Residual stand damage following ground-based skidding operation (Case study: Kheyrud Forest)

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Abstract:
Hyrcanian (Caspian) Forest in northern Iran has a richness of biological diversity, with endemic and endangered species. The use of ground-based skidding is well accepted practice for the extraction of timber from the forest, but this has tended to cause the greatest environmental problems. The aim of the study was to evaluate and comparison of environmental impacts, residual stand damage, regeneration, and to quantify these effects such as: extent of the damage, wounding patterns, size and distribution after logging operations that utilized two different methods: short-log and long-log. A Timberjack cable skidder was used and the study location was in the Kheyrud Forest. Post harvesting assessment of damage to the residual stand was compared along skid trail by 100% inventory method and also for the assessment of regeneration damage along winching strips. The results showed that along winching strips the percentage of damage to the regeneration was 44 and 36 %, while the tree damages along skid trails reached 2.3 and 4.1 % in the short- and long-log methods, respectively. The greatest average amount of damage to a bole occurred along the first 1 m up from the ground (97%) and also within 4 m of the skidder centerline (80%). These results clearly show that the short-log method causes less damage to the residual stand than the long-log method. Tree location to skidder trail appears to have a significant effect on the number and height of scars on a tree. Well designed and constructed trails should be wide enough to allow wood extraction from the forest. Damage to the residual stand might be reduced by proper planning and training of logging crews.

Keywords: environmental impacts, forest harvesting method, residual stand damage, regeneration

1 Introduction

Hyrcanian (Caspian) forest in northern Iran has a richness of biological diversity, with endemic and endangered species, and a diverse range of economic and social conditions. About 45% of the Hyrcanian forests are located in mountainous areas, where forest lands are not readily accessible with ground-based logging equipments, but cable yarding technologies are still undeveloped in this forest area. Accessibility is the most critical factor influencing feasibility of operations in mountainous terrain (Heinemann 2004). Rubber-tired skidders are used on the more gentle slopes and on designated skid roads in steeper terrain. Crawler tractors (bulldozers) are used on steeper topography to skid direct to the landing (Sobhani and Staurt 1991). The use of wheeled and tracked skidders is a widely seen and well accepted practice in Hyrcanian forests. It is also the one that tends to cause the greatest environmental problems.

From the beginning of the twentieth century, the increasing use of mechanized wood harvesting brought with it the problem of damage to the remaining trees in forest stands (Vasiliauskas 2001). Not all tree species are equally susceptible to mechanical injury. Dameg to the residual stand in forest operations is most often caused during transport of timber (Vasiliauskas 1993; Han 1998; Froese and Han 2006; Kosir 2008). Trees are wounded by machines and logs under extraction (Siren 1982). Most of the resulting wounds occur at or near the base of a tree (Bettinger and Kellogg 1993; Kovbasa 1996; Han 1998; Froese and Han 2006). In spruce stands harvested by partial and shelterwood cuttings, only 15 per cent of all tree wounds were situated higher than 0.5 m, and over 60 per cent of the trees were damaged at the root collar, i.e. 0.3 m height from the ground (Vasiliauskas 1993). Logging wounds vary 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). In another study only 5 percent of all scars exceeded 30.5 cm^2 (Sidle and Laurent 1986). On Norway spruce, logging wounds may reach 1000-3500 cm^2 in size. However, a number of studies in spruce stands showed that most logging wounds are usually smaller than 100 cm2 (Siren 1982; Vasiliauskas 1993; Athanassiadis 1997). Most trees wounded due to forest operations are not randomly distributed within a stand, but are situated close to the extraction trails (Han 1998; Froese and Han 2006). Damage to residual trees is related to several variables besides the logging system, including species (Shigo 1966; Ostrofsky et al. 1986; Bettinger and Kellogg 1993), 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 (Ostrofsky et al. 1986). Residual stand-damage data from a mixed conifer stand in northern Idaho showed that wounding occurred on 37.4% of the remaining trees (Froese and Han 2006). Also, damage to trees was concentrated along the skid trails or the skyline corridors, systematic plot sampling consistently provided estimates similar to the results of a 100% survey, and scars less than 10 cm in width were closed in 8 years (Han 1998). The most common type of damage to crop trees is scarring; scar size is critical to closure (Ostrofsky et al. 1986; Han and Kellogg 2000; Youngblood 2000). Apart from tree species, length of wound decay may depend on a number of other factors such as wound age and size, and tree diameter (Vasiliauskas 2001). Different studies about the damage to the residual stand have been conducted in Iran (Hosseini 1994; Rashidi 1995; Rashidi 1995; Naghdi 2004; Nikooy 2007). Our study was designed to broaden current knowledge of residual stand damage, with the following objectives: (1) assess and measure the damage after logging along winching strips and skid trails in the short-log and long-log method; (2) quantitatively compare the characteristics of stand damage; and (3) recommend practices to reduce damage during skidding operations.

