Relationship between Diameter and Gross Product Value for Small Trees

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Abstract

Managing forests for non-timber objectives such as habitat for threatened or endangered species, water quality, recreational opportunities, aesthetic features, and other outputs need not preclude production of wood products. In fact, removal of some trees is often necessary to accomplish these non-timber objectives. The trees selected for removal are, however, typically smaller (6-10 inches at breast height), than have historically been offered for sale by public landowners in the Western United States. This paper reports work at the USDA Forest Service, Pacific Northwest Research Station that is intended to help people who design these timber sales to understanding the relationship between tree size and wood-product value. Actual recovery data collected by the Forest Service are used to illustrate the influence of log size on gross product value recovered at sawmills, veneer mills, and chip mills.

Introduction

Raw material availability is a major concern in most mills but design constraints usually create a situation where equal volumes of small and large diameter logs are not the same in the eyes of the mill manager. Wood processing facilities are designed to produce a certain output in a given time period, often expressed as volume per shift. Since they typically process a fixed number of logs per minute, they require raw materials within a specific range of log diameters to meet their designed volume output. If too many large logs are processed, down stream equipment centers become overloaded. The resulting bottlenecks may not reduce volume production but extra people are needed to maintain flow within the mill. If too many small logs are processed, equipment centers become starved and volume production suffers because not enough wood flows through the mill. An excess of large logs is rarely a problem but too many small logs is all too common a situation.

If forest managers responsible for designing timber sales are aware of the processing constraints imposed by the design of the mills within their purchasing circle they can consider these constraints when planning sales. Understanding the technical limitations

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faced by mill operators may help forest managers design sales that both meet their management objectives and return the greatest revenue to the landowner because the raw material generated by the sale is suited to the mills in the area. This does not mean that only large trees should be included in all sales. On the contrary, understanding the types of processing facilities in the area and the types raw material they use should make it possible to design timber sales that contain a narrower range of tree sizes than sales designed without considering processing.

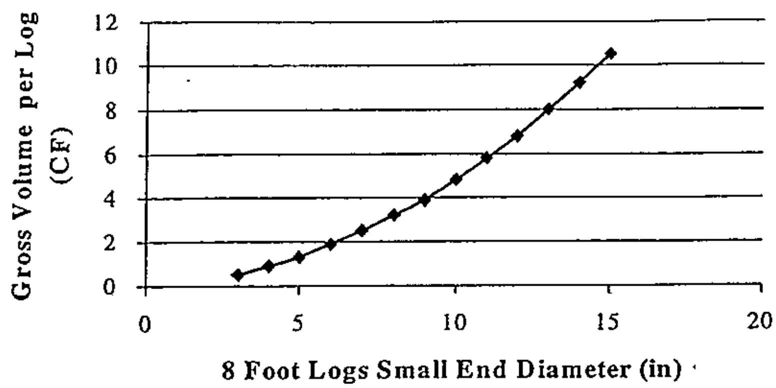
In this presentation, I will discuss technical limitations associated with volume throughput and materials handling as they relate to the value of different products. Each will be covered for chip plants, sawmills, and veneer mills. My intention is not to present any detailed engineering information but rather to provide a sense of why mill managers and owners may be attracted to one timber sale but not another that offers a similar volume of different size trees. I will not cover the efficiency of harvesting or transportation systems but average diameter is also important in determining the viability of those operations. Inefficiency in processing small diameter wood both in the woods and at the mill makes small wood a high cost resource even though the quality of end products manufactured from small trees harvested in the Inland West is often as good or better than products manufactured from larger trees.

Technical Limitations by Product

Mills that process too many small logs tend to have problems with volume throughput, materials handling, and marketing. Volume is a function of the square of diameter so a small change in diameter results in a large change in volume. As logs become smaller it may simply be impossible for a mill to process enough of them to maintain adequate volume production. Small logs also require special equipment that can properly handle small pieces both in terms of the logs themselves and the products cut from them. Products manufactured from small logs tend to have smaller dimensions or different distributions of size and quality than those from larger logs. This can create marketing problems or result in a product inventory with lower than expected value.

