After the price tables were changed, logs of undesirable lengths were no longer produced. After this initial training period the faller was visited twice a week at the site.

For trees with butt diameters less then 15 inches the use of BUCK was not warranted. With the smaller diameters the logs recommended by BUCK and the logs produced by traditional methods were essentially the same. The extra time to use the computer does not give an increase in net value for the small tree when input time is considered. Because of this the faller used the computer on trees with 15 inch or greater butt diameters. The faller visually determined which trees were too small to use the computer on.

The following method was developed by the faller on trees he determined were large enough to use the computer. After he felled the tree, he used his tape to measure butt diameter. He then tacked the end of the tape to the tree at the butt. He walked approximately 15 to 20 feet up the tree and measured the tree's diameter using calipers. Now he would retrieve the computer from his belt pouch. After saving entries for the previous tree he would put in the butt diameter and his first measurements. He would continue up the tree taking measurements as necessary. While moving up the tree he would carry the computer in his hand. At approximately 60 feet he would make a measurement and make a "tape break" entry. This entry tells BUCK the zero end of the tape is being reset to this point. Resetting the end of the tape, he would proceed up the tree taking additional measurements as needed. Usually he did not need to make a "tape break" entry again. When he got to the top of the tree and had completed entering the last data measurement he would have the computer buck the tree. He would look at the resulting solution and see if it had any major discrepancies. For those trees without problems he would put the computer back into the belt pouch and proceed to buck the tree using the computer solution. For trees with solutions he felt were improper, he would take additional measurements and recalculate the BUCK solution on the computer. For the larger trees having a break near the top, he would not use the computer to calculate log lengths after the break. If he could get a log out of the remaining top he would do so. Since resulting log lengths would be the same for both the traditional method and BUCK, he used the traditional method. Using BUCK would require input time, which would be inefficient. The only reason to input the data would be to include the log in the inventory data base. By the end of the first week the faller felt the time he spent on a tree was now consistent. He felt that he had completed the learning curve for using the computer. The faller's production rate with the computer was estimated to be about 70% of what he could accomplish using the traditional method. This was estimated by the faller. It was based on a comparison of his production rate on days not using the computer with days using BUCK. He was working with another faller and they compared production on a daily basis, this also indicated a 70% production rate when using BUCK.

OBSERVATIONS

The following observations were made during this study. They are not listed in any particular order.

1. Tape: The best tape for a faller to use is a 75 foot tape with markings on both sides of the tape. A shorter tape requires more frequent tape break entries. Using a shorter tape would result in an increase in time spent during the measurement phase of operation. Having markings on both sides of the tape makes it

easier to read (faller input). The tape does not have to be turned over to be read. When using a 75 foot tape it is recommended that the tape break location be around the 60 foot mark. The faller's method was adapted to include this after he accidentally pulled two tapes out of their holders when attempting to measure to the 75 foot mark.

2. Computer size: The dimensions of the computer were satisfactory, but it was heavy. When hanging from the faller's belt it was uncomfortable and a little awkward. The size of the keyboard was very nice (fallers input). The keys were big enough that the faller could operate the computer with his gloves on. A smaller keyboard would require the removal of the faller's gloves to operate. The handheld computer used was a Paravant RHC-88. It weighs 4.5 pounds. It has dimensions of 9.4" L x 6.4" W x 2.6" H.

3. Computer operation: For this study the computer was carried in a belt pouch by the faller. This resulted in a new problem becoming recognized. When carried in the belt pouch, keyboard buttons were being randomly pushed. Often the computer would lock up with an illogical entry being displayed. To clear this entry and allow the computer to continue to operate the faller would have to keep pressing the 0 key for a minute. This creates a small delay at the beginning of each tree while the faller gets the computer ready.

4. The operator made a modification to the measuring procedure. After he measured the butt diameter, he waited until he had

measured the next data entry point to enter butt diameter data into the computer. This allows for fewer computer handling operations.

