

Final Report

In-Woods Decision Making of Utilization Opportunities to Lower Costs of Fire Hazard Reduction Treatments

Joint Fire Science Program: Project# 01-1-2-03

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Executive Summary

Fuels reduction treatments generate a large amount of biomass, most of which is small in diameter and of marginal economic value. Opportunities to process this material are few in many parts of the United States limiting the ability to reduce the threat of wildfire to our communities. Compounding the problem are estimates of harvest and transport costs for small trees that are based either on incomplete information or on localized knowledge not applicable in other regions. There is inconsistent knowledge of critical cost factors leading to discrepancies in contract bid rates and the subsequent viability of wood products businesses—the viability of which is necessary to aid in reducing the risk of catastrophic wildfire on public and private lands.

The result of this research is an accumulation of information on harvest costs and product values necessary for identifying economic thresholds of fuels reduction projects. This information was used to develop a Windows-based, public domain financial/engineering software program called the **Harvest Cost-Revenue (HCR) Estimator** that can be used to evaluate stand-level economic thresholds for harvesting small diameter ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) in the southwestern U.S. The HCR Estimator was developed for a variety of users including logging contractors and forest planners. Its purpose is to identify costs of fuel reduction treatments and evaluate in-woods decision-making regarding tree-selection, residuals left on site, and product suitability for regionally based wood markets. Because different wood manufacturing processes require various log sizes and quality, it is important that forest planners and contractors be able to estimate project costs for varying harvest specifications knowing their markets and the transportation distances to them. These costs, along with possible offsets from stewardship and service contracts, are compared against total financial return to arrive at potential net profit (or loss). This information can then be used to identify per acre cost thresholds, appraise contract bid rates, and assess stumpage values for small diameter timber and biomass. It also provides useful information to assess the feasibility of prospective small wood utilization enterprises for heating and electricity, wood-plastic composites, bio-chemicals, engineered lumber, and other value-added products.

Introduction

Recent estimates suggest that up to 40 million acres of forest have high fuel loads and could benefit from some type of fuels reduction treatment. About 10 million of these acres are in Region 3 on Forest Service land (GAO 1999). If we assume that mechanical fuel removals are appropriate on half of this land, that treatments are implemented over a 40-year period, and that 500 to 1000 cubic feet of raw material are removed per acre, then between 250 million and 500 million cubic feet of additional raw material will enter the market per year. Some estimates put

this number at closer to 1 billion cubic feet per year. The existing industry in the interior west, estimated at about 900 million cubic feet annually, cannot absorb this added volume. It is necessary to identify the types of processors and their capacity that can most efficiently handle this influx of material if such an ambitious treatment program is to be implemented. Ultimately, the market will determine the outcome, but the manner in which fuels reduction treatments are designed and implemented will have a bearing on the outcome. Better estimates of harvest costs and raw material values, including better calculations of merchantable volumes, will expedite implementation of fuel reduction projects.

The idea of funding the costs of treatments by selling the wood and biomass removed during these treatments is appealing. However, this has been particularly difficult to realize in much of the western United States because of diminished wood processing capacity. In many places, the remaining infrastructure mostly represents remnants of an industry established to manufacture high value lumber from larger trees. Relatively little capacity exists that can efficiently utilize the small diameter resource resulting from fuels reduction treatments (Larson and Mirth, 1999).

There are at least two very different approaches to processing this small diameter material. The biomass product stream (e.g., wood chips, fiber, slash, shavings, and pulp) involves high capacity, high capital cost processing options (Koch et al., 1989); the solid wood products stream (e.g., lumber, roundwood) uses lower capacity, lower capital cost processing options. To maximize utilization, logic dictates that the best way to process these types of material is through the biomass products stream. However, the high financial investment relative to low economic return makes most biomass utilization unrealistic. As a result, much attention is given to low volume, low capital investment in solid wood products, such as narrow width lumber, posts and poles, and specialty roundwood products like decorative vigas and latillas.

Wood products compete in regional, national, and global markets so product prices are largely out of the control of individual manufacturers. Therefore, they must harvest, transport, manufacture, and market their products at competitive prices, or receive subsidies to stay in business. This research provides a critical step in the development of a fully integrated system from silvicultural prescription, through stem selection, harvesting, in-woods processing, transport, and product market selection. A decision is made at every functional step about the possible allocation and processing of woody material. In an integrated system, each decision is informed by knowledge about subsequent functions. Together, they provide information on the economic viability of fuels reduction treatment programs. Specifically, the purpose of this research was to examine 1) ways to lower harvesting and transport costs through various levels of in-woods processing, and 2) provide decision support tools to help evaluate economic thresholds of different fuels reduction treatments given various product markets suitable for the types of small diameter material removed.

Project Objectives:

1. Characterize the forest resource in the woods by providing a simple measure to identify product potential
2. Improve small diameter wood utilization through in-woods processing
3. Estimate the amount of various products in the small diameter resource

4. Calculate the influence of residuals left in the woods on fuel load

Research Methodology

Primary data collection focused on ponderosa pine stand density and diameter, pre- and post-treatment fuels survey, time and motion study of equipment productivity, lumber recovery, chippable material volume, post-treatment soil disturbance, and regional small diameter market potential. Data were collected on four 20-acre units on the Coconino National Forest in northern Arizona. Each plot was selected to represent a range of variability in slope, tree diameters, tree heights, and stand density.

Two plots were located on the Fort Valley Experimental Forest (Units #13 and #23) in coordination with the Rocky Mountain Research Station and the Greater Flagstaff Forests Partnership. Ten acres in each 20-acre unit were harvested using a cut-to-length (CTL) harvester and forwarding system processing trees to the merchantable top in the woods, leaving treetops intact, and followed by forwarder extraction of tops to the landing. The remaining 10 acres in each unit was harvested using the CTL harvester with processing of the complete stem to reduce slash height, followed by in-woods piling for subsequent jackpot burning by Forest Service personnel (Figure 1). The two units on the Fort Valley Experimental Forest were harvested late summer of 2002.