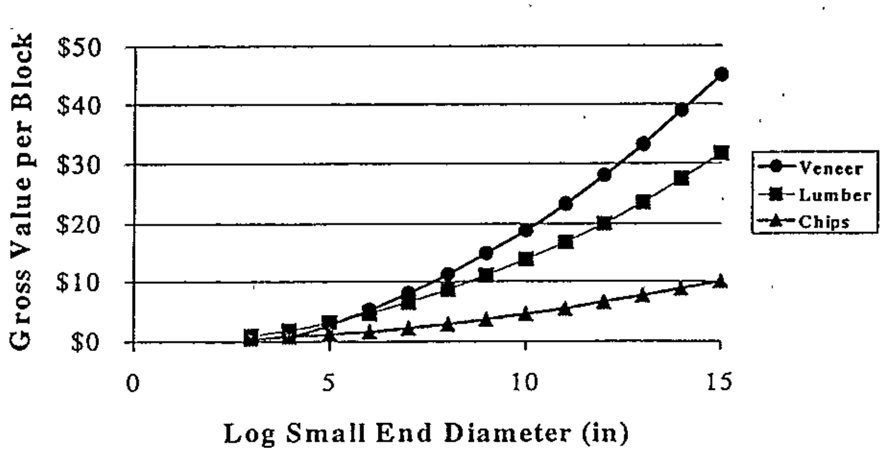
The relationship between log diameter and volume is tremendously important in determining the profitability of a mill processing small wood. Chip plants, sawmills, and veneer mills are generally designed as linear processing systems. They handle one log at a time so the amount of product manufactured from each log is a key factor in determining how much volume a mill produces during each shift. This is different than say a pulp mill where raw material arrives as chips and individual log size is only important to the extent that it affects raw material costs.

Figure 1. Gross volume of 8 foot logs by small end diameter.



The change in gross cubic volume with diameter of eight-foot logs is shown in Figure 1. An eight-foot log length was chosen for this illustration because veneer is usually peeled from eight-foot blocks and keeping length the same for each mill type makes comparisons easier. The gross revenue per log for each of the three technologies is closely related to log volume but the actual revenue for similar size logs varies by product (Figure 2). This figure does not account for harvesting, transportation, or manufacturing costs. Their inclusion would change the relationships both within a mill type and between mill types but gross revenues alone are adequate to illustrate the impact of changing log size within the mill. Consideration of costs needed to calculate net revenue could easily be made with the Financial Evaluation of Ecosystem Management Activities (FEEMA) software described later in this session.

Figure 2. Gross revenue value per 8-foot log or block.



Chip Plants

Chip plants are mills devoted exclusively to pulp chip manufacture. They usually consist of a bucking saw, debarker, chipper, chip screens, chip storage hopper, and conveyors. Such a simple design makes it easy to visualize how gross revenue per log changes with diameter. I assumed that 85% of the wood volume is converted to usable chips, 10% is converted to fines or other screening rejects and is sold as hog fuel, and 5% is lost during the manufacturing process, e.g., during debarking. Chips were priced at $94 per bone-dry unit (1.2 oven-dry tons) based on data from the Pacific Rim Wood Market Report for August 1998 (Barr 1998). Hog fuel was priced at $50 per oven-dry ton. These prices are actually delivered prices but to simplify calculations they were not converted to F.O.B. prices since changes in their magnitude moves the curve up or down but do not change its shape. The important points are that:

1. the gross revenue per log relationship is similar to the curve for gross volume per log and,
2. the gross revenue per log increases very quickly as log diameter increases.

Since processing a log through a chip plant typically takes about the same amount of time regardless of diameter, the output of the plant is highly dependent on average log size. For example, per shift production is about 3.8 times higher if average diameter is six inches as compared to a shift where the average diameter is three inches. In addition, for each cubic foot of chips produced from three-inch logs, 20 linear feet of log must be debarked. If a six-inch log is chipped, only 5.5 linear feet of log is debarked to produce the same cubic foot of chips. Using this example it is fairly easy to see why chip plant operators are concerned about the size of logs they process even thought they can often handle logs down to one or two inches small end diameter (SED).

Chip purchasers usually require a relatively bark free product. Consequently, either efficient debarking is essential or considerable expense is required for downstream processing through additional screening or some type of air density separation system. Chip plants are usually designed to minimize equipment costs and operating expenses and this makes downstream bark separation undesirable. Drum debarkers, ring debarkers, and chain flail debarkers are three technologies frequently used in chip plants. None is very efficient at removing bark from logs under about 2-3 inches in diameter. Drums and chain flails tend to grind or break away the small ends of small-diameter pieces and ring debarkers fail to remove bark from these pieces because their jaws do not close far enough. Very small pieces tend to become stuck in conveyers and other equipment more frequently than larger pieces. A piece with a one or two inch SED behaves more like a spear than a log as it travels along a conveyer system and the small end can easily slip under the chain or lodge in any irregularities in the equipment and jam stalling processing. This can also create a safety hazard if pieces break and protrude at odd angles or fly out of equipment.