5. It was noticed that diameter inputs can have a large effect on BUCK results, especially with smaller trees. The outer diameter of the tree is measured with a caliper. An estimate of bark thickness is then subtracted from this measurement. The value entered into BUCK is then rounded down to the next whole inch. This faller was able to determine a tree's inner bark diameter very accurately by the end of the first day. BUCK assumes that this is an absolute measurement at this location. In actuality the faller may think the diameter is a 1/2" or even 3/4" bigger. With smaller diameter entries the log output recommended by the computer may be less then optimal. This will cause the computer to generally buck the premium logs at a shorter length then desired, in order to catch a desired (price break driven) diameter that may actually occur further out on the stem than the input states. The faller on a couple of occasions disagreed with the original BUCK recommendation. When he added a measurement at the desired cut location and had the computer reanalyze the data, the new solution frequently agreed with the faller's desired log length.

There are several ways to improve diameter measurements on a tree. One would require the faller to take diameter measurements where the inside bark diameter is at whole inches. The other would be to change the BUCK program to allow fractional diameter entries.

The requirement to make measurements at whole inch locations is probably not practical. Having the faller making multiple measurements as he moves up (or down) the tree trying to find a whole inch diameter that is also close to an even foot of length is going to take longer. This could increase measurement input time significantly. Entering a fractional diameter should have a minimal impact on the time of the measurement phase.

6. A faller already carries many things in the woods to do his job: a chainsaw, a shovel, an ax, water, gas, and bar oil. Now he must also carry a computer and calipers. The computer, when carried in a belt pouch, was workable. The same can not be said for the calipers. They are lightweight but, large and awkward to carry. The faller was unable to find a easy way to carry them. When the faller was measuring and delimbing a tree he would be carrying the chainsaw, computer and calipers in his hands. To operate any of these items he would have to put the others down. The faller believed calipers would be a problem on sites with moderate to heavy brush.

7. Mills: It was during the Show-me trip with the mill timber buyers that a couple of things became apparent. One is that the mills did not like the use of the BUCK program. It seems the major issue is the mills do not know what to expect from a harvest site where the computer is being used. There were two main fears: One, they would end up with a bunch of short logs, i.e. scale was maximized. Two, if more than one mill was

selected they would end up getting the lower grade logs when they had in fact made a bid for logs of all grades. To prevent this most mills are going to make an all or nothing bid on sales involving the use of BUCK, which limits its ability to maximize value.

DISCUSSION

OBJECTIVE 1

Analysis shows using BUCK slows down the crosscutting phase of a tree's harvest by 0.79 minutes. This increase was surprising as the fallers were given the logs sizes to cut by a researcher. One reason that could account for this is the faller taking more time measuring log lengths, knowing this was a study and having the desire to be accurate. Also, on a tree using the traditional method, they would measure from scuff marks made while measuring the tree. If there were no changes then the log lengths were marked and additional measuring was not needed. For the "computer" trees they measured lengths from the top of the log, which would mean more time was spent using the tape.

Using the regression equation with values of BUTTDIA = 35" and #LOGS = 5 gives a BUCKTIME of 6.34 minutes. Using the computer would add 0.79 minutes. This means the computer increases the time it takes to crosscut a tree by approximately 12 percent. This would be in addition to previously documented increases in time the faller spends entering data to use BUCK (Table 1). Adding this to the previously observed increases changes total time per second growth tree from 12 minutes without the computer to 16.79 minutes with the computer. This is a 40 percent increase in time (and cost) of falling and bucking. It is possible the increased time to make crosscuts would decrease if BUCK was routinely used. The fallers, knowing this was a study, may have been a little more precise measuring (therefore slower) on the BUCK trees.

OBJECTIVE 2

Both researchers had a net gain in volume due to differences in diameter values. Errors were more frequently made on larger sized logs. This indicates the researchers were over estimating bark thickness on these trees. No feedback was given to the researchers on their estimates. As was determined in objective three, feedback after making a crosscut is available. With this feedback a very accurate estimate of inner bark diameter can be made.

There is an obvious difference between the researchers in the way they graded the logs. This seems to have been the result of Beta consistently making surface quality assessments on logs more conservatively than Alpha. This was surprising because researcher Alpha had trained researcher Beta on how to collect and input tree data for use by BUCK. This included training on how to determine the surface quality of a felled tree. The large difference between the researchers shows how sensitive BUCK output is to the surface quality input for a tree.

