The Effect of Kerf Thickness on Hardwood Log Recovery

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Abstract

When sawing a log into lumber or other products, the saw blade removes material to separate the wood fibers between the resulting two parts, a loss of material that is commonly referred to as saw kerf. Thicker kerfs result in greater waste and less material available to produce lumber. Over the past decades, with the advancement of materials and technology, saw blade thickness has decreased. However, the reduction in material loss owing to a reduction in saw kerf may not always translate into a statistically significant increase in lumber product recovery. In this study, we explored the effect of saw kerf thickness on lumber recovery for a range of hardwood log diameters using the US Forest Service's Log Recovery Analysis Tool (LORCAT) sawmill simulation tool. Results indicate that the recovery gains realized depend upon the log diameters sawn, the lumber target thickness, and the change (reduction) in the thickness of the saw kerf.

Kerf is the amount of wood removed by a saw blade when sawing a log into lumber or into other products. The thicker the saw blade, the wider the saw kerf, and the greater the volume of wood converted into sawdust instead of lumber. Over time, but especially since the 1950s, materials and technology have improved and the thickness of saw blades has decreased greatly. After World War II, common kerf thicknesses for circle saws ranged from 0.281 to 0.375 inch and band saws had mean kerf thicknesses of about 0.1563 inch (Hallock 1962). In 1992, Steele et al. (1992), in their compilation of 266 sawmill studies, documented a mean circular sawmill kerf of 0.282 inch and a mean band sawmill kerf of 0.162 inch. The trend for thinner kerfs continued and Lin et al. (2011) found in a study of five small hardwood sawmills in West Virginia mean band sawmill kerfs of 0.125 inch.

Hallock (1962) determined that reducing the kerf thickness from 12/32 inch (0.375 in.) to 9/32 inch (0.281 in.) increases the volume of lumber recovered by approximately 7 percent. However, the difference in kerf thicknesses examined by Hallock, i.e., 0.094 inch, today is a common kerf thickness used by portable sawmills. Further, common kerf thicknesses found in today's commercial band sawmills are not much thicker than 0.094 inch. Thus, reductions in kerf thickness in today's mills will necessarily be fractions of the improvements seen in circle saw mills a few decades ago.

Hallock's study also proved that it is not necessary for a kerf thickness reduction to result in an extra board sawn for an improvement in recovery. Recovery improvements also can result from increases in the length and width of the lumber sawn (Hallock 1962, Steele 1984). However, the largest improvement to recovery results when an extra board can be sawn and as the incremental reduction in kerf thickness gets smaller, gains in recovery of usable products become more and more difficult to achieve. For example, if a saw blade with a 0.185-inch kerf width is used to saw a 22-inch-diameter log and seven boards are sawn from a face before reaching the cant surface, there will be a total of seven kerfs (not counting the slab kerf). If the kerf is reduced by 0.085 inch, there will be a gain of 0.595 inch on that face (Fig. 1). If the same gain can be achieved on the opposing face, a total gain of 1.19 inches results. Depending on the kerf thickness (an extra kerf is needed to saw the extra board), green allowance, and sawing variation, that might be just enough wood to saw an extra 4/4 (1-in.) board from this log. In addition, as kerf thickness decreases, it has the effect of moving boards outwards from the center of the log, into the quality zone.

Determining the impact that a change in kerf thickness will have upon lumber recovery depends on numerous factors, such as log diameter, target lumber thickness, cant size, and the resulting interactions among these factors in

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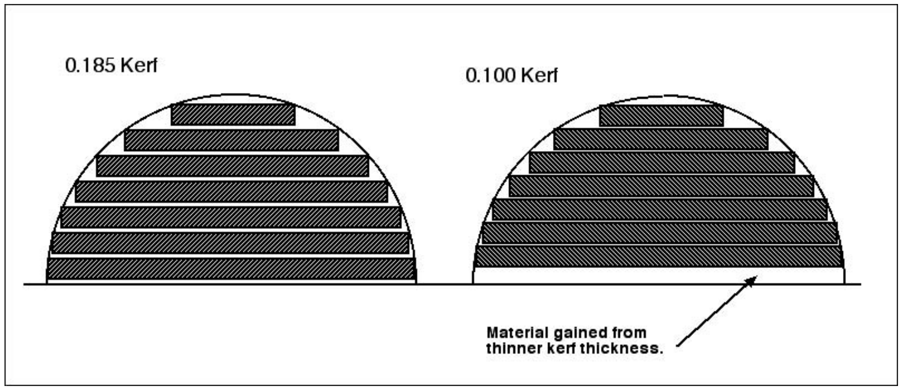

Figure 1.—Graphical comparison of potential material gain resulting from the use of a 0.085-inch-thinner kerf.

respect to kerf thickness. Also, for example, when sawing to a thicker target size, such as 8/4 (2-in.), there will be fewer cuts than if 4/4 lumber is produced. Producing a larger cant will also result in fewer cuts. Hence, the fewer cuts made, the lower the impact of kerf thickness on product recovery. In this paper, we analyze the effect of kerf thickness for a range of log small-end diameter (SED) classes and a range of kerf thicknesses for 4/4 lumber allowing us to determine how much of a reduction in kerf thickness is necessary to realize a significant recovery (yield) improvement.