Sawmills

Most western sawmills manufacture both lumber and pulp chips and depending on market conditions may favor one of these products over than the other. The gross value of lumber for the sawmill example was calculated using a lumber recovery factor (LRF) of:

$$LRF = 8.59 - 19.56/d \qquad \text{I}$$

where d is the small end diameter of the log .

LRF was used to calculate the volume of lumber in board feet of lumber per cubic feet of log. This value was then multiplied by the log volume to get total board feet of lumber and a value estimated using the Random Lengths framing lumber composite price of $347 for the week of July 31, 1998 (Anderson, 1998). The amount of chips and sawdust was calculated by estimating lumber volume on a cubic foot basis using the cubic recovery percent (CR%) equation:

$$CR\% = 60.967 - 147.04/d \qquad \text{II}$$

It was assumed that the sawdust volume was always equal to 10% of the lumber volume and chip volume was estimated by subtracting lumber and sawdust volume from log volume. Chips and sawdust (hog fuel) were priced using the method described for the chip plant. The equations used for the LRF and CR% were derived by combining sawmill recovery studies conducted by the PNW Research Station and selecting data for trees in the 4 to 20 inch breast-height diameter range.

The resulting gross-revenue-per-log curve for lumber increases more quickly than the curve for the chip plant (Figure 2). This happens because lumber has a higher per cubic foot value than chips and as log diameter increases, relatively more lumber is produced. In the chip plant, product proportions remain constant regardless of diameter so gross revenue increases more slowly than in the sawmill or veneer mill.

Even without considering manufacturing costs it is easy to understand why sawmill managers prefer to process larger logs. One hundred sixty, five-inch logs must be sawn to produce a thousand board feet (MBF) of lumber but only 31 ten-inch logs are needed to produce the same volume. A mill using current technology can process 30 eight-foot logs per minute per primary breakdown center regardless of diameter. Typically an eight-hour shift includes about 350 minutes of operating time so about 10,500 logs are processed per shift. Using the lumber recovery factor in Equation I, a mill processing only five-inch logs will produce 65 MBF per shift but one processing only 10-inch logs produces 336 MBF per shift. This results in gross revenues of $22,750 and $117,600 or a difference of about $95,000 per shift. Obviously no mill would process only one size log but the difference in revenue for changing piece size is nonetheless striking.

When logs much less than four inches are processed in sawmills lumber size becomes a problem. Markets for lumber having nominal widths less than four inches (3.5 inches actual) are relatively small and value declines rapidly for this narrow width lumber. For example, recent prices for 8 foot studs were $100 per thousand higher ($370 vs. $270) for 2x4s than 2x3s (Anderson 1998). Using actual sizes to calculate volume, the 2x4s contain only about 4% more wood per MBF than the 2x3s but they sell for 37% more. When log SED falls below about 3.5 inches it is not possible to manufacture 2x4s so the gross value of each cubic foot of lumber handled drops from $6.38 to $4.86. At the same time the mill must process 350 2x3s to make one MBF but only 188 2x4 studs. As a result, the materials handling problems and costs become much greater in the mill processing smaller logs while gross revenues drop by more than one third.

Veneer Mills

The same types of calculations used to derive the gross value relationship for lumber were used for veneer and the results are similar. In this case, equations used to estimate recovery of full sheets, fishtail (pieces less than full length and width), strip (random width full-length pieces), and core were provided by Christensen (In Press) and are the same ones used in the FEEMA model. Veneer prices were obtained from the July 31, 1998 issue of Random Lengths (Anderson 1998). Full sheets were priced at $48 per thousand square feet (MSF) 1/10th inch basis and fishtail and strip were combined and priced as random width at $24.50 per MSF 1/10th inch basis. Core was priced as chips plus 10% and roundup was prices as chips.

A steeper value/diameter relationship is apparent for the veneer mill than chip plant and sawmill (Figure 2). The difference results from the higher value per cubic foot of veneer relative to lumber and chips as well as the changing proportions of products already discussed to explain the difference in shape of the lumber and chip curves. Again it is important to recognize that the gross revenue realized by a veneer mill is closely tied to log volume.