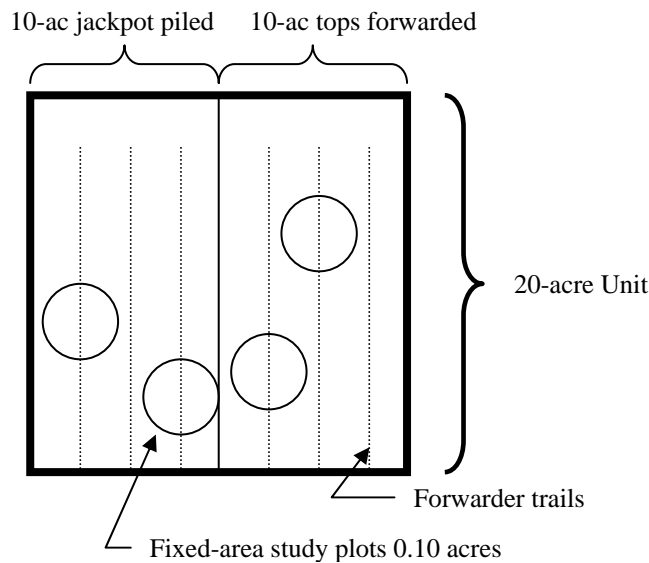


Figure 1. Schematic layout of one of the two Fort Valley Experimental Forest harvest plots.

The other two units were located on A-1 Mountain (Units #40 and #41) on the Coconino National Forest within existing fuels reduction projects. The entire 20 acres in each unit were harvested using a conventional whole-tree harvesting system with processing to the merchantable top occurring at the landing. The system consisted of three machines – the drive-to-tree feller-buncher that cuts and bundles trees, the grapple skidder that drags whole trees to the landing, and the stroke-delimber that delimits, bucks and then sorts the logs at the landing. The two units on A-1 Mountain were harvested in the fall of 2002.

Stand data – A sample of small diameter ponderosa pine trees (5” – 9” diameter at breast height) were selected from each fixed-area study plot to represent a range of stand densities and harvest conditions. Stems removed, diameter distribution, initial stand density, and volume per acre by size class was recorded for each plot. Pre- and post-treatment fuels surveys were conducted for each plot where crown and surface fuels were measured. Trees over 2” diameter at breast height (d.b.h) were measured using 1/10-acre fixed plots (Figure 1). Dead and down debris and fuel loads in slash were also measured. Forest regeneration was measured on 1/300th acre plots. The graphs in Figure 2 show the number and size of trees cut per diameter class for two of the study plots.

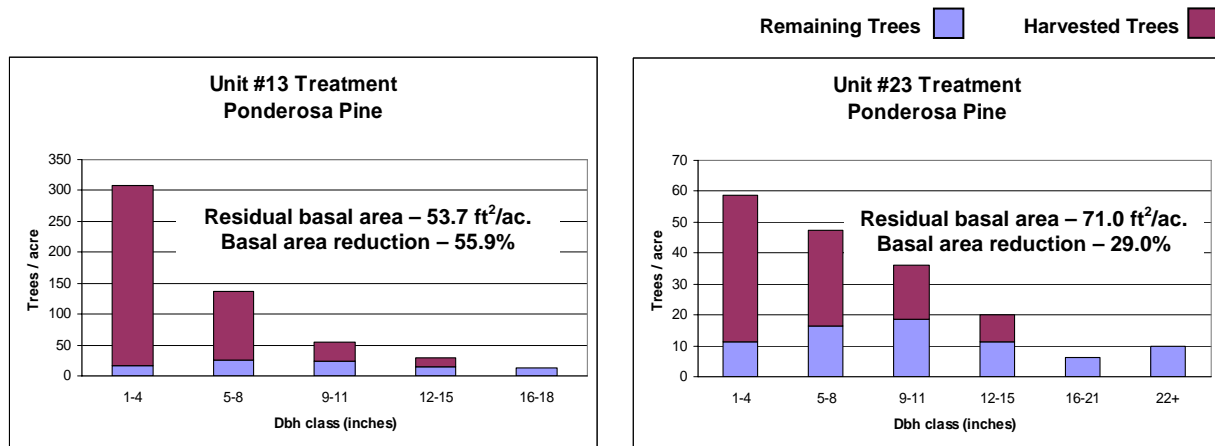


Figure 2. Post treatment study plot data for the Fort Valley units, number of trees harvested, and number of trees remaining by dbh class.

Forty small diameter (1” – 4” d.b.h.) trees were dissected for developing stem volume equations. A random sample of small diameter trees representing the range of population was selected from each of the four 20-acre units so that all logs produced from each of these trees could be tracked through the harvesting and processing procedures. Logs from these trees were transported to Skyline Forest Resources for manufacture of solid wood forest products using a MicroMill[®].

Harvesting Systems – The 20-acre units were identified and flagged prior to harvest. Log lengths multiples of 8 feet with an additional 3 inches of trim for the CTL harvest system or 4-inches for the conventional whole-tree harvesting system. Harvester and support activity were observed during all operations within each 20-acre plot. Machines were videotaped and study personnel took notes on the operation. Researchers measured and marked cut logs designated for MicroMill[®] processing prior to forwarding or skidding. These logs were marked with paint and tags on one end for easy identification during yarding and loading. Forwarder and skidder productivity were calculated by pre-measuring log piles. Unloaded travel time, loading time, intermediate travel time, loaded travel, and unloading time were recorded on individual forwarder/skidder cycles. Stand and system variables such as stem size, slope, and extraction distance were used to predict machine productivity. The study process did not interrupt machine productivity for any pieces of equipment.

Lumber Recovery – Logs marked for MicroMill® processing were loaded onto separate trailers. Log specifications were a maximum 10-inches outside bark on the large end or 5-inches outside bark on the small end and 8 feet in length. Approximately 3,000 board feet log scale from each 20-acre unit was transported to Skyline Forest Resources in Escalante, Utah where they were scaled and processed. Cants (4”x4”, 3”x3”) 8 feet in length were sawn, kiln-dried, surfaced, and graded by certified lumber graders. Volume and grade recovery data were collected for all 4”x4”s and 3”x3”s, as well as 1”x4” jacket boards cut from larger logs. The volume and grade of all products from each log were collected so that different end uses (e.g., chips, roundwood, sawn products) could be evaluated and the value of each log calculated.

