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Environmental Impacts to Residual Stand Damage due to Logging Operations in Hyrcanian Forest

Meghdad JOURGHOLAMI

University of Tehran, Faculty of Natural Resources, Department of Forestry and Forest Economics, Zob-e-Ahan Street, Karaj, Iran; mjgholami@ut.ac.ir

Abstract

The development of harvesting systems aims to provide physically feasible, economically viable, and environmentally sound solutions. Residual stand-damage data have been collected from a mixed broadleaved stand in Kheyrud area in Hyrcanian forest in the northern of Iran. After the harvesting operations, for all trees, damage to the bole, roots, extent of the damage, wounding patterns, size and distribution was assessed using stratified systematic sampling with a random start and fixed area plots. Results show that wounding occurred on 16.4% of the remaining trees, but the severity of wounding varied significantly by species. Forty-six percent of wounding for all species combined was considered as small size. The greatest average amount of damage, to a bole, occurred along the first 1m up from the ground and also within 3m of the skid trail centerline (86.4%). Gouges were present on 79% of all scars. The stratification of the study unit would effectively improve accuracy of stand damage surveys. Selection of the appropriate method for damage reduction to trees adjacent skid trails was crucial. According to the results, skidding damage cannot be completely avoided in practice. We suggest that the education and the entertainment of the foresters and workers in forest would be enhanced and the injuries could be explained before the harvesting to the workers. In such a way the damages would be less in the future.

Keywords: Kheyrud forest, forest harvesting, residual stand damage, skid trail, stratification

Introduction

Managed forests based on ecological principles are able to continually provide products and services and this type of management, as well as economically, especially in the long term would be cost-effective. Ecological stability of forest stands with sufficient and appropriate to the species richness and according to their natural condition is fundamental issues of forest ecosystem management. So it is essential that ecological considerations such as follow the natural ecosystems of forests, reduce the damage and avoid exploitation of vulnerable areas combined with harvesting operations (Dykstra and Heinrich, 1996; Heinemann, 2004). At most harvesting systems, a type of scarring and damage of trees was a common type, caused by the harvesting and wood extraction. Damage to residual stand was caused by pests' attack and pathogenic fungi on tree trunk and meanwhile the development of decay, reduced growth of trees in the forest stand (Youngblood, 2000). There are many documents about residual stand damage following forest operation and performance of different skidding systems. Each harvesting systems has a specific damage on forest trees and regeneration (Vasiliauskas, 2001).

The evaluated tree species are not equally susceptible to mechanical damages (Yilmaz and Akay, 2008). Damage to residual stand in forest operations often occur during the timber extraction (Froese and Han, 2006; Han, 1998; Kosir, 2008; Vasiliauskas, 1993). Trees were damaged by skidders and timber which extracted (Siren, 1982). Most of the resulting wounds occurred at or near the base of a tree (Athanassiadis, 1997; Han, 1998; Han and Kellogg, 2000). Logging wounds varied in size to a great extent. In North American conifers, scar sizes on damaged trees ranged from 0.13 to 2976.8 cm^2 (Bettinger and Kellogg, 1993). Most trees wounded due to forest operations were not randomly distributed within a stand, but situated close to the extraction trails (Froese and Han, 2006; Youngblood, 2000). Damage to residual trees was related to several variables besides the logging system, including species (Sidle and Laurent, 1986; Youngblood, 2000), thinning intensity (Benson and Gonsior, 1981), planning and layout (Fairweather, 1991), tree distance from skid trails (Bettinger and Kellogg, 1993), tree size (Ostrofsky *et al.*, 1986), and skid trail spacing (Vasiliauskas, 2001). In contrast, relatively few published studies examined the methods to assess the residual stand damage (Han and Kellogg, 2000). Stehman and Davis (1997) reported that a sampling strategy for the harvest region is divided into two strata: the area near and outside the skid trails. The authors by using hypothetical data proved that under certain forest conditions stratify sampling strategy in achieved likely to more accurately estimate to the damage in comparison with simple random sampling method.

Froese and Han (2006) studied the damage of residual trees to conifer mixed stand and concluded that 37.4% of the residual stands were damaged. Also, 84% of scars in

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all species were less than 194 cm^2 and 67% of damage to trees was the first 2 m of boles. Also, 68% of the injuries were occurred within the range of 4 m from the skid trail central line. Gouges, included 41% of all damaged. Han (1998) compared different sampling methods to assess the damage to residual stand and introduced systematic random sampling method as the best method for estimating damage to residual stand. Fecklin *et al.* (1997) concluded that skidding operations, with rubber-tired skidder, caused damage at about 22% of remaining trees.

