

IMPACT OF TIMBER HARVESTING ON RESIDUAL TREES

IN A CENTRAL HARDWOOD FOREST IN INDIANA

Thomas W. Reisinger and Phillip E. Pope¹

Abstract: Residual stand damage resulting from conventional ground-based logging operations was assessed on six oak-hickory, upland hardwood timber sales in south central Indiana. Two areas were harvested each year--1984, 1986 and 1988--using a combination of individual-tree and group selection methods. An average of 2.6 trees per acre was damaged, and 70% of the exposed sapwood wounds were larger than 100 in.² in size. Skidding caused 71% and felling 29% of these injuries. Study results indicate that the size of the wounds and the percent damage to the larger diameter classes and to higher value species is greater than reported in previous studies. The data suggest that much of the skidding damage was caused by carelessness, and could have been avoided. Damage to residual stands can be kept to a minimum by closer supervision during logging, greater operator care when skidding, and better pre-harvest planning.

INTRODUCTION

Damage to residual trees continues to be a concern of forest managers responsible for implementing individual-tree selection harvests or other types of partial cuts in hardwood forests. Damage may be limited to skinned bark and exposed sapwood, root damage, or broken branches in the crown, any of which can result in decreased vigor and quality. Or the damage may be severe enough to kill the tree. When a tree is wounded, certain physiological changes and cell differentiation occurs in the area surrounding the wound, and the wound usually becomes sealed off from the rest of the tree (Shigo 1966). Most decay and defect problems in trees originate in and spread from some kind of wound, and the impact of these wounds is likely to increase with time (Shigo 1966, Shigo and Larson 1969, Shigo 1984, Carvell 1984). The type and severity of bole damage; the susceptibility of the tree species present; and the rate of wound healing (which may be indirectly related to discoloration or linked to sources of decay) are also important considerations.

Residual tree damage is an inherent aspect of partial cutting, but the level of damage should be minimized to assure future product quality. Recent emphasis on "quality" in the

¹Assistant Professor, Industrial Forestry Operations, Department of Forestry, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061-0324; and Professor, Forest Soils, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907.

manufacturing sector demands that foresters examine the impact of current hardwood logging practices on the production of quality hardwood products. This paper reports on skidding and felling damage to residual trees for six timber sale areas where individual-tree selection and group selection harvesting was conducted over a six-year period. The objectives of the study were to obtain post-harvest data on the impact of harvesting operations on the residual stand; to assess the impact of damage on log quality; and to determine specific guidelines for minimizing stand damage when logging a central hardwood forest (Hammond 1988).

METHODS

Data were collected from six timber sale areas on the Morgan-Monroe State Forest located in the Brown County Hills section of the Highland Rim Natural Region of Indiana (Homoya et al. 1984). This section of Indiana is characterized by deeply dissected, well-drained, uplands underlain by siltstone, shale, and sandstone soils. The topography consists of ridges with moderate to steep slopes ranging from 10 to 70%. The forest type is predominantly oak-hickory with a mixture of other hardwoods such as yellow poplar, white ash, sugar maple, beech, sassafras, and cherry.

General site information for the six study areas is provided in Table 1. Each of the six harvest areas was similar in size, volume of timber that was removed, soil type and terrain. The same type of 4-wheel-drive rubber-tired skidding equipment was used in each. All timber sales were logged during the fall with two areas each harvested during 1984, 1986 and 1988. Sampling design was not replicated; but two similar areas were evaluated every two years over a 6-year period. The areas ranged from 57 to 108 acres in size with the average being 78 acres, and the volume removed averaged 1.41 MBF per acre (1000 board feet). Data on residual basal area prior to harvesting were not available.

Harvest trees on each sale area were marked by Indiana Division of Natural Resources (IDNR) foresters using a combination of individual-tree selection and group selection methods. The group selection method resulted in openings of various sizes; as shown in Table 1, the average number of openings was 2.3 and average size was 5.3 acres. All areas were logged by independent contractors using chainsaws for felling, and cable skidders for moving tree lengths to the landing area. Trees were topped at a merchantable diameter of approximately 8.0 inches and skidded full length (i.e., 18-40 feet). Landing or deck areas were designated by IDNR foresters, but skid trail locations were determined by individual contractors. In all cases, the logging contractors had no prior knowledge that these tracts would be evaluated for residual stand damage.