Products – The capacity of existing wood products industry in the region was assessed based on the volume of small diameter material that could be processed and the types of products manufactured. This information was documented to provide a realistic measure of expected revenue from different fuels reduction projects. Manufacturers of different products in this region were identified. Distance to their facility from the harvest site was collected. Information regarding raw material requirements as they relate to resource characteristics and products was obtained. These data are used in the HCR Estimator calculations.

Other Field Data – The total volume of slash material that could be chipped for biomass was calculated for each 20-acre unit based on harvesting technique and stand treatment. An assessment of soil disturbance attributable to harvesting was measured for each plot based on observational survey methods.

Computer Software Development – Existing literature and software programs designed to calculate harvest costs, transportation costs, and market values were examined for techniques and equations used. Applicable equations were incorporated into the development of the Harvest Cost-Revenue (HCR) Estimator in addition to productivity equations collected in the study. Biomass and log volume equations were obtained from field data collection and regional surveys in coordination with the U.S. Forest Service Region 3 Regional Office in Albuquerque, NM.

Results by Objective

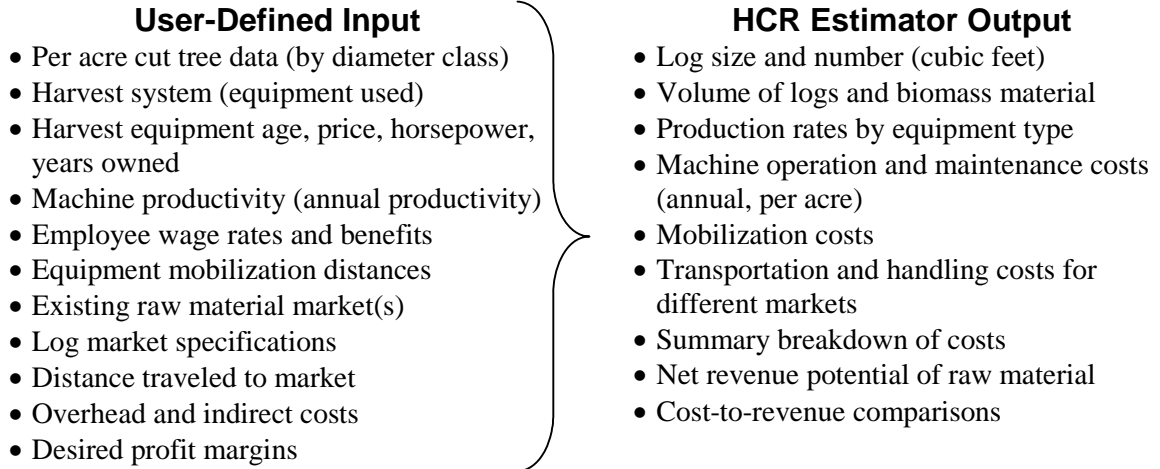
1) Characterize the forest resource in the woods by providing a simple measure to identify its product potential

Because different markets require various sized logs and quality of wood, it is important that forest planners and contractors be able to estimate costs for varying harvest specifications and transportation distances. The primary output of this research is the development of the HCR Estimator, an interactive software program used to evaluate stand-level economic thresholds for harvesting small diameter ponderosa pine in the southwest US. Users of the model are able to identify costs of treatments and evaluate in-woods decision-making regarding tree-selection, residuals left on site, and product suitability for regionally based markets. Outputs can be used to appraise contract bid rates, and assess stumpage values for small diameter timber and biomass. They can also provide useful information to assess

feasibility of prospective small wood utilization enterprises for heating and electricity, wood-plastic composites, bio-chemicals, engineered lumber, and other value-added products.

The HCR Estimator differs from other harvesting and revenue models in that it depends on an internal log calculator to determine merchantable volumes and log potential as a function of stand data and market conditions. In most other models, resource data is based upon gross assumptions such as all trees 5-in d.b.h. and greater are merchantable, or marketable log volume equals total tree volume. This log calculator represents the next generation of spreadsheet based harvesting models where merchantable tree definitions and volumes are calculated directly from tree data and log market specifications. Follow-on predictions of treatment activities are linked directly to log potential, better reflecting true stand-level conditions and revenue potential. The model has three parts with required user-defined inputs (defaults are available for those choosing to use them):

- 1) **Log Calculator** – calculates the size and volume of logs generated from fuels reduction and forest restoration treatments as a function of cut trees per acre by size class and log market specifications as determined by primary and secondary manufacturing businesses.
- 2) **Cost Estimator** – determines harvesting and transportation costs from production rate relationships for commonly used harvesting equipment under normal circumstances. Equipment purchase price, operation and maintenance, labor costs, and handling and transportation costs are estimated based on fuel prescription and contract specifications.
- 3) **Revenue Predictor** – estimates net financial return of the biomass and logs removed from forest treatments and sold to primary and secondary manufacturing businesses. Financial returns are based on existing market specifications in the region assessed against total product costs. For instance, logs with a 4-inch top (inside bark) that are 8-feet long used to make wood pallets will have a different market value than logs having a 6-inch top (inside bark) and are 16-feet in length used for dimension lumber. Furthermore, different markets presumably have different costs associated with harvesting requirements and transportation distances to manufacturing facilities. These costs along with possible offsets from service and stewardship contracts are compared against total financial return to arrive at potential net profit.



2) *Improve small diameter wood utilization through in-woods processing*

The HCR Estimator was used to assess site-specific project costs for varying harvest prescriptions and contract specifications. Stand density, species composition, and fuel reduction prescription significantly affected the cost of harvest operations. Type and size of equipment used, site slope and operability, labor, and use rate of equipment also significantly affected harvest productivity, which affects overall project costs.