Methods

Using the Log Recovery Analysis Tool (LORCAT), a sawmill analysis tool (Thomas et al. 2021, Thomas and Buehlmann 2021), a series of simulations were constructed and executed to research the impact of saw kerf size on product recovery. The log data processed by LORCAT consists of four key elements: SED, large-end diameter (LED), length, and grade. LORCAT is a geometry-based sawing simulator that, by itself, does not consider any defect information in its calculations. However, LORCAT's results use the Forest Service log grades and grade yield tables to account for the effect of log grade (defects) on recovery. Hence, LORCAT allows users to obtain estimates of their recovery including lumber quality and values. Yet, as this study is focused on volume or number of boards recovered, log and lumber grades and values are omitted from consideration.

The length of all logs used in this study was set to 12 feet. As log diameter is of critical importance to the outcomes of this study, we used a mill study data set consisting of 2,030 red oak (*Quercus rubra*) logs by Wiedenbeck et al. (USDA Forest Service, unpublished data set, 2004). These authors found that SEDs processed in mills surveyed ranged from 8 to 27 inches. Using the Wiedenbeck et al. (USDA Forest Service, unpublished data set, 2004) LED and SED data, the authors calculated the mean and standard deviation of taper per foot of log length for each 1-inch SED class.

A set of SEDs was created for the study that ranged from 8.0 to 27.9 inches in 0.10-inch increments, where there are 10 logs in each 0.10-inch increment, creating a database in LORCAT containing 100 logs for each 1-inch SED class for a database total of 2,000 logs. Next, using the taper distribution data, we created a random normal distribution of taper for the 100 logs in each SED class. The LED of each log was then calculated as LED = SED + taper × log length (12 feet). This resulted in a data set of evenly distributed log diameters that reflected a real-world sample based on the data of Wiedenbeck et al. (USDA Forest Service, unpublished dataset, 2004) data.

In the simulations, each log was sawn into 4/4 lumber and no cants were produced. The actual lumber target thickness was 1.147 inch, which is the target thickness (4/4) plus a 0.125-inch green allowance (i.e., shrinkage allowance) and a sawing variation allowance. A sawing variation allowance of 0.022 inch, the mean within board sawing variation for band saw mills (Steele et al. 1992), was used in all simulations.

For the analysis of kerf thickness, the kerf thickness ranged from 0.09 to 0.20-inch in 0.01-inch increments. All the logs were sawn using a sawing pattern like the one shown in Figure 2, where boards are sawn from two faces to make a cant or billet that is then sawn into lumber. For the smaller diameter logs with an SED less than 12 inches, a minimum opening face size of 5 inches by 8 feet and a billet thickness of 5 inches was used. For logs with an SED of 12 inches or more, a minimum opening face of 6 inches by 8 feet and a billet thickness of 6 inches was used. This was

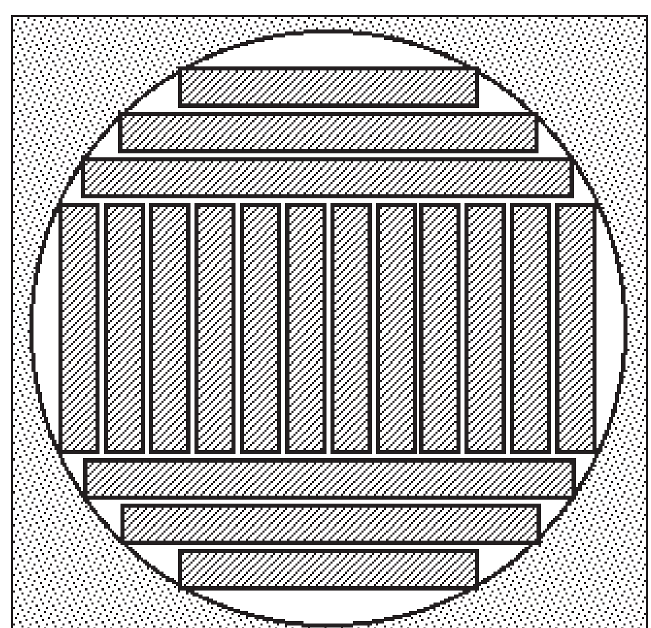

Figure 2.—General sawing pattern design used for all logs.

done to reduce yield loss on small-diameter logs as a smaller opening face specification pushes the outer board surface closer to the surface of the log and hence results in a thinner slab cut and consequently less residue.

Using LORCAT (Thomas and Buehlmann 2021), we determined the total lumber recovery volume and the number of boards produced by SED class and kerf thickness. LORCAT is a geometrically based sawing simulator that models logs as truncated cones defined by length and by large and small end diameters. As such, the log definitions that are processed do not contain any defect information (Thomas and Buehlmann 2021).

Using the R statistical program (R Core Team 2020) we compared the variances of the volume (board foot) recovery and board count simulation results for the various kerf thicknesses and SED classes. Using Levene's test (Brown and Forsythe 1974), it was determined that the variances among the SED classes were not equal. Thus, a nonparametric approach was required to analyze the differences among the SED classes. To determine which kerf thickness resulted in significantly different recovery or board count within each SED class, the aligned rank transform (ART) statistical test (Wobbrock et al. 2011) was used in conjunction with R. ART allows for the analyses of multifactor designs while traditional nonparametric tests permit the analysis of only a single factor. Post-hoc pairwise comparisons were conducted using ART-C (Elkin et al. 2021). ART-C showed the instances where the differences between any kerf thickness within an SED class were significant. A significance level of 0.05 was used for all comparisons.