Different studies about the damage to the residual stand have been conducted in Iran (Hosseini, 1994; Mousavi, 2009; Naghdi, 2004; Nikooy, 2007; Rashidi, 1995). Hosseini (1994) studied the first research in this field about residual stand damage in north of Iran and results showed that gouges and large scar size mostly associated with activities of the wood extraction. 82.5% of scars were occurred at 2 m boles. This study was designed with the following objectives: to assess and to measure the damage after logging along winching strips and skid trails, to compare the characteristics of stand damage.

Materials and methods

Study site

The research was carried out in compartment no. 208, in Namkhaneh District within Kheyrud Educational and Research Forest in the Hyrcanian forest region in the north of Iran. The altitude ranged between 830-1150 m and the forest lying on a southwestern aspect. The slope on these sites ranged from 15 to 50% with an average of 30 percent. An average rainfall ranged from 1420 to 1530 mm/year, with the heaviest precipitation occuring in the summer and fall. This area was dominated by natural forests containing native mixed deciduous tree species such as *Fagus orientalis* Lipsky, *Carpinus betulus* L. and *Acer velutinum* Boiss. The management method is mixed un-even aged high forest with single and group selective cutting regime. Trees to be removed were felled, limbed and topped motor-manually. Felled trees were bucked and processed with chainsaws into logs, sawn-lumber and pulpwood. The logs with 5-25 m length were extracted by wheeled cable skidders to the roadside landings. The fuel wood was extracted by mules. The field study was conducted from August to September 2010 in Kheyrud Forest. The compartment area, tree per hectares and volume per hectares were 31.3 ha, 282, 403 m^3, respectively. Also, total removed tree and volume of removed tree were 153 and 720 m^3, respectively.

Experimental design and data collection

To access the extent of injury, pattern, size and distribution of damages following skidding with rubber-tired skidder (Timberjack 450 C), systematic-random and stratification sampling method was used in the skidded area. In the stratified sampling method, the sample plots without damage were excluded from the analysis; thereby the accuracy of inventory of the damage has been improved. Due to the scattering of the marked trees because of single selection systems and in order to reduce the inventory errors, network inventory dimensions of 25*25m was used. To determine the amount of damage to standing trees, plots with a sample area of 5, 3 and 1 R (500, 300 and 100m^2) were taken and implemented (Fig. 1).

Intensity of inventory to determine the severity of damage in a systematic random sampling method, given

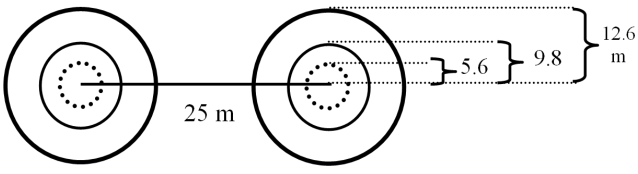

Fig. 1. Dimensions of inventory network and size of sample radius plots used to assess damage

the size and area of a sample network, were 80, 48, and 16%, respectively. Due to the scattering of marked trees in the Parcel, inventory network was randomly implemented in the area. In this study, a total of 57 sample plots with 1R area, 70 sample plots with 3R area, 78 sample plots with 5R area, and totally 78 plots of 469 sample plots have been included in damaged class.

Residual damage to regeneration along winching strips

Residual damage along winching strips and skid trails was assessed in 208 compartments. Damage to the residual stand along the winching strip was studied in sites randomly located within the study area. Species and DBH were recorded for all trees along the winching strips and skid trails and each tree was examined for any kind of damage. All injured saplings and trees with a DBH >10 cm were measured and recorded, and classified according to 3 main classes of damage: 1) one wound per tree; 2) 2-3 wounds per tree; 3) more than 3 wounds per tree. In addition, total number, diameter and tree species around the skid trails and winching strips, total damaged trees, location of wound (s) on each tree (on roots, up to 1 m, above 1 m), size of wounds (less than 500 cm^2, between 500-1000 cm^2 and more than 1000 cm^2) and degree of injuries (deep and light) were recorded.