Residual stand damage data were obtained from 179 permanently marked 0.2 acre plots centered on transect lines uniformly distributed throughout each study area. Transect lines were spaced 5 chains (330 feet) apart and perpendicular to the topography; plot centers were placed 4 chains (264 feet) apart along the transect lines. This sampling design approximated a 20% sampling intensity.

Table 1.--General information for the six study sites located on Morgan-Monroe State Forest, Indiana.

Study Site	Year of Harvest	Tract Size (acres)	Volume Removed (MBF/acre)	Number & Acreage of Openings ¹	Residual Basal Area ²
A	1988	71	1.43	-- (0.0)	36.9
B	1988	70	2.19	2 (5.0)	58.8
C	1986	57	1.70	2 (6.6)	45.7
D	1986	108	1.37	4 (9.7)	72.7
E	1984	84	2.49	2 (6.0)	48.6
F	1984	76	1.77	8 (15.0)	58.4
Mean		78	1.41	2.3 (5.3)	56.4

¹Per tract.

²Basal area (square feet) per acre with openings.

Damage to residual stems was determined by examining all trees located within the sample plot boundaries (53-foot radius). A harvest-inflicted wound was defined as bark removed accompanied by exposure of cambium or sapwood on stems 6 inches dbh or larger, damage to branches or crown, and/or root damage. Destroyed, bent, or leaning trees less than 6 inch dbh were not recorded. Wound characteristics were recorded by species and dbh; data collected included:

1. Number of wounds per tree;
2. Position of each wound above groundline (to the nearest 1.0 foot);
3. Size of exposed sapwood wound (to nearest square inch);
4. Maximum depth of wound (to nearest 0.1 inch);
5. Percent crown damage (was determined ocularly); and
6. Root damage (was noted, but not measured).

Skid trail patterns and landing locations were mapped for each timber sale area. A hand-held compass and 150-foot steel tape were used to record bearings and distances for mapping primary and secondary skid trails throughout each tract. This information was digitized into a geographic information system (GIS), and the location of skid trails and landing areas were plotted along with study area transect lines, plot centers, contour lines, and haul roads.

RESULTS AND DISCUSSION

Number of Trees Damaged

Bark removals accompanied by sapwood exposure on stems 6 inches dbh or larger were the primary type of logging injury recorded. As indicated in Table 2, the average number of trees with exposed sapwood for all areas was 2.6 per acre, or 198.6 per tract. Area A had the fewest (1.9) injured trees per acre, one of the lowest volumes of timber removed (1.43 MBF/acre), and a low residual basal area (BA) of 36.9 ft.². In contrast, Area B had the highest number (4.0) of damaged trees per acre with one of the larger volume removals (2.19 MBF/acre) and residual BA (58.8 ft.²). This pattern was not apparent in the results for the remaining study areas. The average BA of all residual stands was 56.4 ft.² per acre (Table 1). These values include group selection openings which lowered the overall BA; when openings were not included, the average BA was 65.1 ft.² per acre. Of the injured trees observed, 16 percent received multiple wounds with no particular pattern observed for any individual study area. Nyland and Gabriel (1971) also found that logging damage is often distributed irregularly throughout the stand, and the occurrence of logging wounds seemed independent of the density of the original or residual stand or the intensity of cut.

Size of Exposed Sapwood

The effect of exposed sapwood wounds on future stem quality is well documented, and depends on the severity of the injury. Previous research indicates that individual wounds greater than 100 in.² are likely to cause decay (Nyland and Gabriel 1971). Exposed cambium wounds will callous and produce some decay in the butt log, but the damaged trees will rarely die because of these wounds. For this study, 70% of the wound sizes were greater than 100 in.², and the overall average size of tree wounds for all areas was 342.5 in.² (Table 2). Area A had the smallest average wound size (179 in.²) while D had the largest average wound size (535 in.²). In a study in West Virginia on 50-70% slopes, Lamson et al. (1985) reported that less than 1% of the residual trees (4 trees per acre) had any wounds exceeding 100 in.² in size. Their study found exposed sapwood wounds averaged 17, 39 and 26 in.² for sapling, pole-size and sawtimber-size trees, respectively. In contrast to the West Virginia study, over half the wounds in this study were in the 150 in.² or larger class (Figure 1).

