International Journal of Advanced and Applied Sciences, 3(8) 2016, Pages: 52-56

Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Wood waste during full-length and cut-to-length harvesting systems in caspian forests

Farshad Keivan Behjou [1,*], Mahdi Ramezani [2], Ehsan Zandi Esfahan [3], Alireza Eftekhari [3]

[1]*Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran*
[2]*Department of Environmental Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran*
[3]*Rangeland Research Division, Research Institute of Forests and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran*

A R T I C L E I N F O

Article history:
Received 9 May 2016
Received in revised form
5 August 2016
Accepted 16 August 2016

Keywords:
Wood waste
Forest operations
Full-length harvesting
Cut-to-length harvesting
Caspian hardwood forests

A B S T R A C T

A field-based study was performed to examine wood waste associated with full-length and cut to length harvesting systems in Caspian forests of Iran. Damaged logs were recorded with additional information obtained for the location, dimensions, and type of damage. The data were analyzed statistically to determine significant differences of damages during logging process. The results indicated that cut to length harvesting systems caused more volume loss to logs than full-length harvesting systems; also bucking resulted in significantly more volume loss when compared to skidding, decking, and loading operations. Study showed that the process of skidding, decking, and loading of logs has very little impact on damage levels. Volume losses of damaged logs were not sensitive to tree species and log size.

1. Introduction

The forests in northern Iran are most often harvested by one of two methods including full-length and cut to length harvesting systems. On the other side, there have been substantial increases in demand for veneer type products from hardwood species. In most of the cases, logging operations in the region are along with high amount of wood waste and this is one of the problems in logging operations. Williston (1979) found that breakage and skidding damage associated with harvesting operations destroyed almost 6% of the total value of harvested logs. McNeel and Copithorne (1996) stated that species is a factor in defining the amount of breakage expected during harvest. Damage to harvested trees or logs can occur during the felling, bucking, skidding, decking, loading, and hauling functions of the timber harvesting process (Wang et al., 2004). McMorland and Guimier (1984) found that shears cause very many but shallow splits, while saw chains cause less frequent but deeper splits. Greene and McNeel (1989), Faust and Greene (1989) reported log damage by feller-bunchers with both shear and saw heads and found that the damage usually occurred in the first twelve inches of the butt log. Even small improvements in volume recovery could lead to large improvements in financial gains (Boston and Dysart, 2000). Han and Renzie (2005) found that feller-buncher felling results in greater wood volume waste as a results of a thicker saw blade kerf than dose chan saw felling. Wang et al. (2004) found that felling resulted in significantly more log damage when compared to skidding, decking and loading operations. Hall and Han (2006) found that the average stump height of mechanized felling is 5.8cm (17%) lower than manual felling. Unver and Acay (2009) developed a prediction model bye consideration friction vector affecting skidded log, friction surface area of the log and skidding distance parameter. Improper bucking might not damage the log in a physical sense, but it could damage the potential value gained from bucking correctly (Sessions, 1988; Pickens et al., 1992; Zavala, 1995). The implementation of correct log bucking procedures can potentially increase the yield from each tree harvested, which correspondingly can improve profits for the logger and sawmill. Dragging the logs over the ground could present some type of potential damage to the harvested logs (Wang et al. 2004).

Damage to hardwood logs is especially important in the Caspian hardwood forest region, where much of the hardwood timber harvested is sawn into grade lumber or turned into veneer or veneer-based composites. The objectives of this study were to:

* Corresponding Author.
Email Address: farshad.keivan@gmail.com (F. Behjou)
http://dx.doi.org/10.21833/ijaas.2016.08.009

1. determining wood waste during bucking, skidding, loading or decking operations in Caspian hardwood sites;
2. Identify how operational factors such as harvesting system, function, tree species, and log size affect damage;

2. Materials and methods

Wood waste during logging operations was studied with two harvesting systems on four different Caspian hardwood forest sites. Harvesting functions investigated included bucking, skidding, decking, and loading. Two harvesting systems including chainsaw bucking, skidding with a cable skidder, decking/loading with loader were analyzed (Table 1). The operator's experience in using chainsaws varied from 5 to 16 years (Table 1).