There are several factors that can lead to differences in surface quality assessments or grade assignments given to a log. One of these is surface quality assigned to a tree for BUCKs use is made on the personal judgement of the person measuring the tree. Differences between the various surface quality assignments can be small and one person may assign a marginal log the higher value while someone else would give it the lower value.

Another cause of input error is surface quality assessment being determined from the top side of a tree that is lying on the ground and therefore characteristics and/or defects on the downside of the tree can be easily missed. Also, as previously mentioned, using surface quality of a log as input means that any internal defects are not accounted for when BUCK optimizes the tree. A defect may result in a lower grade than expected being assigned to a log when scaled.

There are some additional reasons why a log may have been misgraded that do not involve the BUCK program. Scalers determine log grade visually, and as there are several different scalers doing the grading there is some difference introduced here due to the individuality of the scalers. When logs are visually scaled on the truck, some defects on a log noted by the computer operator may not be visible to the scaler. This may result in an improvement in a log's grade when scaled.

Even taking into account all the errors that a log grade may be subject to, with a 10% difference in profit due to grade calls, the difference between researchers is significant. This shows profit as calculated using BUCK is very sensitive to tree surface quality input. There was no feedback given to the researchers on their surface quality assignments. If feedback is available, it would be possible to tell a faller he was consistently over or under calling log grade and allow him to improve his surface quality judgement. Differences between estimated grade and scaled grade should become smaller as the operator's experience approaches the scalers. Taking someone with no grading or scaling experience and expecting them to make good surface quality assignments with only a couple of hours of training is unrealistic.

Many of the misgraded logs were probably ones having a surface quality close to the border line between the different quality zones. While handling the log the loader was afforded a more accurate determination of quality and on this determined which mill to send the log to. The sorter's ability to see the interior condition of each log was probably a benefit here.

The previous observations show how important the loader is in a logging operation. Even if all the logs were properly graded and cut in the field, a poor sort on the landing can lose a lot of the expected return when logs are sent to the wrong mill. Conversely if you have a very good loader sorting, one may actually get more than expected with the ability to send marginal logs to a higher paying mill.

It was noted that several logs were assigned a lower grade by the scaler due to minimum volume requirements. Price tables were adjusted to consider this during the implementation study. This added at least an hour to the office preparation time and increased the complexity of the price tables. Because of the small volume associated with the logs in this category (less then 60 board feet), the reduction in total profit from the grade reduction with these logs is minimal. It is probably not cost effective to make any changes to the BUCK program to correct this.

OBJECTIVE 3

This study shows implementing BUCK on a commercial operation can be achieved. The steps required to implement BUCK for a harvesting operation are:

1) Obtain the BUCK program and a computer and caliper for each of the fallers that will be using BUCK.

2) Train office personnel on how to use the program. This should include training on how to set up mill price and surface quality tables.

3) On a sale, determine the minimum requirements for the purchasing mills.

4) Train fallers on computer operation.

5) Have the fallers use BUCK on a daily basis.

6) Monitor computer data and compare to scaling tickets. Provide feedback to the fallers.

Having a commercial faller use the computer as a part of his normal felling procedure highlighted several points. A faller can be trained to use BUCK in several days. By conducting training in the field, the training can proceed at a pace comfortable to the faller. For this study the faller was easily trained in 2 days. The operator was interested in BUCK and had a positive attitude about using the computer in the field. He did not have any problems, besides those discussed in this paper, with using the computer on a daily basis in a thinning operation.

A computer should have a large keyboard. The Paravant's keyboard was large enough to allow the faller to operate with gloves on. Since the faller normally wears gloves, a small keyboard would require frequent delays for doffing and donning gloves.

The diameter entry for BUCK is to the whole inch. The faller was able to estimate inner bark diameter to a fractional inch. Feedback is available to the faller right after crosscutting a tree. A faller can take a measurement of a log's diameter several times throughout the day. Comparing this to the caliper measurement allows a faller to fine tune his bark thickness estimates. The rounding down to the whole inch diameter also causes BUCK to cut shorter length logs. Consider for example, a log with a 15" butt diameter and a smooth taper, which measures at 31 feet a 12.5" diameter. The operator would have to enter 12" for diameter at this point using the current version of the BUCK program. Assume a price break occurs for logs at 12 inches in diameter. BUCK would recommend cutting a 30 foot log for this tree. The actual location of the 12" diameter is at 37 feet. A 36 foot log is frequently a preferred length log that would bring in a higher value than a 30 foot log. There would be no indication when this occurred in the BUCK data. It assumes inputs are an accurate measurement for each entry. This would cause BUCK to cut shorter logs, potentially with a lower value than the maximum possible. In objective 2, the diameter measurements were off 50 percent of the time. Usually the error was on the conservative side, scaled diameter being larger than BUCK diameter. This may be an indication the above was occurring.