Wound Depth and Position

A deep wound or gouge is of greater concern than bark abrasion or exposed sapwood. Wounds less than 4 inches wide tend to heal in as little as 2 to 4 years; but the longer the wound remains open the more discoloration and rot will result (Carvell 1984). For this study, the average depth of the tree wounds was 1.16 inches (Table 2). Trees on Areas E and F had

Table 2.--Number of trees injured and size, depth, and position of wounds for the six study sites.

Study Area	-----Injured Trees-----		-----Wound-----		
	mean (per acre)	total (per tract)	Size mean (sq. in.)	Depth mean (inches)	Position ¹ mean (feet)
A	1.9	136	178.9	0.78	2.71
B	4.0	280	248.0	0.71	3.53
C	2.3	132	438.5	0.81	0.76
D	2.0	216	535.2	0.96	1.90
E	2.2	181	297.0	2.01	0.47
F	3.2	245	244.3	1.39	0.50
Mean	2.6	198.6	342.5	1.16	1.76

¹Position above groundline.

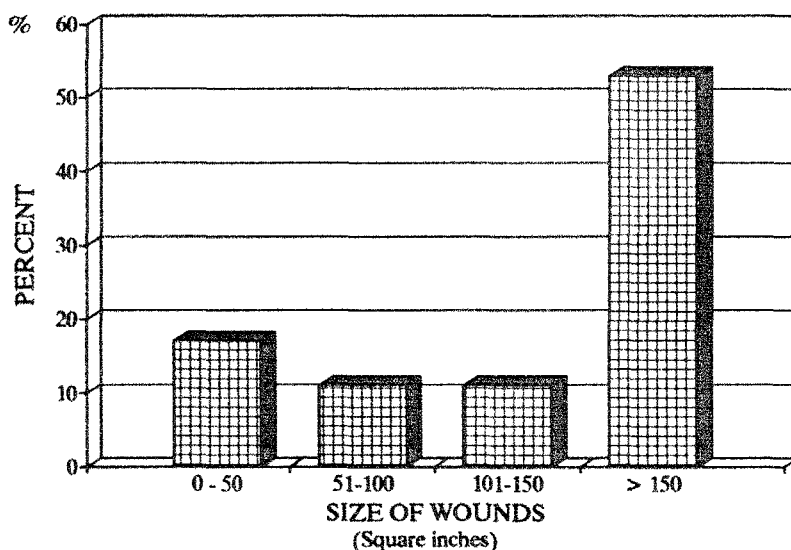


Figure 1. Percent of wounds by 50 in.² size classes for the six study areas.

the deepest wounds at 2.01 and 1.39 inches, respectively. The mean depths for wounds on trees in the other areas were shallower, ranging from 0.71 to 0.96 inches. Residual trees found on the two tracts (Areas E and F) harvested four years ago have developed deep season checks from drying which accounts for the increase in depth. The most common location for

wounds on the tree stem was 2.0 feet above groundline (Table 2, Figure 2). For areas A and B, the average wound was higher than 2.0 feet; and the average was below 2 feet for the other four areas. Because the wounds on Areas A and B were fresh, they were more easily detected higher up on the stem than on the areas harvested 2 and 4 years ago. Overall, 73% of the wounds were below 2 feet and 78% were below 4 feet, which agrees with the results reported by Nyland and Gabriel (1971).

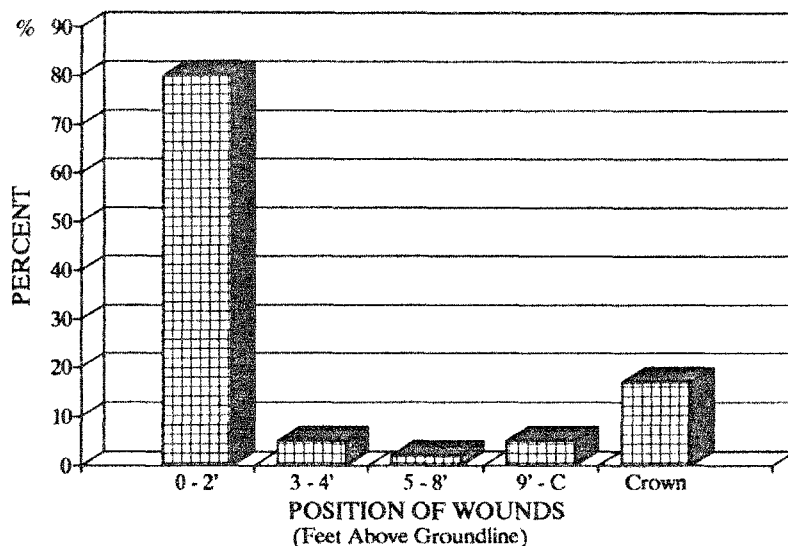


Figure 2. Percent of wounds by position class (above groundline) for the six study sites.