The harvest sites were located in the north of Iran and had similar species composition, average slope, and stand conditions (Table 2). The tract size ranged from 46 to 66 ha with average slopes of 20 - 45%. Average residual stand density for the four tracts was approximately 171-197 trees/ha with an average DBH ranging from 41.4 to 51.2 cm and average merchantable height ranging from 10.5 to 13.1 m, respectively. Selective cuttings were conducted on all sites and harvest intensity was 20.8m^3 per hectare. The major species sampled were beech (*Fagus orientalis*), hornbeam (*Carpinus betulus*), alder (*Alnus subcordata*), maple (*Acer velutinum*), and elm (*Ulmus glabra*) (Table 2).

Table 1: Harvesting machines and operators' experience by site

		Site 1	Site 2	Site 3	Site 4
		Full-length system	cut to length system	Full-length system	cut to length system
Bucking	Machine	Chainsaw	Chainsaw	Chainsaw	Chainsaw
	Experience	7	11	13	9
Skidding	Machine	Cable skidder	Ranger	Cable skidder	Ranger
	Experience	13	14	6	7
Loading	Machine	Loader	Loader	Loader	Loader
	Experience	14	11	8	11

Table 2: Conditions for sites, harvests, and machines in the field study

	Site 1	Site 2	Site 3	Site 4
Harvest system	Full-length	cut to length	Full-length	cut to length
Harvest method	Selective cut	Selective cut	Selective cut	Selective cut
Harvest season	Winter summer	Winter summer	Winter summer	Winter summer
Slope (%)	35-39	20-30	28-35	39-45
Aspect	N-NW	N-NW	NE	NW
Total sampled log	1000	1000	1000	1000
Trace size (ha)	48	46	61	55
Stand density	181	170	179	169
Species composition	Mixed hardwood	Mixed hardwood	Mixed hardwood	Mixed hardwood
Average merchantable height	13	11	12	12
Average DBH	46	48	45	51

In addition to site and stand conditions, variables measured for each sawlog in the field included bottom and top diameter, length, tree species, damage type, damage location, damage dimensions, log grades, and comments for each individual log. Bottom and top diameters were measured in centimeters and the length of each saw-log was recorded in meters.

A total of 1000 hardwood logs from each of the four harvesting sites were sampled for measurable damage sustained during the harvesting operations. Of the 1000 observations per harvesting site, 250 observations were made for each of the four harvesting functions: bucking, skidding, decking, and loading. Sampling was done one function at a time. Damage was evaluated before and after each function to eliminate double counting of any damage caused by previous function. Bottom diameters of observed logs were between 73.4 and 96.9cm while top diameter varied from 21.1 cm to 31.3 cm. The length of observed logs ranged from 4.3 to 7.9 m and the log volume ranged from 1.01 to 1.45 m^3.

3. Results

There were 94 logs that had wood damage and 451 logs that had bark damage, which accounted for 2.35% and 11.27% of the total 4000 observed logs, respectively (Table 3). Damage volume was a volumetric measurement of the damage area and was calculated based on the length, width, and depth of the damaged area at the greatest point. The grade of each log was determined based on the log's dimensions and the visual defects of the log (Carpenter et al., 1989; Hanks et al., 1980).

Saw-log damage was analyzed in terms of volume losses. Volume loss was computed based on the damage dimensions. Pre- and post-damage log grades were given to all logs based on their dimensions, superficial condition, and damage severity. Damage volume was deducted from a log with slight damage while both volume deduction and degradation were considered for a severely damaged log. A log pricing system was developed based on current saw-log market prices from the local hardwood lumber industry and Tehran (Capital city of Iran) timber market reports (Emanuel and Rhodes, 2002).

Table 3: Damage distributions of observed logs and log attributes by species

Species name	Percent	No. of damage	Bark damage	Wood damage	Damage (%)	Bottom diameter (cm)	Top diameter (cm)	Length(m)	Volume (m^3)
Beech	64	356	79	23	5.3	87.5	20.3	4.9	1.24
Hornbeam	16	173	91	15	3.4	76.1	24.3	4.6	1.11
Elm	4	198	165	19	6.3	94.3	30.1	4.1	1.20
Maple	10	318	54	25	4.1	90.1	21.2	4.3	1.21
Alder	6	223	62	12	2.5	75.1	22.7	7.1	1.35

A monetary volume was assigned to the log based on its species, grade, and current hardwood saw-log market prices. This system then assigned a post-damage volume loss and monetary value to each log based on the amount of damage the log had sustained. Each log then had a pre-damage and a post-damage monetary value associated with it. Log size was computed based on its volume and grouped into five different categories of 1.0, 1.1, 1.2, 1.3, and 1.4 m^3. In order to compare the log damage, percentage of volume loss were defined and computed based on the ratios of damage volume over log volume, respectively.