2 Material and Methods

2.1 Study Sites

The research was carried out in two compartments 208 & 209 which were located in Namkhaneh District within Kheyrud Educational and Research Forest. The altitude was ranging from 1000 to 1135 m and the forest lies on a southwestern aspect. The slope on these sites ranged from 10 to 70 percent with an average of 40 percent. An average rainfall range from 1420 to 1530 mm/year, with the heaviest precipitation occurs 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., *Acer velutinum* Boiss., and *Alnus subcordata*. The management method is mixed un-even aged high forest with single and group selective cutting regime. Trees to be removed are felled, limbed and topped motor-manually. Felled trees are bucked and processed with chainsaws into logs, sawn-lumber and pulpwood. The logs with 5-15 meter length are extracted by wheeled cable skidders to the roadside landings. The fuel wood is extracted by mules. Table 1 summarized some characteristic of study site. The field study was conducted from August to September 2010 in Kheyrud Forest.

Table 1: Study site description

Compartment	Area (ha)	Tree per (ha)	Volume per ha (Sylve)	Total removed tree	Total volume of removed tree (m3)	DBH of Removed tree (cm)
208	27	173	504	270	872.3 (32 m^3/ha)	20-135
209	56	123	301	181	719.5 (13 m^3/ha)	20-135

2.2 Experimental design and data collection

Residual damage along winching strips and skid trails was assessed in compartments 208 and 209. Damage to the residual stand along the winching strip was studied in sites randomly located within the study area. In order to determine the percentage of damage and type of damage at log extraction stage along skid trails, the full inventory method was used. 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 >10cm 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 cm2, between 500-1000 cm2 and more than 1000 cm2) and degree of injuries (deep and light) were recorded.

2.3 Residual damage to regeneration along winching strips

The length of then winching strips differed, but the width of the winching strips was kept constant at 6 m (3 m from each side). All seedlings with a diameter greater than 25 cm up to 3 m around the main winching strips were recorded and studied for any kind of damage. Because of the different surface area of the winching strips, the calculation of percentage damages was weighted as follows (Eq. 1) (Naghdi 2004; Mousavi 2009):

$$M_w = \frac{\sum_{i=1}^{n} g_j s_i}{\sum_{i=1}^{n} s_i}\left[i = 1,2,\ldots n\right] \tag{1}$$

Where Mw = average percentage of damaged trees along winching strip, percent; g = percentage of damage along winching strip in the sample; s = surface area of winching strip in the sample, ha; i = sample number; n = number of samples.

3 Results

3.1 Residual damage to trees along skid trails

Results show that 90 and 62 trees were damaged following skidding operation in long-log and short-log method along the skid trails, respectively. In the long-log method, Carpinus Betulus which represented 53 % of total damaged species and Fagus orientalis and other spices are representing 30 % and 17 %, respectively (Table 2 and Fig. 1). In the long-log method, on average, 81% of the damage on a tree occurred within 1 m of ground level, 18 % on roots and any scar were located above 1 meter. However, in the short log method, in 71 % of cases, wounds were located within 1 m from the ground on the bole, 26 % on roots and 3 % were located above 1 m (Fig. 1a).