The percentage of wounds over 100 in.² is greater than results found in previous studies (Lamson et al. 1985; Wendel and Kochenderfer 1978; and Biltonen et al. 1978). Such wounds, if they fail to heal quickly, could seriously affect the future quality of those trees injured. The low stem location of the wounds, however, could negate most of the detrimental effects to stem quality. Wounds near the ground are not as detrimental to the tree as wounds higher up on the stem (Shigo 1984). The wounds that cause the most concern are the large wounds located up on the main bole 4-10 feet above ground, and a low percentage of this type of wound was noted (Figure 2). However, a large volume of wood is lost in future harvests if the lower two feet of the butt log is of poor quality.

Tree Diameters and Species Damaged

Injury to stems was most common for trees in the 11- to 14-inch dbh class (Figure 3); 37 trees (34%) in this category and 34 (31%) in the 6-10 inch class were injured. For the 15- to 18-inch and 19- to 22-inch classes, tree damage occurred more frequently than the frequency of that diameter class in the residual stand. The 6- to 10-inch and 11- to 14-inch diameter classes had a lower frequency of damage than their frequency of occurrence in the stand. In

contrast to these findings, previous studies have reported that residual stand damage is usually concentrated in the lower diameter classes (Deitschman and Herrick 1957; Nyland and Gabriel 1971; Lamson et al. 1985). The results of this study suggest that the most likely cause of this damage is carelessness -- the skidder operators disregarded or failed to maneuver around the larger residual stems.

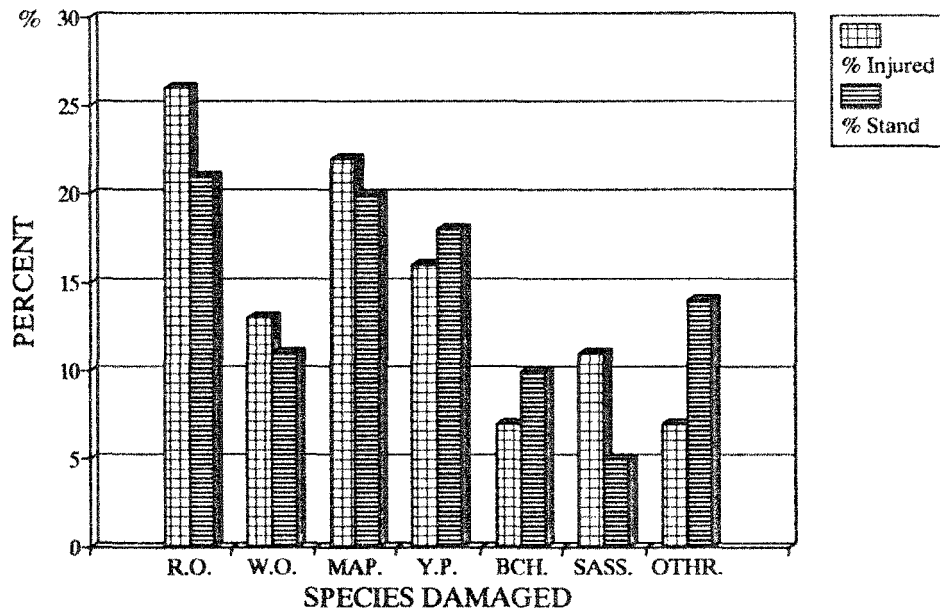


Figure 3. Percent of tree species injured for the six study sites.

Red and white oak, sugar maple, and yellow poplar were injured more often than other species found in these stands. As shown in Figure 4, the percentages of red oak, white oak, and sugar maple stems damaged were higher than their overall percentages in the residual stand. All other species had a lower injury percent than the frequency of occurrence in the stand. Red and white oaks combined accounted for 39% of the injured species while the percent of the oaks found in the residual stand was only 32%. One explanation for this could be the skidder operators' failure to recognize the value of future commercially important crop trees. Regardless of the reason, bark scraped from these stems is likely to reduce the future quality and value of these trees.