Machine productivity and cost, as functions of stand and system variables, were quantified through an elemental time study where each piece of equipment was videotaped for each major activity (e.g., move to tree, harvest, process, clear tree) for a sample of trees. The elemental time study provided detailed information from a sample of machine cycles for a cut-to-length (CTL) harvesting system and a conventional whole tree harvesting system.

CTL system productivity quantified for this study included a Timberjack 1270 cut-to-length harvester and Timberjack 1010B forwarder. A total of 138 cycles were videotaped during the detailed time study of the CTL harvester. The average d.b.h. of trees harvested was 7.8 inches. The average cycle time per tree was 43.67 seconds, which equates to 82.4 trees per hour fully cut, delimited, and processed into market specified log lengths. Figure 3 illustrates how time per tree varies with the size of trees harvested.

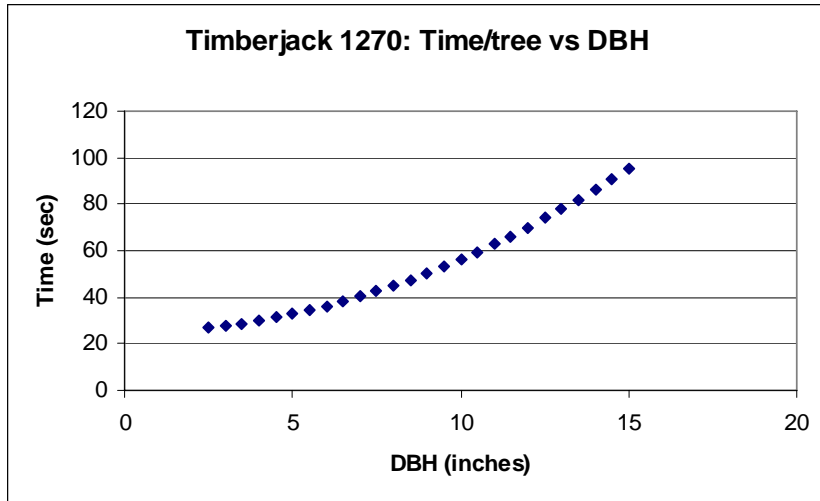


Figure 3. Time required to process a tree using Timberjack cut-to-length equipment.
 EQ: Time/tree (seconds) = 0.314194646 (d.b.h.²) + 24.796

Conventional whole-tree harvesting productivity quantified for this study included a Hydro-ax 421E drive-to-tree feller-buncher, Caterpillar 528 skidder, and Denharco 4400 stroke delimeter. A total of 409 cycles (935 trees) were videotaped during the time study of the feller-buncher. Tree data was recorded for 157 of the 409 cycles. Machine elements included move-to-tree, fell, move-to-dump, and pile. The average number of trees per cycle was 2.45 with an average d.b.h. of 8.6 inches. The average total cycle time per tree was 16.43 seconds, which equates to 220 trees per hour. Figure 4 illustrates number of trees per cycle for the feller-buncher. The regression analysis indicated that the number of trees per cycle and the basal area per cycle best predicted time per tree.

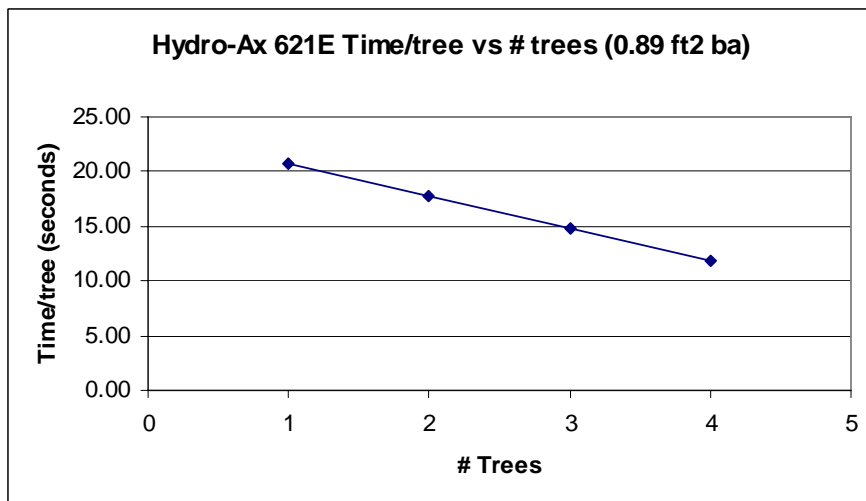


Figure 4. Time per tree versus number of trees per cycle for the Hydro-Ax feller-buncher
 EQ: Time/tree (seconds) = -2.988 (# of trees) - 4.788 (basal area) + 28.02
 $R^2 = 0.34$, $P = 0.0001$

The time study of the grapple skidder resulted in 100 cycles (525 trees). Machine elements included travel-empty, loading, travel-loaded, and decking. The average skid distance was 98 yards and the average number of trees per turn was 5.25. With an average time per tree of 36.5 seconds, productivity was calculated to be 108 trees/hour. Using regression analysis to model time per tree, the log of the number of trees per cycle and the distance were found to be the best predictors. This is illustrated in Figure 5.

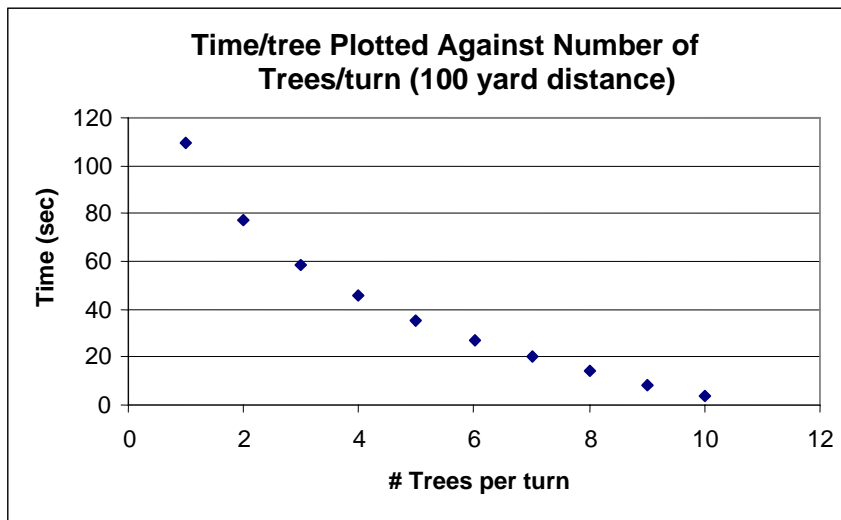


Figure 5. Time per tree versus number of trees per cycle for Caterpillar grapple skidder.