Table 2: Number and percent of damage tree along skid trails

Spices and DBH / Skidding method		spices			DBH class (cm)				
		Hornbeam	Beech	other	0-10	10-20	20-40	40-70	>70
Long- log	No.	48	27	15	3	8	32	30	17
	percent	53	30	17	3	9	36	33	19
Short- log	No.	26	32	4	1	11	9	24	17
	percent	42	52	6	1	18	15	39	27

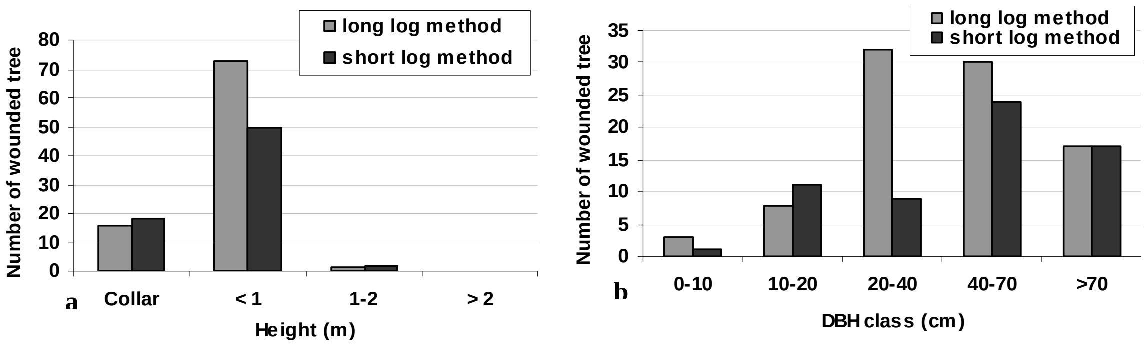

Figure 1: Number of wounded tree as a function of height of wound in the bole (a) and DBH class (b) in the short-log and long-log methods

In the long-log method, fifty percent of all scars found in this study were smaller than 500 cm^2 (Fig. 2a). Another 28% were scar sizes between 500 and 100 cm^2 and 7% were scars larger than 1000 cm^2. By short-log method, 48% of the grand fir scars were smaller than 500 cm^2, 29% between 500 and 1000 cm^2, and 23% larger than 1000 cm^2. In the long log method, 67 % of the wounds were deep, with the remainder being classified as light and very deep. However, in the short log method, 90 % of the wounds were deep, with the remainder being classified as light and very deep. In the long-log method, the majority of the damage (71%) also occurred within 3 m of the skidder centerline (Fig. 3a). At distances of 3 to 4 m, the occurrence of scarring was 21% of the total; only 8% of the damage was found more than 4 m from that line. Also, in the short-log method, result show that the most of the damage (48%) also occurred within 3 m of the skidder centerline (Fig. 3a). At distances of 3 to 4 m, the occurrence of scarring was 34% of the total; only 18% of the damage was found more than 4 m from that line. Overall, in the long-log method 31 % of damaged trees had one wound per bole, 62 % had 1-3 wounds, and 7 % had more than 3 wounds per bole. However, in the short- log method, 47 % of damaged trees had one wound per bole, 47 % had 1-3 wounds, and 6 % had more than 3 wounds per bole (Fig. 3b).

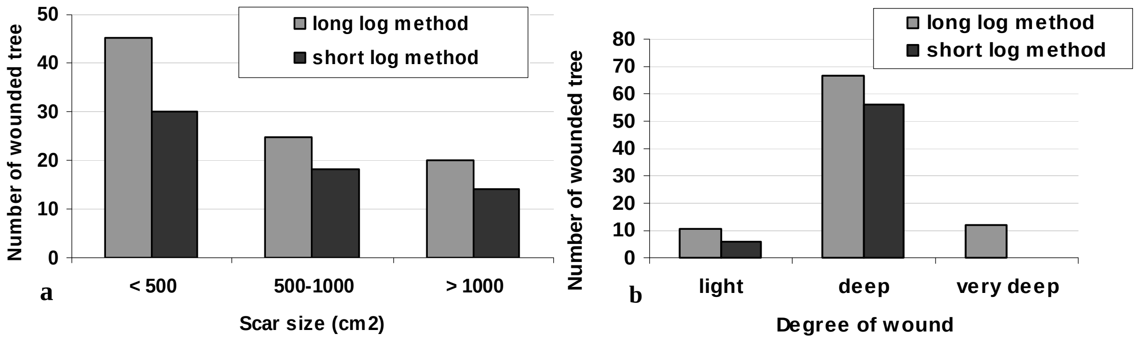

Figure 2: Number of wounded tree related to scar size (a) and degree of wound (b) in the short-log and long-log method