Results and discussion

Analysis of the network sample

A total of 622 trees measured in a sample, 520 safe trees and 102 trees were damaged. In other words, 16.4% of forest trees were injured after skidding operation. Analysis of data showed that on average there were 9 trees in each plot of 5R (500 m^2) area that the averages of damaged trees in 1 tree per sample plot. Tab. 1 shows the statistical parameters to analyze the sample plots.

The percentages of damage trees in sample plot of 1R (100 m^2), 3R (300 m^2) and 5R (500 m^2) area were 23, 15.8 and 5 percent. By increasing sample size, the number of damaged trees to sample size was decreased and the time

Tab. 1. Statistical parameters to analyze the sample plots

Factor	Total trees			No damaged trees			Damaged trees		
	1 R	3 R	5 R	1 R	3 R	5 R	1 R	3 R	5 R
Total	309	454	622	238	360	520	71	94	102
Average	5.4	6.78	8.9	4.2	5.42	7.56	1.2	1.37	1.35
Max.	10	18	25	7	14	24	3	4	4
Min.	3	3	3	2	2	2	1	1	1
St. De.	1.54	3.03	5.84	1.11	2.6	5.76	0.54	0.67	0.57
St. De. Err.	0.2	0.38	0.74	0.15	0.33	0.73	0.07	0.08	0.04
Inventory Err.	7.41	11.04	16.2	6.97	11.87	18.8	5.69	7.02	10.6

and cost of plot measuring were increased. Based on the results, the sample plot of 3R (300 m^2) area was the best sample size to calculate the amount of damage to residual trees.

Damage to residual stand

Measurement of trees, damaged in the skid trail, showed that 102 trees were damaged from some degree of injury. 62% of the hornbeam trees (*Carpinus betulus*) were damaged, beech (*Fagus orientalis*) and other species were consisting of 24% and 14% of damaged trees, respectively. The results showed that the most of damaged trees are related to 40-20 and 70-40 cm diameter class of trees. In the other hands, valuable trees were suffering from some degree of damage (Fig. 2b). The study of the height in case when scar on tree trunk showed 75% of wounds, located within 1m from the ground on the bole, 18% on roots and 1%, located above 1 m (Fig. 2a). However, there is no wound on 2 m above the trunk and about 93% of wounds showed at the first 1 m of tree trunk.

Study of the scars' severity showed that 21% were superficial and 71% of them were deep, with damage to the cambium (Fig. 3), and only 8% of wounds were very deep (damage to tree wood, including wood Split).

The results about the wounds area in tree trunk showed that 46% of the scars were smaller than 500 cm^2, 29% between 500 and 1000 cm^2, and 25% larger than 1000 cm^2 (Fig. 4). Wound by at least 42 cm and the maximum was 2319 cm^2. The average wound size of each tree was 508 cm^2. Wounds on the class, less than 500 cm^2, the average wound per tree was 271 cm^2, while the minimum and maximum area of each tree wounds in this group were 42 and 468 cm^2 respectively. Wounds on the class between 500-1000 cm^2, the average wound per tree was 688 cm^2 and minimum and maximum area of each tree wounds in this group were 935 and 508 cm^2, respectively. Wounds on the class, more than 1000 cm^2, the average wound per tree was 1395 cm^2, while minimum and maximum area of each tree wounds in this group were 2319 and 1001 cm^2, respectively.

Overall, in this study, 30% of damaged trees had one wound per bole, 67% had 1-3 wounds, and 3% had more than 3 wounds per bole. Overall, 70% of the trees have more than one wound (Fig. 5).

Results showed that 58% of the total damage to the trees related to skidding and 42% was related to winch-