Results and Discussion

In the factorial approach used by this analysis, each saw kerf thickness (from 0.09 to 0.20 in. in 0.01-in. increments) and log SED class (8.0 to 27 in. SED in 1-in. increments) was compared to every other saw kerf (for example, comparing the 0.09-in. to the 0.10-in. kerf thickness) and to every SED class (for example, comparing the 8.0-in. SED class to the 9.0-in. SED class). Thus, many of the comparisons are meaningless since a significant difference in recovery or the number of boards sawn should be expected when comparing a 10-inch SED log with a 27-inch SED log, regardless of kerf thickness. Thus, we limited the comparisons to those within our 1-inch SED classes. An example of a question answered by our simulation would be if a changing saw kerf thickness (from 0.09 to 0.20 in. in 0.01-in. increments) does have a significant impact on recovery within the 18-inch SED class. These comparisons allow the determination if a change in kerf thickness makes a significant and meaningful difference in total recovery (volume) or in number of boards sawn within each SED class.

Volume

The nonparametric analysis of variance using the ART statistical test (Wobbrock et al. 2011) established that both SED and kerf thickness had a significant effect on volume recovery. Further, a contrast test of main effects (Wobbrock et al. 2011) showed that across all diameters, all differences in volume produced among the different kerf thicknesses was significant at the 5-percent significance level. Similarly, all differences in volume sawn from the different SED classes used were also significant at the 5-percent level. Hence, the findings of this research answers questions like "if the current kerf thickness is 0.16 inch, then how much change in kerf thickness is required to see a statistically significant improvement in recovery for an 18-inch SED log?" Figure 3 provides an answer to this question by showing the 18-inch SED log volume-recovery groups (labeled "volume," right axis) and the kerf thicknesses (top axis). The bars denote that no statistically significant difference between the kerf thicknesses covered by that bar or overlapping bars exists. Examining Figure 3 reveals that the 0.16-inch kerf, indicated by the solid line, is included in three kerf bars, the bars from 0.13 to 0.16 (yellow bar), from 0.14 to 0.17 (purple bar), and from 0.16 to 0.19 inch (orange bar). Thus, within the range where these bars overlap (kerf thicknesses from 0.13 to 0.19 in.), there is no statistically significant difference in board footage sawn attributable to a change in kerf thickness. However, if the kerf thickness is changed to 0.12 inch, indicated by the dashed line in Figure 3, a statistically significant improvement in volume recovery can be expected from 18-inch SED logs. Conversely, increasing the kerf thickness to 0.20 inch or more will result in a statistically significant decrease in volume produced. The mean volume difference between the thinnest and thickest kerfs for 18-inch SED logs is 18.8 board feet (188.0 to 169.2 bdft; Table 1). Overall, the mean volume difference between the thinnest and thickest kerf was found with the smallest SED (8 in., difference of 0.4 bdft; Table 1), and was greatest with the largest SED (27 in., difference of 38.3 bdft; Table 1).

Figure 4 is a graphical representation of the post-hoc pairwise comparisons showing where, within each SED class, the difference of volume sawn was not significantly different between kerf thicknesses. Figure 4 shows the results for all SED classes used in this research. Hence, in Figure 4, as already explained in Figure 3, each bar and each overlap of bars within each SED class (left axis) denotes no significant difference in recovery between the different kerf thicknesses indicated at the top axis. As such, Figure 4 could be used to approximate the change in kerf thickness required to realize a statistically significant improvement in board feet sawn. Figure 4, however, does not allow the reader to make any conclusions as to the statistical significance of resulting board footage obtained between different SED classes. Often, the volume recovery difference between SED classes was found not to be statistically significantly different depending on the kerf thickness. For example, a 9-inch log with a 0.09-inch kerf does not result in a significantly different volume recovery compared to a 10-inch log with a 0.20-inch kerf thickness. However, within the same kerf thickness, the volume recovery by SED diameter is statistically different.

Table 1 reports the mean total board footage sawn by SED class and kerf thickness. Table 1 and Figure 4 combine to provide an understanding of the interactions between SED and kerf thickness for the sawing operations modeled in this paper. For the smallest diameters, 8- and 9-inch SEDs, the total difference in board feet of lumber recovered among all kerf thicknesses simulated (0.09 to 0.20 in.) is 0.4 and 3.2 board feet respectively (Table 1). Examining Figure 4 for these diameters, no significant difference exists in simulated board feet recovered for the 8-inch-diameter log class across all kerf thicknesses. For the 9-inch-diameter