Operational Considerations

Slope and traffic intensity on the study sites had an effect on the number of trees injured. The highest number of injured trees (per acre) occurred on the flattest sites (Areas F and B), while the smallest number of injured trees occurred on the tract with the steepest terrain (Area A). On steeper slopes, the primary skid trails were located on the ridge tops and secondary

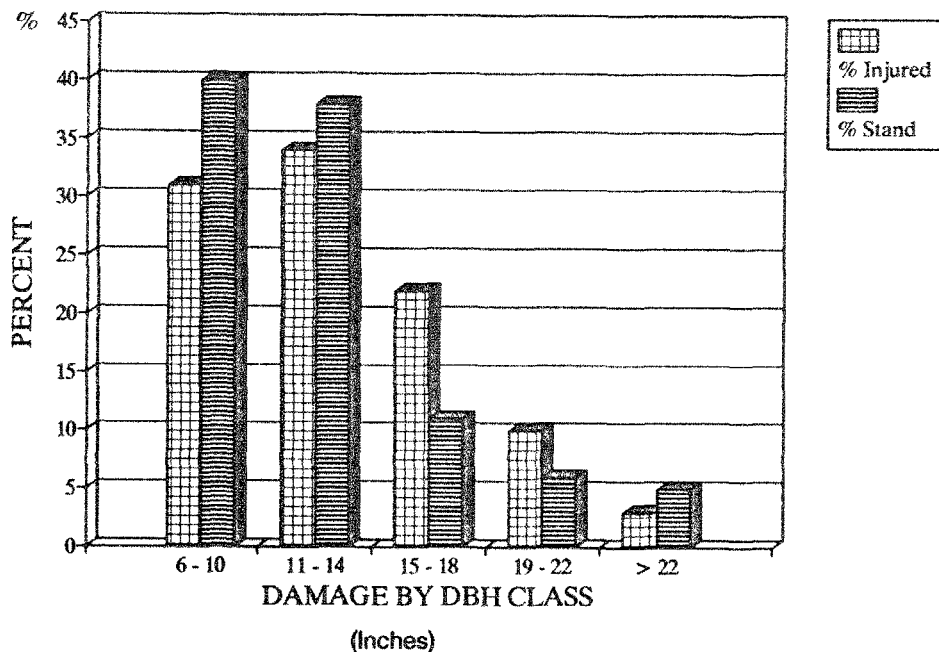


Figure 4. Percent of tree species injured for the six study sites.

skid trails were oriented directly up and down the slopes. Gentle terrain allowed the skidder operators to travel at higher speeds and cover a larger percentage of the total area which, in turn, damaged more residual trees.

As expected, higher rates of stand damage appear to be a function of traffic intensity or number of machine passes. The majority of residual stand damage occurred adjacent to the primary skid trails where the number of machine passes was the highest even though secondary skid trails disturbed 34% more surface area. The average number of trees injured by machine traffic on primary skid trails was 5.8 trees per acre, almost double the number of trees located on secondary skid trails (3.1 trees). Skidding caused 70% of the residual stand damage, felling caused 29%, and 1% of the wounds were caused by landing operations. Ten percent of the wounds were associated with root damage during skidding, and generally were confined to one side of the tree (i.e., adjacent to the skid trail). Other studies involving ground-based skidding report similar results (Nyland and Gabriel 1971; Johnson et al. 1979; Biltonen et al. 1978; and Olsen and Seifert 1984). Nyland and Gabriel (1971) suggest that over half of the skidding injuries might have been avoided by "slightly altering the skid path or using greater caution during skidding."

SUMMARY

The results of this study are similar to those of other studies that have evaluated residual stand damage after conventional ground skidding operations. Past research indicates that it is

inevitable that some trees will be injured during partial cutting, but the amount of damage can not be predicted in advance based on stand density or cutting intensity. The average number of trees (> 6" dbh) injured in this study (i.e., 2.6 trees per acre) is fairly typical for partial cuts in hardwood stands. However, the size of the wounds was larger than expected based on previous studies of logging damage, and a majority of these wounds are larger than 100 in.² size. Wounds this large have a greater potential to cause decay and discoloration, these wounds may not cause defect problems due to their low position on the main bole. The percentage of red and white oaks damaged was also higher than expected. Injury to these and other commercially important species is a concern because it poses a threat to the future merchantability of these hardwood stands. Slower travel speeds and additional care should be exercised by the skidder operators in order to protect future crop trees in the larger diameter classes and those species that have commercial value if product quality is to be maintained in successive harvests.