The data was analyzed by using Statistical Analysis Systems (SPSS). The general linear model (GLM) procedure, which is a type of analysis of variance (ANOVA), was used to determine if significant differences existed among harvesting systems, harvesting functions, tree species, and log sizes (Wang et al., 2004). The GLM can be expressed as follows (Eq. 1):

$$V_{ijklm} = \mu + HS_i + HF_j + SP_k + LS_l + HS_i * SP_k + HF_j^* SP_k + HS_i * LS_l + HF_j^* LS_l + SP_k^* LS + \varepsilon_{ijklm}$$

$$i = 1, 2 \quad j = 1,2,3,4 \quad k = 1,2,\ldots,7 \quad l = 1,2,\ldots,5 \quad m = 1,2,\ldots,n \qquad (1)$$

where V_{ijklm} represents the mth observation of the volume loss for a log; μ is the mean of response variable; HS_i is the effect of ith harvesting system; HF_j is the jth effect of harvesting function; SP_k is the kth effect of species, LS_l is the lth effect of log size; ε_{ijklm} is an error component for all uncontrolled variability; and n is the number of observations within each treatment. The interactions among harvesting systems, functions, tree species, and log sizes were also considered in the model.

The response variables were tested with Tukey's Test at the 5-percent level to determine if there was any significant difference of damage volume loss among harvesting systems, functions, tree species, and log sizes.

Gouge was the most common damage type found in the field study. However, split and slab caused the most volume loss to logs. Split caused 6.6% of volume loss while slab resulted in 6.2% volume loss (Table 4).

Table 4: Wood waste per log based on damage type, location and site

		No. of logs	Volume loss per log (m^3/1000)	Percent of logs volume
Damage type	Gouge	156	7.4	1.3
	Slab	78	26.5	6.2
	Split	85	41.6	6.6
	Scrape	41	2.3	0.4
	Chocker	59	19.1	2.7
Damage location	Bottom	172	13.3	3.7
	Middle	47	7.9	1.6
	Top	22	5.3	1.5
Site	1	79	8.1	1.7
	2	29	76.5	15.1
	3	156	31.4	10.7
	4	134	21.1	26.4

The percentage of volume loss per cubic meter was significantly different between the two studied harvesting systems. Full-length systems caused a loss equal to 15.6% of a log's volume while cut-to-length systems lost 35.54% of volume (Table 5). Bucking damage caused 12.2% volume loss of the logs, which differed significantly from the damage caused during skidding, decking, and loading operations. However, log damage was not significantly different among skidding, decking, and loading operations (Table 5).

The percentage of damaged logs by species ranged from 0.7% for hornbeam to 2.4% for maple (Table 5). Damage to beech resulted in 1.5% loss of the volume, also damage to elm resulted in 1.1% volume loss (Table 5). Volume loss of damaged logs was not significantly different between alder and maple but was significant among these two species (alder and maple) with other species (beech, elm, and hornbeam) (Table 5).

The percentage of volume loss varied as the log size decreased from 0.5% to 4.5% based on different length of logs (Table 5).

Table 5: Means and significance levels of operational variables associated with damaged logs[1]

		Per log (m^3/1000)	%of log's volume
harvest system	Full-length	17.1b	15.6b
	cut to length	31.6a	35.4a
Harvest functions	Bucking	9.5c	12.2c
	Skidding	1.7d	0.4d
	Decking	1.9d	0.5d
	Loading	1.1d	0.4d
Species	Beech	2.9e	1.5e
	Hornbeam	2.2e	0.7e
	Alder	7.1f	1.4f
	Maple	4.9f	2.4f
	Elm	1.7e	1.1e
Log size (m^3)	1	8.9h	4.5h
	1.1	9.9h	2.3hi
	1.2	8.7h	1.4i
	1.3	5.8h	0.5i
	1.4	6.1h	0.5i

[1]Means with the same letter in a column are not significantly different at the 5 percent level with Tukey's Test

4. Discussion

The majority of the volume loss was caused during the bucking function when using a cut-to-length harvesting system. The damage caused by bucking operations in cut to length harvesting system overshadows damage from all other parts of the timber harvesting process. Results suggest that logs skidding, decking and loading have very little impact on damage levels (Table 5). Except for alder and maple all other major hardwood species in this region consisting of beech, hornbeam, and elm showed similar volume loss (Table 5). Alder and maple presented a significant difference in volume loss compared to the other three species observed. One reason for this could be the mechanical properties of Alder and maple. It has been suggested in past studies that more brittle species (such as alder and maple) have a greater susceptibility to damage than other species (such as beech, elm, and hornbeam) showing more resistance. Another reason for differences among species could be the time of harvest. Although, in this study all observations were made during the winter, spring and summer.