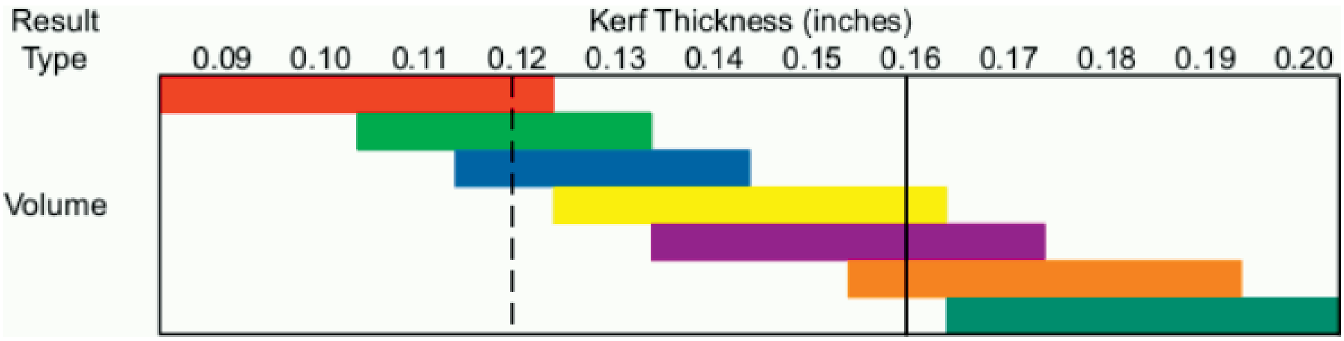

Figure 3.—Statistically significant differences in volume recovery by kerf thickness for the 18-inch small-end-diameter class.

Table 1.—Mean total volume (board feet) sawn by small-end diameter (SED) class and kerf thickness group.

	SED Class																			
Kerf	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.09	27.7	36.6	50.5	63.4	73.9	90.0	102.6	125.8	143.4	164.3	188.0	209.9	232.9	259.2	286.9	314.1	344.0	377.8	406.2	438.3
0.10	27.4	36.4	49.9	63.2	73.3	88.3	100.9	124.3	141.6	162.7	186.0	207.7	231.2	256.4	283.2	312.3	340.7	372.8	401.6	434.8
0.11	27.3	36.2	49.4	61.8	72.5	87.3	99.5	123.2	140.2	161.5	184.3	205.4	228.3	254.9	282.1	310.2	337.7	369.0	398.2	430.9
0.12	27.2	36.0	49.0	61.5	72.0	86.5	99.0	121.9	138.4	159.9	182.9	203.0	225.3	252.0	280.0	308.2	334.5	366.0	394.7	428.3
0.13	27.2	35.8	48.1	61.1	71.4	85.2	98.1	120.5	136.8	158.4	180.8	201.4	222.5	250.2	277.9	306.0	331.0	362.6	391.6	424.5
0.14	27.2	35.5	47.5	59.8	71.2	84.9	97.0	119.5	135.5	157.2	179.0	198.9	221.0	248.9	275.6	301.8	328.1	360.2	389.3	420.4
0.15	27.2	35.0	47.0	59.3	70.6	83.7	95.8	118.7	134.1	155.2	177.4	197.7	220.5	246.5	273.1	299.0	325.1	358.1	385.8	416.7
0.16	27.2	34.6	46.4	58.5	69.3	82.7	94.9	117.8	133.5	153.3	175.5	195.9	218.9	244.0	269.8	296.1	322.0	354.0	382.9	412.2
0.17	27.2	34.2	46.1	57.7	68.8	82.0	93.7	116.7	132.1	152.3	174.1	195.2	216.8	241.7	267.4	292.6	319.1	351.0	379.0	408.9
0.18	27.2	34.0	45.4	57.4	67.9	81.7	125.8	116.1	130.4	150.7	172.1	193.4	214.8	239.0	264.4	290.8	316.4	348.6	375.1	405.7
0.19	27.2	33.8	44.6	56.9	67.6	81.1	124.3	114.8	129.5	149.4	170.4	191.8	212.9	237.1	261.7	288.3	314.7	345.6	371.8	401.7
0.20	27.3	33.4	44.1	56.0	67.2	80.5	123.2	113.3	128.5	147.3	169.2	190.3	211.7	235.4	258.8	287.2	312.6	341.9	368.7	400.0

SED, only the thinnest and thickest kerfs yield significantly different volume than the other kerfs. In general, for the smaller log diameters, a wider range of kerf thicknesses yield lumber volume recoveries that are not statistically different compared to the larger SED classes. This is expected given the greater number of sawing cuts (kerfs) made when processing larger-diameter logs, which provide more opportunities for extra volume to be sawn.

Number of boards

The post-hoc pairwise comparisons of board count determined the groups for which the difference between any kerf thickness and SED class was significant with respect to the number of boards produced. As with the post-hoc comparisons of volume (Figs. 3 and 4; Table 1), we limited the comparisons to within SED classes. That is, we did not consider the comparison of board counts from different SED classes to be meaningful

Figure 5 shows, within each SED class, the kerf thicknesses that produced no statistically significant difference in number of boards sawn (i.e., ''statistically equivalent''), akin to the discussion on Figures 3 and 4. For example, there was no statistically significant difference in the number of boards produced for the 8-, 9-, and 10-inch SED classes among all kerf thicknesses (Fig. 5). Overall, the trends in the significance groups for volume (Fig. 4) and board counts (Fig. 5) are similar, with the key difference being that for board count, the significance bars are larger. The greater number of kerf thicknesses (0.01-in. increments) grouped together means that a larger change in kerf thickness is required to see a significant increase in the number of boards produced within any given SED class compared to the results found in comparing kerf impacts on volume recovery.