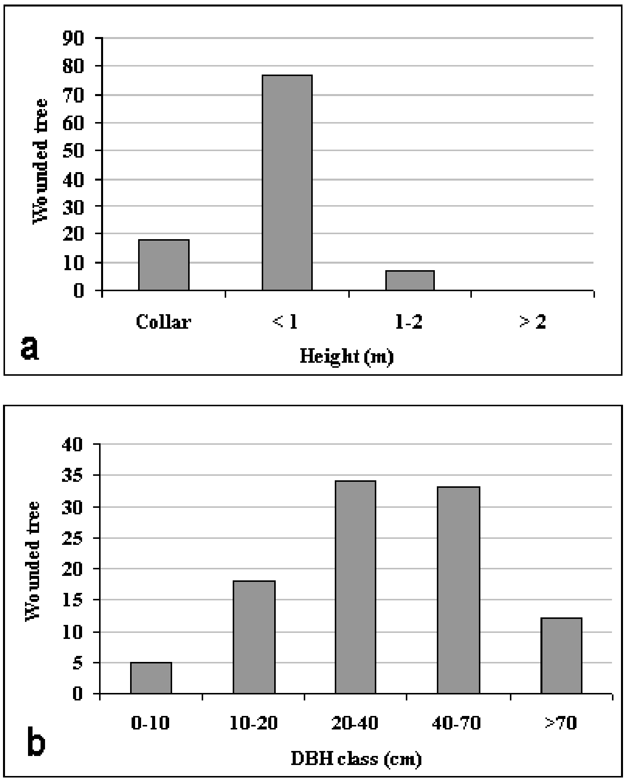

Fig. 2. Number of wounded tree as a function of height of wound in the bole (a) and DBH class (b)

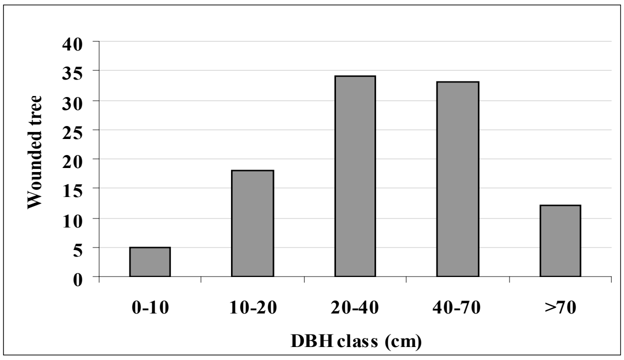

Fig. 3. Number of wounded tree related to degree of wound

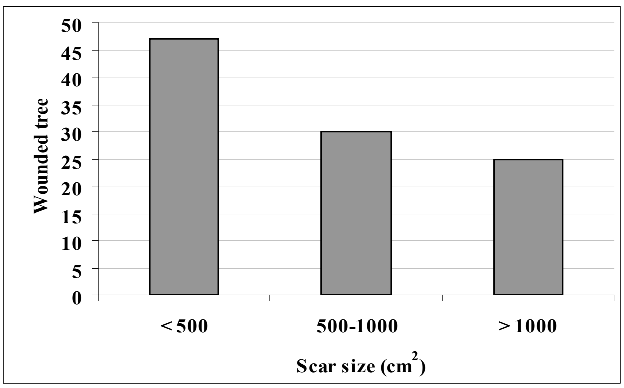

Fig. 4. Number of wounded tree related to scar size

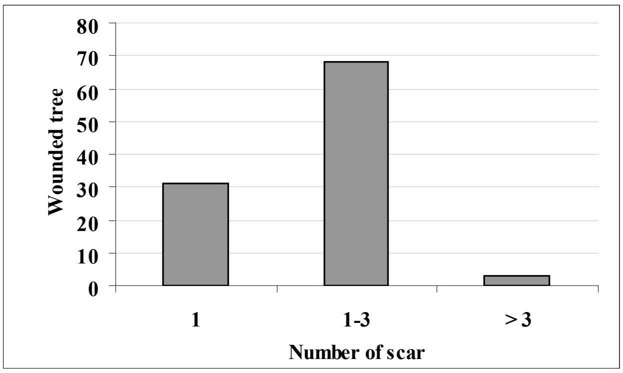

Fig. 5. Number of wounded tree and number of scar

ing. In other words, more than one third of the damage to trees occurred in the winching stage that the main reasons were the incorrect directional tree felling and inappropriate choice of winching routes. Many trees damaged in the skidding operation were not randomly dispersed in the forest stand and located near skid trails. With increasing distance from the center of skid trails, the number of damaged trees was reduced (Fig. 6). The majority of the damage (86.4%) occurred within 3 m of the skidder centerline. At distances of 3 to 4m, the occurrence of scarring was 10.2% of the total; only 3.4% of the damage was found more than 4 m from that line. The average distance of damage tree was 2.56 meters from the center line of skid trails and maximum and minimum of damaged trees were 4.5 and 1.7 m away from the center line of skid trails, respectively. The highest concentration of damaged trees was in the distance of less than 3 m and 97% of damaged trees were in less than 4 meters distance from the center of skid trails.