Another species-specific point to consider is the hardwood market. As demand for certain species rises and falls, more or less of that species may be harvested. Also, a high demand may generate greater care in harvesting certain species, whereas a low demand may be have the opposite effect.

Damage to saw-logs is occurring during harvesting operations, but to a lesser degree than might be perceived by the wood products industry. Certainly, there is room for improvement of motor-manual felling operations. This could be accomplished by formal chainsaw felling instruction, and by paying more attention to value and grade, rather than volume alone. Damage to logs is likely to vary from site to site, and maybe even within a single site. These variations may be driven by geographic factors not considered in this study, which focused on north of Iran.

The information gained from the field study is important in creating new guidelines or training to help minimize hardwood log damage occurring during the timber harvesting process. It would be beneficial to determine how log damage relates to skid trail density, road capacity, multiple landings and their locations, and length of skid. Along with these factors, terrain slope could be analyzed more closely, especially its correlation with the occurrence of switchbacks that may damage logs.

Implementing new and better guidelines or training requirements for fellers could create monetary gains for loggers while better utilizing the forest resources by not damaging valuable hardwood logs in Caspian forests.

Acknowledgements

The author would like to thank Shafaroud Company in the North of Iran for allowing field data collection on their operations.

References

Boston K and Dysart G (2000). A comparison of felling techniques on stump height and log damage with economic interpretations. Western Journal of Applied Forestry, 15(2): 59-61.

Carpenter RD, Sonderman DL, Rast ED and Jones MJ (1989). Defects in hardwood timber. U.S. Dept. of Agriculture, Forest Service, Washington, DC, USA.

Emanuel D and Rhodes C (2002). Bulletin of hardwood market statistics: 1989-2000. Northeastern Research Station, Forest Service, United States Department of Agriculture, Radnor, Pennsylvania, USA.

Faust TD and Greene WD (1989). Effects of felling head type on tensile strength of southern pine dimension lumber. Forest Products Journal, 39(11-12): 82-84.

Greene WD and McNeel JF (1989). Potential costs of shear damage in a southern pine chip-n-saw mill. Forest Products Journal (USA), 39(5): 12-18.

Hall R and Han HS (2006). Improvements in value recovery through low stump heights: mechanized versus manual felling. Western Journal of Applied Forestry, 21(1): 33-38.

Han HS and Renzie C (2005). Effect of ground slope, stump diameter, and species on stump height for feller-buncher and chainsaw felling. International Journal of Forest Engineering, 16(2):81-88.

Hanks LF, Gammon GL, Brisbin RL and Rast ED (1980). Hardwood log grades and lumber grade yields for factory lumber logs. Forest Service, U.S. Dept. of Agriculture, Northeastern Forest Experiment Station, Broomall, Pennsylvania, USA.

McMorland B and Guimier DY (1984). Analysis of felling butt-damage in Interior British Columbia. Forest Engineering Research Institute of Canada, Vancouver, British Columbia, Canada.

McNeel JF and Copithorne R (1996). Yarding systems and their effect on log quality and recovery levels in coastal timber of British Columbia. In the Forest Products Society, Portland, Oregon, USA

Pickens JB, Lee A and Lyon GW (1992). Optimal bucking of northern hardwoods. Northern Journal of Applied Forestry, 9(4): 149-152.

Sessions J (1988). Making better tree-bucking decisions in the woods. Journal of forestry (USA), 86(10): 43-45.

Unver S and Acar HH (2009). A damage prediction model for quantity loss of skidded spruce logs during ground base skidding in North Eastern Turkey.Croatian Journal of Forest Engineering, 30(1): 59-65.

Wang J, LeDoux CB, Vanderberg M and McNeel J (2004). Log damage and value loss associated with two ground-based harvesting systems in Central Appalachia. International Journal of Forest Engineering, 15(1): 61-69.

Williston E (1979). Opportunity areas and leverage points. In the Sawmill and plywood clinic, Portland, Oregon, USA.

Zavala DZ (1995). The effect of log length and lumber thickness over-allowance on lumber recovery. Forest Products Journal, 45(2): 41-45.