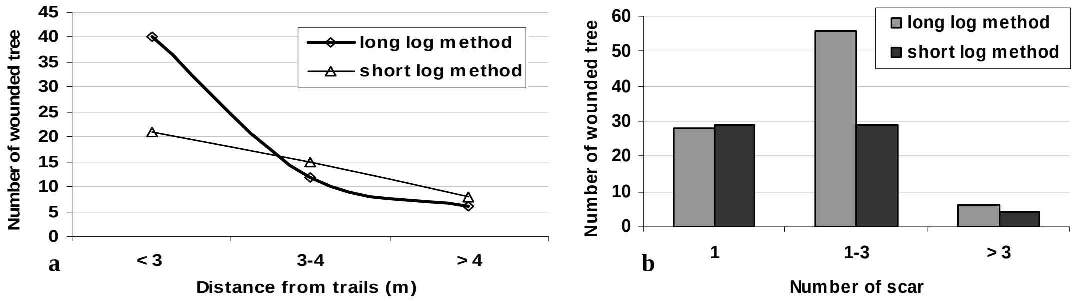

Figure 3: Number of wounded tree as a function of distance from the centerline of a 3-m-wide skidder trail (a) and number of scar (b) in the short-log and long-log methods

3.2 Residual damage to regeneration along winching strips

In the long-log method, 36% of total regeneration was damaged along winching strips. In contrast, in the short log method, 44% of total regeneration was damaged along winching strips (Fig. 4).

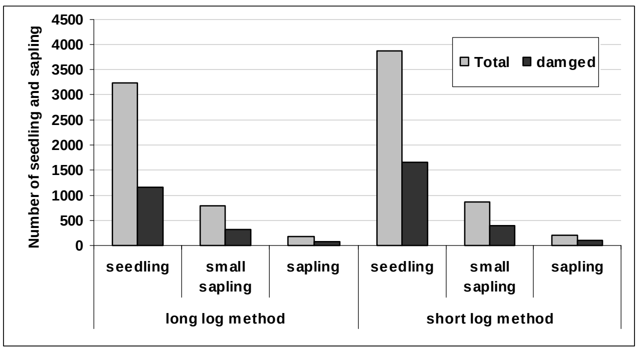

Figure 4: Total of regeneration in winching strips in long and short log method in three groups; seedling, small sapling and sapling

4 Discussion

The results of this study showed that the harvesting operation may cause significant damages to the residual stand. This damage might have been avoided through the application of more careful logging procedures and applying low impact logging methods. Most of the bole damage was caused by winching and skidding when logs struck the standing trees (Han 1998; Froese and Han 2006; Naghdi 2004; Mousavi 2009). The wounds on the injured trees are located in different areas. In most of the cases, the injuries are situated in the bottom 1 m of stem which represents the most valuable part of the tree. Several authors have also noted that most of the wounds occur at or near the base of the tree in logging time (Han 1998; Bettinger and Kellogg 1993; Vasiliauskas 2001; Naghdi 2004; Mousavi 2009). In spruce stands, harvested by partial and shelter wood cutting, only 15 % of all trees wounds were situated above 0.5 m, with over 60 % of the trees being damaged at the root collar 4. In this study about 86.8 % of wounds were located below 1 m (wounds on root are also included) with the remainder being located above 1 m.

Most trees wounded due to forest operations are not randomly distributed within a stand, but are situated close to the extraction trails (Bettinger and Kellogg 1993; Han 1998; Naghdi 2004; Froese and Han 2006; Nikooy 2007). About 90 % of wounded stems were less than 5 m away from the centerline of the extraction route (Siren 1982). However, 85 % of damaged trees were less than 3 m away from skid trails, while 13 % of the damaged trees were between 3-5 m away from skid trails, while only 2 % of damaged trees were more than 5 m away from the centerline of skid trails (Naghdi 2004). In a skyline logging study, the most yarding damage (66% of the total scar area) occurred within 6 m of the skyline corridor centerline (Han and Kellogg 2000). In Iran no studies have documented the progress of wound on the damaged trees in the residual stand. Pathology studies, in order to find the prevalent kind of fungi attack on damaged trees and finding a treatment, helps to improve future stands (Mousavi 2009). Different species have different susceptibility to damage caused by the harvesting operation. Logically, the thick bark of some species increases the resistance to long term damage (Bettinger and Kellogg 1993).

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