EQ: $\text{Time/tree (seconds)} = -105.49 (\log_{10} \# \text{ trees}) + 0.138 * (\text{distance in yds}) + 95.36$
 $R^2 = 0.69, P = 0.0001$

The stroke delimeter videotaped the processing of 218 trees. The average d.b.h. was 10.5 inches with a maximum of 19.6 inches. The number of pieces processed from each tree ranged from 1 to 4 with an average of 1.43. The average total time per cycle was 40.83 second, which yields a productivity of 88 trees/hour. Machine cycles included reach, process, stack, clear, and move. The results of the regression analysis to model time per tree indicated that the number of pieces per tree and d.b.h. squared accounted for most of the variability in the data. Time per tree to process by d.b.h. is illustrated in Figure 6.

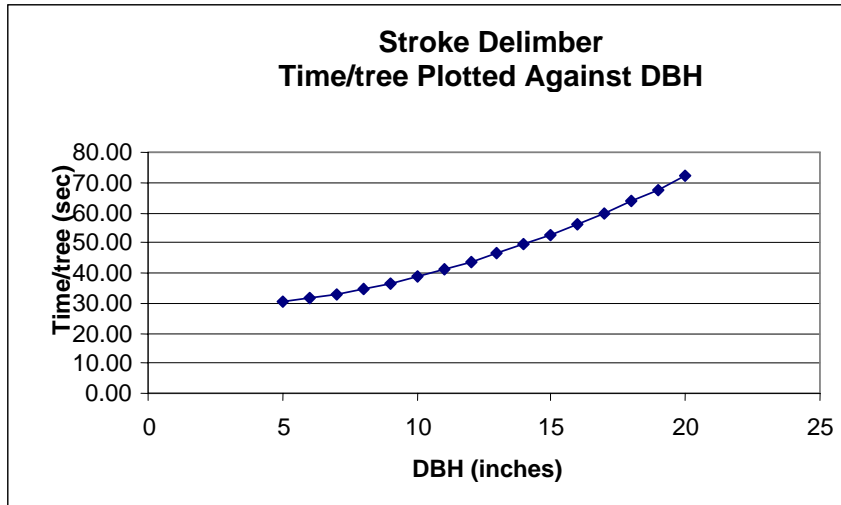


Figure 6. Amount of time per tree by diameter at breast height for the stroke delimeter.

EQ: Time/tree (seconds) = 20.19437 (# log pieces) + 0.1112 (d.b.h.²) - 1.2689
 $R^2 = 0.68, P = 0.0001$

3) *Estimate the amount of various products in the resource*

Duncan’s Multiple Range Test (Rao, 1998) was used to compare mean volume by d.b.h. class between the two harvest sites. The test revealed that there was no significant difference in total stem volume between sites by d.b.h. class. Therefore, all data collected from the four units were combined for the analysis. A General Linear Models Procedure (Rao, 1998) was used to develop prediction equations for estimating total stem cubic foot volume. The best estimators were found to be d.b.h. squared and total height for predicting cubic foot volume. The following is a summary of the equations used for estimating total cubic foot (cf) stem volume of 1- to 4-inch d.b.h. ponderosa pine trees on the Coconino National Forest.

Total stem volume (cf inside bark) = 0.033 + 0.001941D²H
 D = d.b.h. in inches
 H = Total height in feet
 ($R^2 = 0.96; C.V = 13.73; n = 40$)

Total stem volume (cf outside bark) = 0.080 + 0.002544D²H
 D = d.b.h. in inches
 H = Total height in feet
 ($R^2 = 0.96; C.V = 11.91; n = 40$)

The following scatter diagram (Figure 7) shows calculated volumes for each sample tree using Smalian’s Formula with the corresponding regression line displayed (regression equation and statistics above).

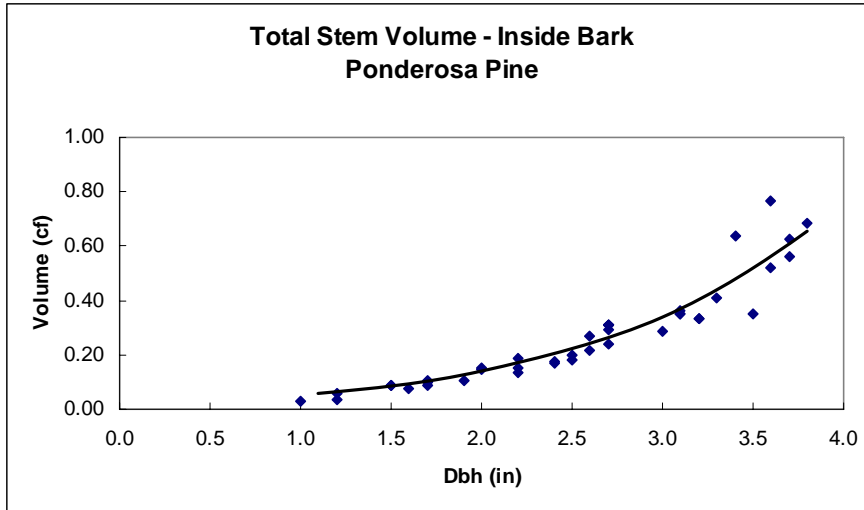


Figure 7. Cubic foot volume of 1- to 4-inch dbh ponderosa pine trees.

The volume of products manufactured from small diameter ponderosa pine was directly related to the size of trees harvested. Mill productivity influences market potential to the extent that per unit costs of production are greater for small logs and log volume recovery declines with small logs. The following table (Table 1) shows the relation of lumber recovery to log size. Note there was very little defect in these small logs, sweep being the primary cause for deduction.