Figure 6 shows the board count groups for the 18-inch SED class with the solid black line showing the board count groups that include the 0.16-inch kerf thickness. A change to a 0.12-inch kerf thickness, illustrated by the dashed line in Figure 6, does not result in a statistically significant increase of the number of boards obtained. This result is different than the situation when sawn volume recovery was compared. As illustrated in Figure 3, changing the kerf thickness from 0.16 inch to 0.12 inch did result in a statistically significant increase of volume recovered. As volume increases continuously based on incremental gains in the positions of the kerf in logs with changes in kerf thickness, board count increases in discrete increments (when another piece of lumber is recovered) and more substantial gains in recovery are required to gain an additional board. Hence, while a reduction of kerf thickness from 0.16 to 0.12 inch results in a statistically significant increase in volume (Fig. 3), the kerf thickness needs to be reduced to 0.11 inch to result in a statistically significant increase in numbers of 4/4-thickness boards cut (Figure 6) for 18-inch SED. For the 18-inch SED logs the mean difference in number of boards sawn between the thinnest and thickest kerfs is two boards (23.4 vs. 21.4; Table 2). As with total recovery, the least gain is seen with the smallest, 8-inch SED, logs, which have a mean gain of 0.1 boards. A mean difference of 3.3 boards exists between the kerf extremes for the largest, 27-inch SED, logs analyzed.

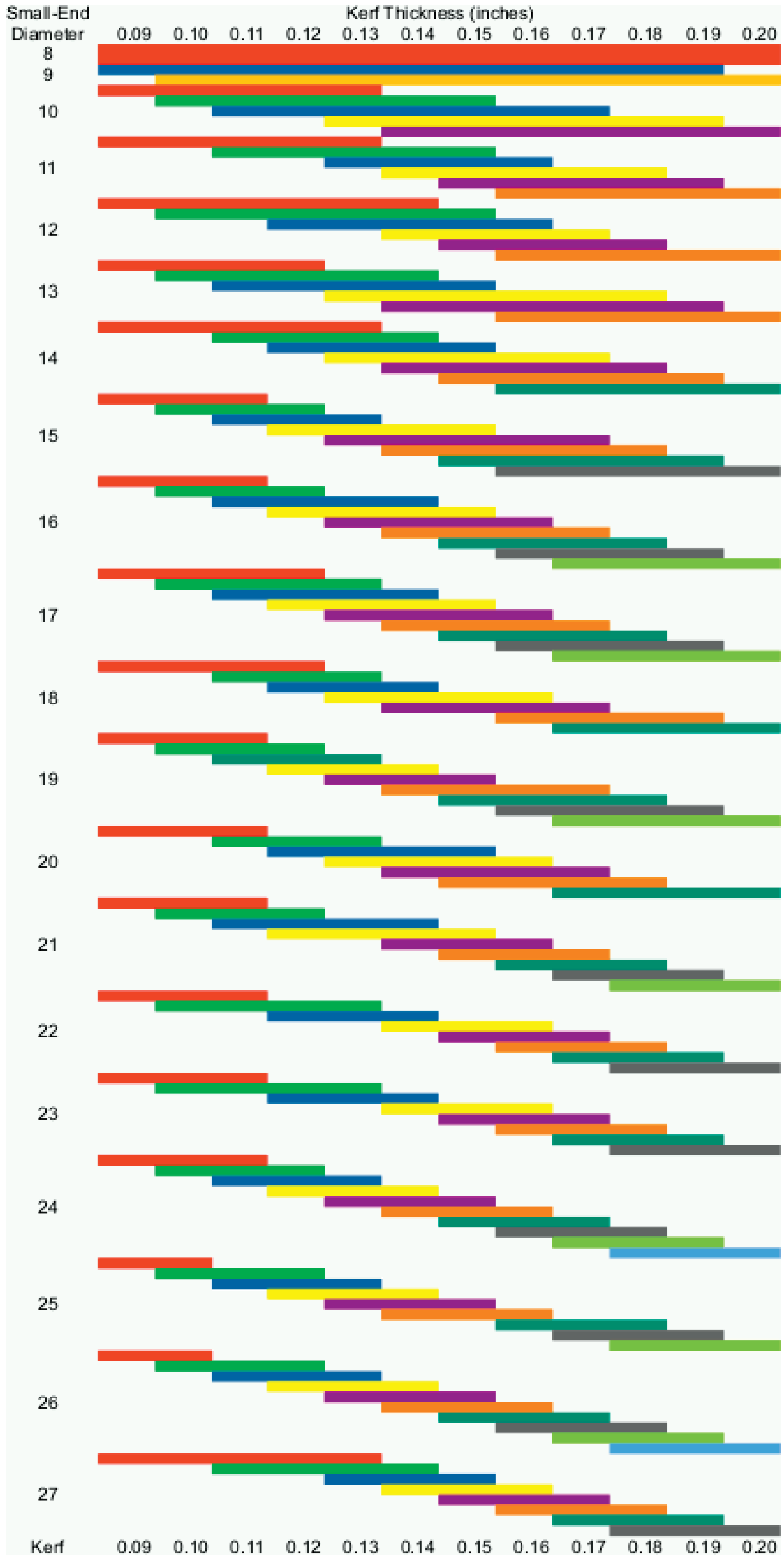

Figure 4.—Statistically equivalent lumber volume recovery groupings by kerf thickness and small-end-diameter classes.