In this study, systematic random sampling method was used with stratification that with acceptable accuracy and ease of implementation and this result is consistent with Han and Kellogg (2000) research. In order to estimate the residual damage caused by the thinning, the researchers were compared four methods in pine stands in West Oregon. They found that there were significant differences in the ease and simplicity of these methods were implemented and demonstrating a systematic random sampling method, the simplest to be used. Beech and hornbeam were included in more than 86% of damaged trees. The high percentage of damage of these two species in the skidding operations wasn't due to the sensitivity of these species to mechanical damage from timber extraction, but primarily related to the dominant presence of these species in this forest. Although the percentage of damage to remaining trees in this study was far less than the other similar internal and external studies. Of course, this study only was considered the amount of damage to the trees related to skidding, and considering the damage caused by tree felling, the damage will be far greater. Froese and Han (2006) estimated damage to residual stand to 37.4%; Fecklin *et al.* (1997) between 22% to 47%; Naghdi (2004) to 19.04% and Nikooy (2007) to 23.5%.

Fig. 6. Number of wounded tree as a function of distance from the centerline of a 3-m-wide skidder trail

About 33% of damaged trees to 20-40 cm diameter class and 32% of trees were related to the class of 40-70 cm. The results showed that with increasing diameter, the percentage of damaged trees was decreased and the loss to follow the reduction in the number of trees as diameter was increased in the uneven-aged forest stand. The findings of this study were consistent with the results of Hosseini (1994), Naghdi (2004) and Nikooy (2007) that the highest percentage of damaged trees has been measured in diameter classes less than 30 cm. Also, importance of this classification was important because in the uneven-aged stand, young and middle-aged trees have a determining role in forest growth and in the selective forestry systems trees were left for many years in stands to do its role in the stands. The secondary factors have been caused to the development of mechanical damage to trees and caused to reduce growth and potential value of forest stand. In this study, about 93% of wounds occurred at or near the first 1m of tree trunk. The importance of the classification of wounds in the base of a tree was that the base of tree was the most valuable part of the tree trunk and was reduced the value of timber in the next harvests. The findings of this study were similar to previous research conducted in this area trees (Han, 1998; Froese and Han, 2006; Mousavi, 2009; Stehman and Davis, 1997). However, Naghdi, (2004) and Nikooy (2007) expressed that the most of the wounds were in the above 2 m of tree trunk.

The results show that more than 50% of wounds per tree have with an area of more than 500 cm^2 that these wounds rarely have been closed and healed. Froese and Han (2006) concluded that 84% of wounds in the all species were much less than 194 cm^2. Since logging injury usually occurs on the lower part of a trunk, wound decay in a tree affects the most valuable timber (Vasiliauskas, 2001). Although, the results of this study did not match with those of Hosseini (1994) and Nikooy (2007). They expressed the highest percentage of wounds have the area less than 100 cm^2. The severity of the wounds indicated that 80% of the wounds were deep, with damage to the cambium that was consistent with Sidle and Laurent (1986) results.

With increasing distance from the center line of skid trails, the numbers of damaged trees have been reduced that the findings of this study was similar to previous research results (Han, 1998; Youngblood, 2000; Yilmaz and Akay, 2008). In addition, Hosseini (1994), Naghdi (2004) and Nikooy (2007) concluded that there was strong correlation between the percentage of damaged trees and increase the distance from the skid trails.

Conclusions

Selection of the appropriate method for damage reduction to trees adjacent skid trails was crucial. According to the results, skidding damage cannot be completely avoided in practice. Therefore, to minimize wounding in this forest stand, a number of the suggestions have been proposed. The description of the wounded trees and reasons for that were done with very interesting details, but we suggest that the education and the entertainment of the foresters and workers in forest would be enhanced and the injuries could be explained before the harvesting to the workers. In such a way the damages would be less in the future. Timber extraction should be completely suspended during the rainy climate and areas with steep terrain should be excluded from the skidding operations. It should also be used in a designated skid trails. In order to control wound infection by decay fungi, a number of wound dressings have been tested to prevent wound decay in forest stand. It is more appropriate to encourage the foresters to adopt methods which avoid damage to residual trees during logging operation. The authors hope that the results of this study will be used in order to optimal management of harvesting operation.

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