Table 1. Gross and net Scribner volumes, percent lumber recovery and lumber tally by log small end diameter (inside bark) for ponderosa pine.

Small End Diameter	Scribner Log Scale		Lumber Recovery		Lumber Tally	
	Gross BF	Net BF	% Green	% Dry	Board Feet	No. of Logs
3"	0.0	0.0	77.1	54.0	101	17
4"	2,640	2,320	67.6	47.5	2,117	306
5"	5,890	5,810	67.5	47.7	5,622	589
6"	3,740	3,720	63.7	44.4	4,560	374
7"	570	570	58.8	40.0	854	57
All Logs	12,840	12,420	66.2	46.5	13,254	1,343

Grade recovery refers to the quality of products (e.g. lumber) that can be produced from a given tree. Independent of volume recovery, grade recovery was related to the size of ponderosa pine trees harvested. The following table (Table 2) displays log size and corresponding grades of milled products using the MicroMill[®].

Table 2. Percent grade recovery by log small-end diameter and product.

Small End Diameter	1x4 Boards		3x3 Cants		4x4 Cants		Total Board Feet
	Common #2 & Better	Common #3 & Worse	Standard Grade	Economy Grade	Standard Grade	Economy Grade	
	-----percent in grade-----		----percent in grade----		----percent in grade----		
3"	0.0	0.0	5.9	94.1	0.0	0.0	101
4"	0.0	0.0	20.7	46.6	5.3	27.4	2,117
5"	0.0	0.3	8.7	7.9	34.3	48.9	5,622
6"	0.3	11.7	0.1	0.5	51.6	35.7	4,560
7"	2.7	24.0	0.0	0.0	25.8	47.7	854
All Sizes (board ft)	37	753	938	1,551	4,610	5,365	13,254

Market potential related to log volume was also assessed. The economic return from products manufactured with the MicroMill[®] small log sawmill was greatly influenced by mill portability for in-woods processing. Where temporary relocation of the mill was logistically feasible, transportation costs could be significantly reduced. However, the milled products would be of lower quality unless they could be economically transported to another location for kiln drying and surfacing, which generally increases market value of finished products, especially ponderosa pine. Independent of in-woods operations, the purchase, cost of operation, and maintenance of the MicroMill[®] did not significantly affect financial viability. Rather, the market value of products recovered (traditional versus niche markets) and cost to purchase raw logs for processing had the greatest affect on market viability.

Taken together, per acre volume and grade recovery is incorporated into the HCR Estimator to calculate merchantable log volume in a given ponderosa pine stand and the volume of biomass generated from tops of merchantable trees, trees too small for log markets, and slash generated from harvesting activities. The log calculator function of the model matches market specifications for raw logs with the predicted volume of logs based on size and form (tree taper, height, bark thickness). Users of the model define log market specifications in terms of minimum and maximum small end and large end diameters, minimum and maximum log lengths, distance to market, moisture content, and price return per unit (i.e., \$/green ton, \$/load, or \$/ccf). For instance, a sawmill that produces 2" x 4" dimension lumber may require a minimum 16'6" length log with a small end diameter of at least 6" inside bark. The HCR Estimator calculates the number of logs in a given stand that meet these specifications based on pre-harvest stand inventories and assesses total economic return on a per unit basis per truckload of logs.

The HCR Estimator also calculates the volume of biomass available either as dirty chips (solid wood, bark, needles, limbs) or clean chips (solid wood only) within a given stand. Biomass market return is assessed based on price return per unit of biomass generated.

Harvesting, handling, and transportation costs for logs and biomass are then incorporated into an overall analysis of total project costs (\$/acre, \$/ton) and assessed against total project revenue generated from user-defined markets. The resulting net profit (loss) analysis provides a detailed breakdown of major cost and profit nodes allowing users of the model to

conduct simple sensitivity analyses by changing model parameters related to fuel reduction prescriptions (number and size of trees harvested), harvest equipment (type and size), and markets (type, distance, financial return).

4) Calculate the influence of residuals left in the woods on fuel load

Initially, this objective focused on the effect of fuel reduction treatments on fuel loads and insects. The original proposal was modified per recommendations made by the JFSP Board to focus on post-treatment fuel loads subsequent to the field data collection for harvesting, volume and grade recovery studies. Data collection was coordinated with the Forest Service Region 3 fuels team to conduct a pre- and post-treatment fuels assessment, which is part of an on-going effort to characterize fuel loadings and fire influences across the Southwest, including effects of mechanical treatment on fuel load. Crown and surface fuels (all trees over 2” d.b.h. and ground and vegetative cover) were measured on 1/10-acre fixed plots. Dead and down fuels were recorded as well as fuel loads in slash piles resulting from harvesting activities. Regeneration was measured on 1/300th acre plots.

The rate of spread (ROS) increased after fuel treatment, as predicted, because the fuel model changed from needle litter to a grass understory where fires move faster with more wind exposure. As shown in the table below, canopy bulk density (CBD) decreased from 0.1009 to 0.042 indicating that the potential for crown fires to run through a forest stand significantly decreased. Also as predicted, the canopy base height (CBH) increased from 22 feet to 39 feet making it more difficult for fires to transition from the surface to the crowns. Fuels Management Analyst Plus software was used to analyze these data.

Table 3. Pre- and post-treatment fuels assessment for Fort Valley Unit #40.

Fort Valley – Unit #40	Pre-Treatment Conditions	Post-Treatment Conditions
Fuel Model	Needle Litter	Grass Understory
Fire Rate of Spread (ch/hr)	4.7	28.5
Surface Flame Length (ft)	2.3	5.8
Fireline Intensity (btu/ft/sec)	33	259
Canopy Base Height (feet)	22	39
Canopy Bulk Density (kg/m3)	0.1009	0.042

Deliverables

The proposal stated, “This project will provide a decision-making tool based on models developed from previous work and validated and refined using data from the sample sites. Publications for each of the different aspects ... of the project will be prepared detailing its

objectives and results.” Deliverables include interactive software and field guide to help planners evaluate scenarios for fuels management prescriptions. A station publication that includes the HCR Estimator, a Windows-based, public domain financial/engineering software program on CD-ROM will serve as a guidebook outlining options and defining cost implications of various prescriptions. Additional technical transfer outputs from this project are listed below. Refereed journal articles are in progress.