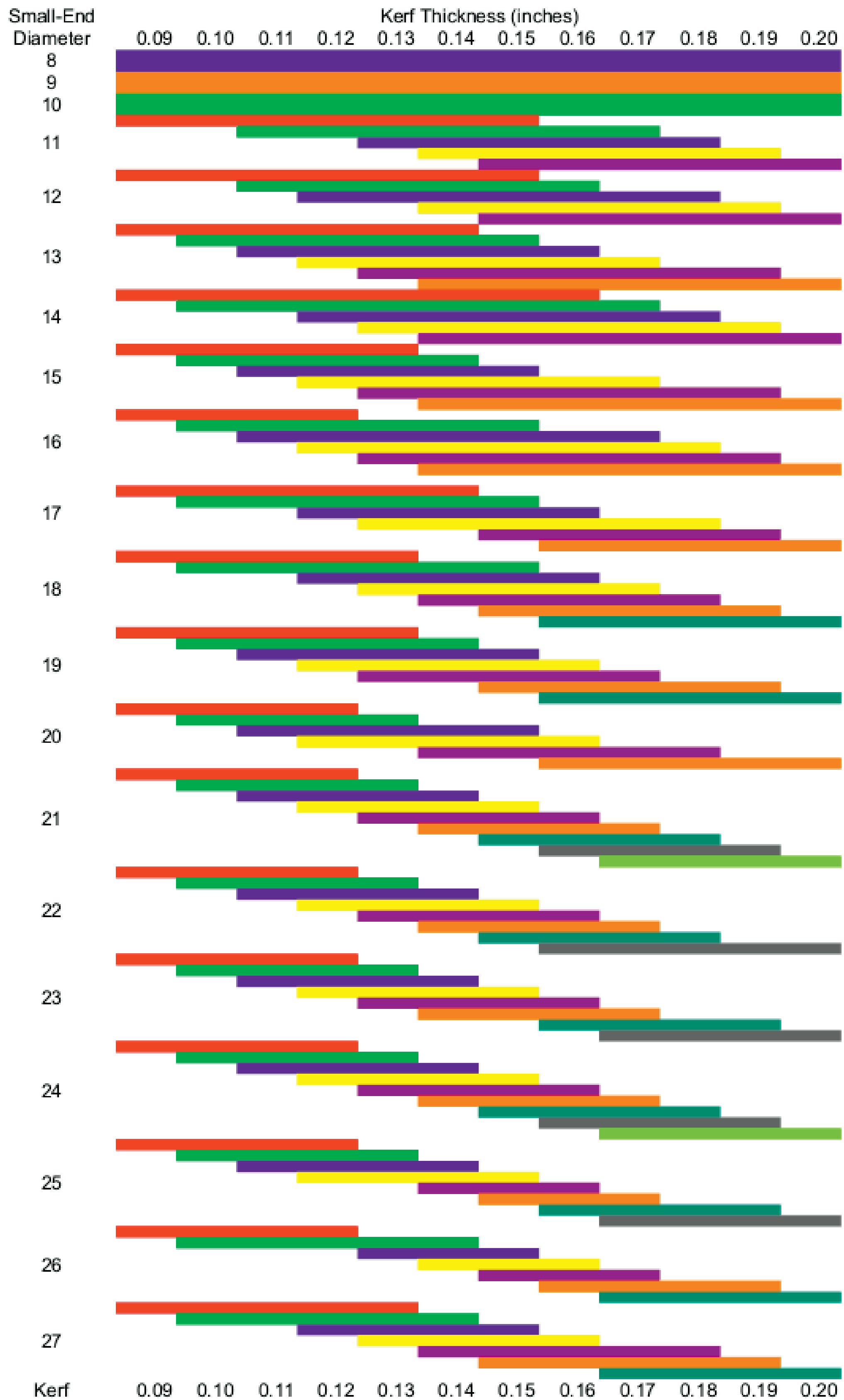

Figure 5.—Statistically equivalent board count groupings by kerf thickness and small-end-diameter class.

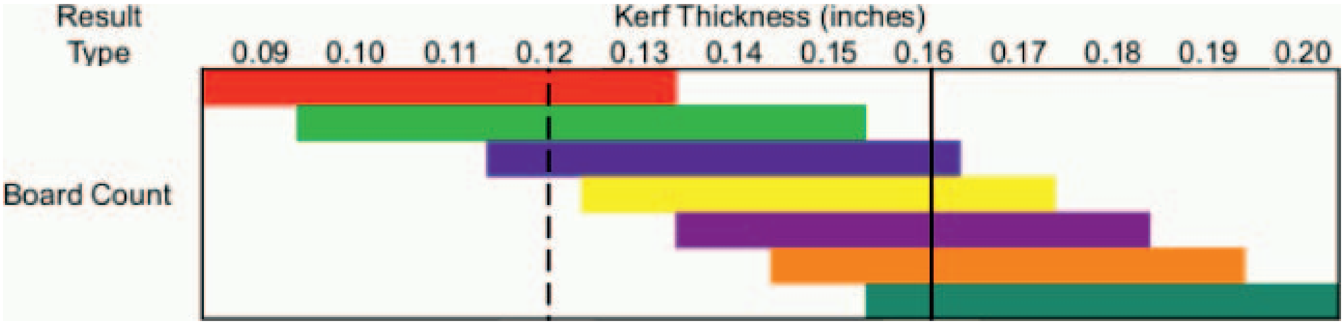

Figure 6.—Board count groups for the 18-inch small-end-diameter class.