Operators of veneer mills also face a problem similar to sawmill operators when processing small logs. An analysis performed by Christensen (In Press) found that, on average, six-inch diameter Douglas-fir veneer blocks yielded two full sheets of veneer (1/10th inch basis), eight-inch blocks yielded five full sheets, and ten-inch blocks yielded ten full sheets. This result is very close to the proportional volume of each block but in terms of operating the mill it has greater implications. It takes the same amount of time to charge each block and drop each core regardless of block diameter so even if equal volumes of smaller and large blocks were peeled, a mill could not produce an equal volume of veneer per shift. In mills where the veneer clipper, rather than the veneer lathe, is the time limiting machine center, the importance of block size is diminished. However, Christensen's analysis also shows that the relative amounts of core and roundup increase with smaller blocks and this negatively influences veneer recovery and gross product value for veneer mills.

Conclusions

Log diameter influences both the volume output and the operating efficiency of mills. Mill managers can create confusion by discussing the minimum diameter a given mill can handle rather than the range of sizes it was designed to process. Minimum piece size often relates to the limitations of a particular piece of equipment while the capacity of the mill usually relates to how all of the equipment centers in the mill are integrated to provide an even flow. Log diameter is an important factor in determining whether a mill can efficiently utilize the material from a given timber sale. The average diameter and the variation in diameter are more important considerations than the minimum log diameter. If forest managers understand the relationships between log diameter and mill efficiency they will be better prepared to design sales that meet their objectives and are marketable.

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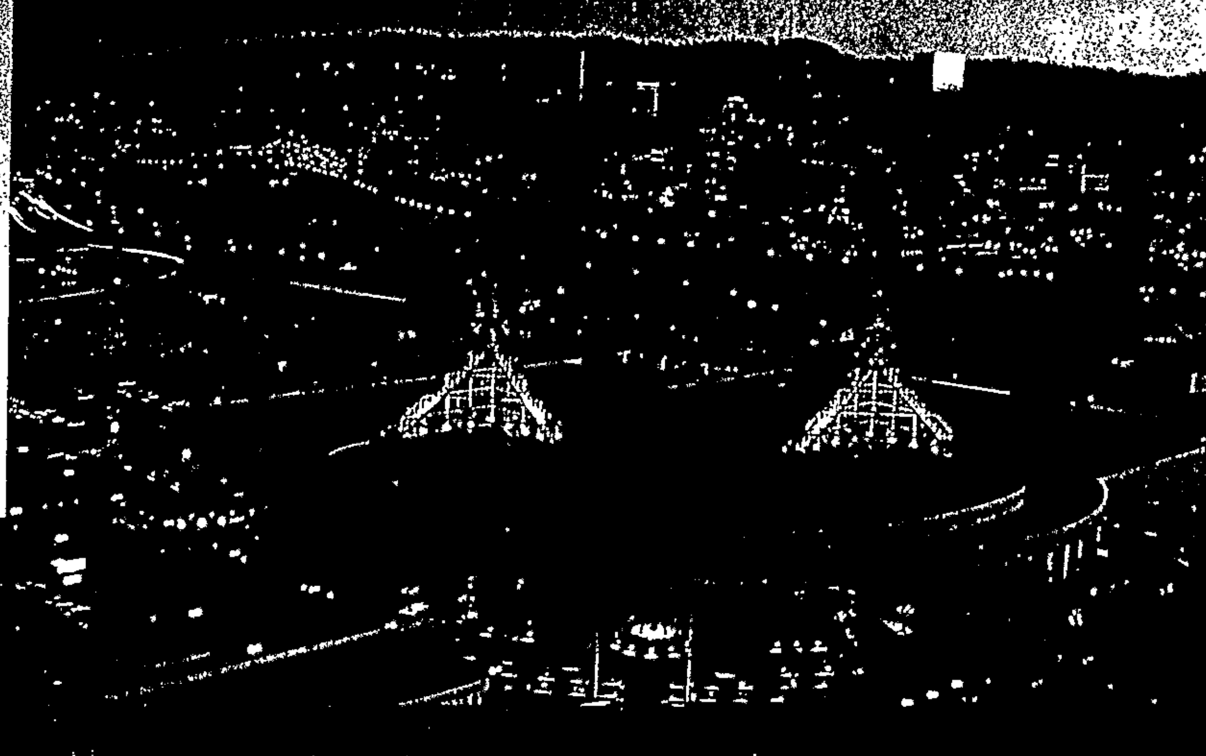

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