1. Refereed articles, technical reports, book chapters

- a) Economic assessment of using a mobile MicroMill for processing small diameter ponderosa pine (PNW-GTR-623, December 2004)
- b) The Harvest Cost-Revenue (HCR) Estimator for southwestern Ponderosa Pine: CD-Rom and User’s Manual (PNW-GTR-XXX, anticipated Fall 2005)
- c) Matching forest thinning opportunities and community development with public land managers’ responsibilities (NC-GTR-XXX, anticipated Winter 2005)
- d) Overview of the HCR Estimator: An interactive tool for assessing fuel reduction costs (*Forest Science*, anticipated submission Winter 2005)
- e) Comparing costs and benefits in policy decisions regarding small wood utilization using the HCR Estimator (*Forest Science*, anticipated submission Winter 2005)
- f) Calculating log and biomass volumes for accurate project assessment (*Forest Products Journal*, anticipated submission Winter 2005)
- g) Matching the utilization of forest fuel reduction by-products to community development opportunities, In *People, Fire, and Forests* (Oregon State Press, anticipated Spring 2006)
- h) Evolution of sustainable communities and sustainable forests: The paradox of small wood utilization, In *Advances in Community research and natural resources* (Kluwer Academic Publications, anticipated Summer 2006)
- i) Additional harvesting cost manuscripts are being prepared by Dr. Robert Rummer, Southern Research Station using information from the productivity study of the cut-to-length and forwarding system, and the conventional whole-tree harvesting system.

2. Presentations, Proceedings, and Posters

Lowell, E.C. 2005. Pacific Northwest Research Station wood utilization research in the western United States. American Forest and Paper Association: Agenda 2020. Madison, WI. May 11, 2005.

Becker, D.R. 2005. Determinants to Locating New Wood Products Industry in Northern Arizona. **[Invited Presentation]** Ecological Restoration Institute Seminar Series. Flagstaff, AZ. May 16, 2005.

Becker, D.R.; Larson, D.; Lowell, E.C.; Rummer, R.B. 2004. HCR Estimator – Calculating Costs and Revenue for Southwest Ponderosa Pine. **[Invited Presentation]** Four Corners Sustainable Forests Partnership Annual Workshop: Transitioning after Sunset and Still Sustaining Our Forests. Eager-Springerville, AZ. October 20-22, 2004.

Becker, D.R.; Moote, M. 2004. The Collaborative Forest Restoration Program: The Multiparty Monitoring Process. **[Invited Presentation]** Monitoring Science and Technology Symposium:

Unifying Knowledge for Sustainability in the Western Hemisphere, Denver, CO. September 20-24, 2004.

Becker, D.R. 2004. Matching Utilization Options with Resource Constraints and Community Needs in Arizona. [**Invited Presentation**] Arizona Industries of the Future, Kick-Off Conference, Phoenix, AZ. June 15-16, 2004.

Becker, D.R.; Viers, J. 2004. Antecedents to Community Benefits from the Utilization of Fuel Reduction By-Products. [**Presentation**] Tenth International Symposium of Society and Resource Management: Past and Future, Keystone, CO. June 2-6, 2004.

Becker, D.R.; Larson, D.; Lowell, E.C.; Rummer, R.B. 2004. Estimating Harvest Costs and Product Values for Southwest Ponderosa Pine. [**Invited Presentation**] SmallWood 2004: Creating Solutions for Using Small Trees, Forest Products Association, Sacramento, CA. May 18-21, 2004.

Becker, D.R. 2004. Community Partnerships and Stimulating Private Investment in Small Log Utilization. [**Invited Presentation**] Small Log Conference on Utilization, TimberWest Publications, Coeur d'Alene, ID. March 31 – April 2, 2004.

Lowell, E.C.; Larson, D. 2004. In-Woods Decision-Making of Utilization Opportunities to Lower Costs of Fire Hazard Reduction Treatments. [**Presentation**] JFSP PI Annual Meeting, Phoenix, AZ. March 6-9, 2004.

Becker, D.R. 2004. Matching Utilization Options with Resource Constraints and Community Needs. [**Invited Presentation**] Northern Arizona Chapter of Society of American Foresters, Flagstaff, AZ. March 4, 2004.

Becker, D.R. 2003. Partnerships and Utilization of Small Diameter Wood on the Gila National Forest. [**Invited Presentation**] Gila National Forest and the New Mexico Twenty-Communities Initiative, New Mexico State Forestry, Silver City, NM. October 27, 2003.

Becker, D.R. 2003. The Social Realities of Bioenergy in Northern Arizona. [**Invited Presentation**] International Energy Agency, Task 31, Conventional Forestry Systems for Sustainable Production of Bioenergy, Annual Workshop, Flagstaff, AZ. October 5-10, 2003.

Thompson, J. 2003. Productivity of a tree length harvesting system thinning ponderosa pine in Northern Arizona. In: [**Proceedings and Presentation**] 2003 council of forest engineering 26th annual conference. Bar Harbor, Maine: University of Maine, New England Regional Council on Forest Engineering: 5p.

Lowell, E.C. 2003. In-Woods Decision-Making of Utilization Opportunities to Lower Costs of Fire Hazard Reduction Treatments. [**Presentation**] JFSP PI Annual Meeting, Phoenix, AZ. March 11-13, 2003.

Becker, D.R. 2003. In-Woods Decision-Making of Utilization Opportunities to Lower Costs of Fire Hazard Reduction Treatments. [Poster] Southwest Fire Initiative Conference, Flagstaff, AZ. April 29, 2003.

Becker, D.R. 2003. Lumber Recovery from small diameter Ponderosa Pine in Northern Arizona. [Invited Presentation] Arizona Sustainable Forests Partnership, Show Low, AZ. May 15, 2003.