Table 2.—Mean total number of boards sawn by small-end diameter (SED) class and kerf thickness.

	SED Class																			
Kerf	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0
0.09	6.1	7.1	10.1	12.1	12.1	14.3	15.5	18.2	19.4	21.2	23.4	24.9	26.3	28.2	30.2	31.8	33.3	35.7	36.8	38.5
0.10	6.1	7.1	10.0	12.0	12.0	14.1	15.4	18.0	19.1	21.0	23.2	24.7	26.1	28.2	30.0	31.6	33.2	35.3	36.4	38.3
0.11	6.0	7.1	9.8	11.8	11.8	14.0	15.2	17.8	18.9	20.9	23.0	24.4	25.8	27.9	29.7	31.4	32.9	35.0	36.2	38.0
0.12	6.0	7.1	9.7	11.8	11.7	13.9	15.1	17.6	18.8	20.8	22.9	24.3	25.5	27.6	29.5	31.2	32.5	35.0	36.1	37.7
0.13	6.0	7.1	9.4	11.7	11.7	13.7	15.0	17.4	18.5	20.5	22.6	24.1	25.3	27.3	29.2	30.9	32.3	34.6	35.7	37.4
0.14	6.0	7.0	9.2	11.5	11.6	13.6	14.8	17.2	18.3	20.4	22.4	23.8	25.1	27.1	28.9	30.6	32.0	34.4	35.5	36.9
0.15	6.0	6.9	9.1	11.4	11.3	13.4	14.7	17.1	18.3	20.2	22.3	23.6	25.0	26.9	28.7	30.4	31.7	34.1	35.1	36.6
0.16	6.0	6.9	8.9	11.1	11.1	13.3	14.6	16.9	18.2	20.0	22.0	23.4	24.7	26.6	28.3	30.2	31.5	33.7	34.8	36.3
0.17	6.0	6.8	8.8	11.0	10.9	13.1	14.4	16.8	18.0	19.8	21.9	23.3	24.5	26.4	28.2	29.9	31.1	33.4	34.5	36.1
0.18	6.0	6.8	8.6	10.8	10.8	13.1	18.2	16.6	17.9	19.7	21.8	23.0	24.3	26.2	28.0	29.8	30.8	33.1	34.2	35.8
0.19	6.0	6.7	8.4	10.7	10.7	13.0	18.0	16.5	17.7	19.5	21.5	22.8	24.1	26.0	27.8	29.3	30.6	32.9	34.0	35.6
0.20	6.0	6.7	8.3	10.6	10.6	12.9	17.8	16.4	17.7	19.3	21.4	22.5	24.0	25.8	27.5	29.2	30.4	32.7	33.7	35.2

Table 2 gives the mean total number of boards sawn by SED class and kerf thickness. Reviewing the results for the 18.0-inch SED class shows that the mean number of boards obtained increased by 9.35 percent between saw kerf thicknesses of 0.20 and 0.09 inches. However, for volume (Table 1), board footage increased by 11.11 percent due to the smaller incremental gains possible when counting board footage.

Overall, the kerf thickness trends for board counts (Figs. 5 and 6) are similar to those found with volume where the smaller diameters had overlapping bars (i.e., no statistically significant difference) that encompassed a wider range of kerf thicknesses, and larger diameters encompassed a smaller range. However, the kerf thickness groups for board count generally consisted of one to three more kerf thicknesses than corresponding board footage kerf groups indicating that a larger change in kerf size is necessary to see a statistically significant change in board count as compared to what would be necessary to see a significant change in volume. Also, as per the study's design, for logs with an SED of 12 inches or less, the minimum board width was 5 inches; for all other logs the minimum width was 6 inches. A minimum opening face length of 8 feet was used for all logs. Given these minimum board sizes, the addition of an extra board due to a sufficiently reduced saw kerf thickness would result in a gain of 3.3 or 4.0 board feet for the 9- to 12-inch and for the 13- to 27-inch SED classes, respectively. If a full-length board was added due to a reduction in kerf thickness, then the volume (board feet) board footage gained would be 5 or 6 board feet Consulting the mean total board feet sawn by SED in Table 1, we see that, on average, a minimum-sized board is added between the thinnest and widest kerf thicknesses. While the addition of a single board is not a significant gain in numbers of boards sawn, it is a statistically significant volume (board feet). The significance and nonsignificance of these gains are indicated in Figures 4 and 5.

While this study investigated log diameters by SED in 1-inch increments—the diameter class increments in which logs are traded—it is not known if the trends found at 1-inch increments are similar to those at say, the 0.10- or 0.25-inch SED increments. Also, if boards of a larger target thickness are sawn, there will be fewer kerfs and thus less opportunity for recovery or board count gains. Conversely, if a sawmill has markets for thinner, narrower, or shorter boards, additional boards may be recovered. Lastly, if the log is sawn to produce a cant, gains will be limited further. Hence, besides questions regarding the benefits of saw kerf reductions in terms of volume or board count metrics, future research should also be directed towards the economic merit of thinner kerfs.