The majority of the residual stand damage (71%) is caused by skidding along primary skid trails with twice the number of trees damaged on the primary skid trails as on the secondary trails. Terrain seems to influence the position and number of skid trails used, and in turn affect the number of stems injured. Normal levels of residual stand damage associated with individual-tree/group selection cuts can be tolerated and should not cause serious quality problems (Lamson et al. 1985). Because partial cuts require frequent entry to the stand, continued efforts to minimize residual stand damage of each harvest must be encouraged particularly for high quality hardwood stands. The results of this research suggest that greater emphasis be given to the following recommendations.

1. **Operator training.** This research as well as past studies indicate that skidding damage (more than felling injuries) depends upon human factors and can often be avoided. New employees should be trained and experienced machine operators must be made aware of the value of residual crop trees and the importance of minimizing stand damage if uneven-aged stand management practices are to be successful.
2. **Closer supervision.** Many times the machine operators' paycheck is based on production rather than the quality of, or care taken in, carrying out that job. Close supervision of the skidding and felling operations by the logging foreman, management foresters, and/or the landowner is essential if machine operators are to be convinced that care should be exercised to avoid damage to potential crop trees. If that does not work, financial incentives for doing a quality job or penalties for excessive logging damage may need to be specified in the harvesting contract.
3. **Pre-harvest planning.** Preliminary planning done prior to beginning the harvest should consider ways to minimize residual stand damage. The use of pre-planned or designated skid trails offers a solution because pre-planning confines most of the machine traffic within a smaller area, thus reducing the amount of residual stand damage. The practice of leaving designated "rub" trees along main skid trails, where the majority of the trees are damaged, can also greatly decrease the number and severity of damage to residual trees. The "rub" trees receive a larger share of the skidding damage, and are then removed at the end of the harvest.

LITERATURE CITED

- Biltonen, F.E., W. A. Hillstrom, H.M. Steinhilb, and R.M. Godman. 1978. Mechanized thinning of northern hardwood pole stands: methods and economics. USDA For. Serv. Research Paper NC-137. 9pp.
- Carvell, K. L. 1984. A silvicultural evaluation of cable yarding for partial cuts. In Proc.: Mountain Logging Symposium, Jun. 5-7, Morgantown, West Virginia. pp133-141.
- Deitschman, G.H. and D.E. Herrick. 1957. Logging injury in the central states upland hardwood. J. For. 55(4):273-277.
- Hammond, S.C. 1989. Impacts of timber harvesting on soils and residual trees in Indiana's Morgan-Monroe State Forest. M.S. Thesis. Purdue University, Dept. of Forestry and Natural Resources. 93pp.
- Homoya, M.A. D.B. Abrell, J.R. Aldrich, and T.W. Post. 1984. The natural regions of Indiana. Proc. Indiana Acad. Sci. 94:245-269.
- Johnson, J.A., W.A. Hillstrom, E.S. Miyata, and S.G. Shetron. 1979. Strip selection method of mechanized thinning in northern hardwood pole size stands. Michigan Tech. Univ. Res. Notes No. 27. 13pp.
- Lamson, N.E., H.C. Smith, and G.W. Miller. 1985. Logging damage using an individual-tree selection practice in Appalachian hardwood stands. No. J. App. For. 2(4):117-120.
- Nyland, R.D. and W.J. Gabriel. 1971. Logging damage to partially cut hardwood stands in New York State. State Univ., Coll. of For., Syracuse Univ., AFRI Res. Pap. 5. 38pp.
- Olsen, E.D. and J.C.W. Seifert. 1984. Machine performance and site disturbance in skidding on designated trails. J. For. 82(6):366-369.
- Shigo, A.L. 1966. Decay and discoloration following logging wounds on northern hardwoods. U.S. Dept. Agric. For. Serv. Res. Pap. NE-47.
- Shigo, A.L. 1984. How to assess the defect status of a stand. North. J. App. Forestry 10(9):41-49.
- Shigo, A.L. and E.H. Larson. 1969. A photo guide to the pattern of discoloration and decay in living northern hardwood trees. USDA, For. Serv. Res. Paper NE-127. 100pp.
- Wendel, G.W. and J.N. Kochenderger. 1978. Damage to residual hardwood stands caused by cable yarding with a standing skyline. South. J. Appl. For. 2(4):121-125.