Calipers are awkward to work with, however, they give the most accurate diameter measurement of any method tried (Olsen et al. 1989). Since BUCK output can be sensitive to diameter input, it is probably best to continue using calipers for measuring diameter.

The current version of BUCK is unable to handle more than one tree species. This may limit its effectiveness in mixed species stands. This should be corrected in the next version of BUCK.

Logging and hauling costs were determined from contract data kept by the OSU Research Forest. Accurately knowing this data is important if BUCK is to work properly. If this data is unavailable for a particular site, it may be very difficult to determine, especially for someone like a small woodlands owner.

Data for every measured tree and bucked log can be stored.

This data, on a harvest site, is available when BUCK is used. As of yet, a practical use for this data has not been developed. If BUCK was used regularly, this data would be useful in improving management decisions. It could also be useful for maintaining data on a mill's log inventory.

CONCLUSION

The results of this study show using BUCK has an impact on more than just the measuring phase of a tree's harvest. Using BUCK slows down the crosscutting phase too. On a typical second growth tree, the total time added by the computer is 4.0 minutes for measurement and 0.79 minutes for crosscutting.

Recommendations for areas of future study:

1. A new version of BUCK is needed. Improvements can be made in several areas. It should allow for decimal diameter entries. Probably the best scale would be to the nearest tenth of an inch. One computer should be able to do all of the trees in a mixed species stand. It should be easy for an operator to use. There are several keyboard operations the operator must do in the field that can be simplified. An example would be to reduce the keystrokes for a "tape break" entry. A method needs to be developed to eliminate the random entry problem discovered in the implementation study. A possibility would be to require the "shift" key to be pressed while data entries are made.

A longer implementation trial may be desired first. This trial was only three weeks long and involved only one faller.

Another study may find a couple of other major improvements needed in the BUCK program not noted in this study.

2. A full implementation study should be run. This study should compare the profit from several like units. The computer should be used on all of the trees (with greater then 15 inch butt diameter) in the units that use the optimizing program. By comparing BUCK to traditional methods on a unit basis a more accurate estimate of the increase in profit from using the computer can be made. It would be best to run the study several months after the fallers have been using the computer in the field. This would allow the fallers to get comfortable using the computer. It would also allow them to develop their own routine or methodology. This should eliminate any learning curve effects.

Literature Cited

Garland, J., J. Sessions, and E. Olsen. 1989. Manufacturing logs with computer-aided bucking at the stump. For. Prod. J. 39(3):62-66.

Official Rules for Log Scaling and Grading Bureaus. 1982. (Eugene, OR. Columbia River Log Scaling and Grading Bureau).

Olsen, E., J. Garland, and J. Session. 1989. Value loss from measurement error in computer-aided bucking at the stump. App. Engr. in Agri. 5(2):283-285.

Olsen, E., S. Pilkerton, and J. Garland. 1991a. Evaluating timber sale bids using optimal bucking technology. App. Eng. in Agri. 7(1): 131-136.

Olsen, E., S. Pilkerton, J. Garland, and J. Sessions. 1991b. Questions about optimal bucking. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 71, 18p.

Sessions, J. 1988. Making better tree-bucking decisions in the woods: An introduction to optimal bucking. J. For. 86(10):43-45.

Sessions, J., J. Garland, and E. Olsen. 1988. BUCK: A computer program for optimal bucking. Compiler 6(3):10-13.

Sessions, J., J. Garland, and E. Olsen. 1989a. Testing computer-aided bucking at the stump. J. For. 87(4):43-46.

Sessions, J., E. Olsen, and J. Garland. 1989b. Tree bucking for optimal stand value with log allocation constraints. For. Sci. 35(1):271-276.