Summary

This study, using the US Forest Service's LORCAT sawmill simulation tool, explored the effect of saw kerf thickness on lumber recovery by volume and by number of boards produced for a range of red oak log diameters based on a 4/4 lumber target thickness. As saw kerf thickness has been decreased considerably over the past decades, incremental reductions of the saw kerf thickness have become smaller, making it less likely to result in significant improvement in volume or numbers of boards sawn. For example, for an 18-inch SED log, reducing saw kerf thickness from 0.16 to 0.12 inch will result in a statistically significant improvement of volume recovered (gain of 7.4 bdft). However, when measuring the same change in saw kerf thickness by the number of boards produced, no statistically significant improvement of board count recovered is achieved (mean gain of 0.9 boards). For board count recovery to show statistically significant improvement, the saw kerf thickness would have to be reduced to 0.11 inch (mean gain of 1.0 board). Hence, efforts to improve volume and board count recovery benefit the most from reducing saw kerf thickness when the saw kerf thickness is reduced by a large amount and when larger SED logs are sawn.

In this study, we examined log diameters by SED in 1-inch increments—the diameter class increments in which logs are traded. However, it is not known if the trends found at 1-inch increments are similar to those at, say, the 0.10- or 0.25-inch SED increments. Questions also remain about the influence of sawing thicker or thinner lumber, and producing cants of various sizes. Another issue that has received scant attention by the industry's experts is the effect of sawing variation. Furthermore, while a kerf thickness reduction may result in a significant improvement in recovery, it is unclear if such an action results in a significant improvement in profit as thinner kerfs presumably incur higher costs. Lastly, as kerf decreases and boards are moved closer to the log edge, the potential for obtaining a larger number of higher-grade lumber exists since more of the outer boards are in the higher-quality zone of the log. However, it is unknown if the value improvement due to this factor would be significant.

The analysis of the effect of kerf thickness on lumber recovery is an example of a geometric fitting problem, much like the classic box-fitting problem. Except in this case, we are fitting boxes (lumber) into a cylinder (log). Changes to the size of the boxes, or the distances between the boxes (kerf thickness and sawing variation), or the size of the cylinder change the results (lumber recovery). An investigation into all possible interactions between lumber thickness, cant size, kerf thickness, and sawing variations would require considerable effort. As such, the main goal of this paper was to investigate the interactions at play between varying kerf thicknesses and the resulting impact on lumber recovery. For that, the LORCAT sawmill simulation tool (Thomas and Buehlmann 2021) provided an easy-to-use tool to model these factors and predict what effect, if any, a change might cause.

Literature Cited

Brown, M. B. and A. B. Forsythe. 1974. Robust tests for the equality of variances. *J. Am. Stat. Assoc.* 69:346, 364–367. DOI:10.1080/01621459.1974.10482955

Elkin, L. A., M. Kay, J. J. Higgins, and J. O. Wobbrock. 2021. An Aligned Rank Transform Procedure for Multifactor Contrast Tests. *In*: UIST 2021 - Proceedings of the 34th Annual ACM Symposium on User Interface Software and Technology, October 10–14, 2021, virtual conference; Association for Computing Machinery, Inc, New York. pp. 754–768. https://doi.org/10.1145/3472749.3474784

Hallock, H. 1962. A mathematical analysis of the effect of kerf width on lumber yield from small logs. Forest Products Laboratory, USDA Forest Service, Madison, Wisconsin. Report No. 2254. 23 pp.

Lin, W., J. Wang, J. Wu, and D. DeVallance. 2011. Log sawing practices and lumber recovery of small hardwood sawmills in West Virginia. *Forest Prod. J.* 61(3):216–224. DOI:10.13073/0015-7473-61.3.216

Rast, E. D., D. L. Sonderman, and G. Gammon. 1973. A guide to hardwood log grading. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. Gen. Tech. Rep. NE-1.32 pp.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/. Accessed January 5, 2022.

Steele, P. H. 1984. Factors determining lumber recovery in sawmilling. Forest Products Laboratory, USDA Forest Service, Madison, Wisconsin. GTR-FPL-39. 8 pp.

Steele, P. H., M. W. Wade, S. H. Bullard, and P. A. Araman. 1992. Relative kerf and sawing variation values for some hardwood sawing machines. *Forest Prod. J.* 42(2):33–39.

Thomas, R. E. and U. Buehlmann. 2021. LORCAT: The log recovery analysis tool. https://www.woodproducts.sbio.vt.edu/lorcat/. Accessed December 15, 2021.

Thomas, R. E., U. Buehlmann, and D. Conner. 2021. LORCAT: A log recovery analysis tool for hardwood sawmill efficiency. USDA Forest Service, Northern Research Station, Madison, Wisconsin. Res. Pap. NRS-33.

Wobbrock, J. O., L. Findlater, D. Gergle, and J. J. Higgins. 2011. The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. *In:* Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11), May 7–12, 2011, Vancouver, British Columbia, Canada. ACM Press, New York. pp. 143–146.