Becker, D.R. 2002. Demonstration of Utilization Opportunities on Fort Valley Experimental Forest. [Invited Presentation] Greater Flagstaff Forest Partnership, Flagstaff, AZ. October 29, 2002.

In addition to the identified presentations, Robert Rummer has included information from the productivity study of the cut-to-length and forwarding system, and the conventional whole-tree harvesting system in numerous presentations on biomass harvesting and recovery. The information is also included in the two Inter -Regional Mechanical Fuels Treatment Training courses.

3. Consultations, Workshops, and Trainings

The sharing of information and knowledge among scientists, community partners, and agency planners was accomplished through multiple channels of communication. In addition to the poster and professional presentations identified above, one-on-one consultations, workshops, and trainings were conducted to reach a broader audience.

One-on-one trainings, consultations, and distribution of the program and user's guide continue in an effort to increase awareness of fuel reduction treatment costs and improve the accuracy of predicting associated costs. Consultations included sharing of technical information, published reports, guidance on finding requested information, and site visits. Consultations were provided for community partners, private wood manufacturing businesses, logging contractors, agency representatives, tribal foresters, and elected public office representatives. The result of this research has also been highlighted in a number of newsletters and science finding reports, including the Ecological Restoration Institute's annual science highlights.

Workshops and trainings were held to Beta test the HCR Estimator software program and to train users on its functions and application. Prior announcements were circulated to US Forest Service, Bureau of Land Management, Bureau of Indian Affairs, stand lands departments, university scientists, consulting foresters, private wood manufacturing businesses, logging contractors, non-governmental organizations, and community partners. Follow-up solicitations were sent to targeted businesses and agency representatives to maximize workshop attendance and diversity of participants. Workshops were held at the following locations to maximize exposure to logging contractors and district office personnel:

<u>Date</u>	<u>Location</u>	<u>Beta Test Version</u>
October 21, 2004	Eager, Arizona	HCR Estimator 1.0
March 9, 2005	Flagstaff, Arizona	HCR Estimator 1.1
March 10, 2005	Show Low, Arizona	HCR Estimator 1.1

March 21, 2005	Ruidoso, New Mexico	HCR Estimator 1.2
April 7, 2005	Durango, Colorado	HCR Estimator 1.3

Total attendees – 132 participants

Forest planners, district rangers, and contract specialists with the Forest Service, Bureau of Indian Affairs, and the Bureau of Land Management are currently using the model to conduct project appraisal for specific fuel reduction treatments, set minimum contract bid rates, assess the stumpage value of material removed, and develop stewardship contract specifications. Private industry and logging contractors are using the model to estimate their operation and maintenance costs of equipment and to generate detailed cost estimates for project bidding. Other community partners and economic development agencies are using the HCR Estimator to determine major cost nodes used in enterprise development for small wood utilization and local job creation.

4. Key Partnerships

The direct result of this research has been to strengthen collaboration among scientists, forest planners, district rangers, logging contractors and community partners in planning for and executing fuels reduction projects in and around fire-prone areas. Resources and funding have been leveraged from the following agencies and organizations:

- Pacific Northwest Research Station – in-kind salary, travel
- Southern Research Station – in-kind salary, travel
- Northern Arizona University – in-kind salary
- Rocky Mountain Research Station – administrative support and overhead
- Greater Flagstaff Forests Partnership – in-kind salary
- Southwest (formally Four Corners) Sustainable Forests Partnership – facility rental, staff support
- Northern Arizona Wood Products Association – staff support
- Colorado Wood Utilization & Marketing Program – facility rental, staff support
- Coconino National Forest – planning and contracting
- Fishlake and Dixie National Forest – measurement specialists
- Region 3, National Forest System Regional Office – model consultation and application
- Skyline Forest Resources, Escalante, UT – staff support, equipment use

Future model develop is being coordinated with various research stations and organizations. The data collected in this project and model interface are being considered by scientists at the Forest Service San Dimas Technology & Development Center and Southern Research Station for use in related applications. Data has been shared with Region 3 timber staff and the San Dimas Center for emerging model development focused on expanding the HCR Estimator to include other tree species in the United States.

5. Decision and Reference Tools

Harvest Cost-Revenue (HCR) Estimator. This decision support tool is a calculator to estimate financial thresholds of fuel reduction treatments. The calculator includes a harvest costing function that estimates machine productivity given treatment options, stand conditions, and equipment features. The volume and quantity of merchantable logs generated is calculated as a function of log market specifications. Labor costs are calculated based on the time required to complete project tasks, employee benefits, worker's compensation, and state unemployment rates. The cost of loading and transportation are calculated based

on the size and volume of logs, distance traveled to and from processing and manufacturing locations, and speed of travel. Net revenue is then calculated based on total revenue generated from the sale of logs and contract offsets minus total costs for harvesting, transportation, and labor given a specific fuel prescription project. The HCR Estimator is provided in CD-ROM format as a self-extractable Windows-based program. A field guide in the format of a user's manual is also provided.

JFSP Webpage. <http://www.fs.fed.us/pnw/sev/esp/ESP-JFSP.htm>. This link on the PNW Research Station website provides reference information on the model including data collection, methods, partners, and key references.

6. Project Extension

A one-year, no cost extension was granted for the project to enhance the science delivery and application of the HCR Estimator. This was accomplished by adding two interactive training workshops to the originally scheduled trainings in Flagstaff and one in New Mexico. The result was that we were able to reach more potential users of the model thus improving its application to particular user needs. One-on-one support training was also made available through FY05.

The model was enhanced to include a Visual Basic computer interface that is self-extractable on any Windows-based operating system. Additional default settings and a greater range of pre-determined user input preferences were included based on input from timber/contracting staff, contractors, and other participants in the workshops. The extension also provided time to prepare an additional publication that will provide a policy-drive sensitivity analysis of fuel reduction tradeoffs. Scientists continue to examine ways the model can interface with other harvest costing models like My Fuel Treatment Planner (MyFTP) as well as models like the Forest Vegetation Simulator (FVS) that are currently underway.

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