SELECTIVE LOGGING AND DAMAGE TO UNHARVESTED TREES IN A HYRCANIAN FOREST OF IRAN

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Selective logging in mature hardwood stands of Caspian forests often causes physical damage to residual trees through felling and skidding operations, resulting in a decline in bole quality and subsequent loss of tree value. This study evaluated the logging damage to residual trees following logging operations. A total density of 5.1 trees/ha and 17.3 m3/ha of wood were harvested. On average, 9.8 trees were damaged for every tree extracted, including 8 trees destroyed or severely damaged. The most common types of damage included uprooted stems, stem wounds to the cambial layer, and bark scrapes. Damage to trees sustained along skid trails was found to be significantly more than the damage that incurred within logging gaps and winching areas. The results of this study suggest that logging practices also need to be accompanied by close supervision of field personnel and post-logging site inspections to be implemented properly.

Key words: Selective logging; Logging damage; Skid-trails; Logging gaps

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INTRODUCTION

Damage to the trees left behind after selective logging (*i.e.* residual stand damage) is a result of harvesting activity and may include root abrasion and breakage, bole wounds, broken branches, and broken crowns (Froese and Han 2006). However, selective cutting can be defined as a cutting regime based on certain defined criteria for the choice of trees that maintain or develop an uneven-aged forest structure over time (Lexerod and Eid 2006). Long-term field experiments with selective cutting in uneven-aged coniferous forests showed that inappropriate forest structures and poor conditions for natural regeneration may cause low volume production and low profitability (Lundqvist 1989; Andreassen 1994). This increased interest is partly due to expected enhancements for landscape aesthetics and biodiversity, and partly because of expected benefits for regeneration costs, timber quality, and profits (Lexerod and Eid 2006). Several studies (Larsen 1997; Tarp *et al.* 2000) have claimed that near-natural forest management is capable of developing more sustainable forestry practices that protect ecological structures and functions. In Caspian forests, logging operations are generally performed by using selective cutting methods including single-tree and group selection. Chainsaw and cable skidder are two main forest machines for harvesting in the region. However, the logging operations result in serious residual stand damage during felling, winching, and skidding operations (Nikooy *et al.* 2010). As of now, Iranian law requires the development of forest management plans that seek sustainable timber harvesting on all of Iran's permanent production forestlands (Marvie Mohajer 2007). Today, Iranian forest management plans are based on removal of isolated mature trees on a sustained yield basis with the goal of improving the overall commercial value of the forest (Marvie Mohajer 2007). Despite noteworthy advances, damage to future crop trees during selective logging is thought to be one of the largest silvicultural challenges facing sustainable forest management in the region (Nikooy *et al.* 2010).

The importance of damage in the course of logging has been illustrated in the literature. It has been found that the occurrence of logging wounds is dependent on the harvest operation (Nyland and Gabriel 1971; Reisinger and Pope 1991). Smith *et al.* (1994) showed that sapwood wounds pose no immediate threat to the tree but increase the likelihood of attack by insects or diseases. Timber extraction, measured as the number of harvested trees per hectare might additionally have consequences for a number of forest functions, including biodiversity maintenance, carbon sequestration, and the production of subsequent timber crops, as shown by Panifil and Gullison (1998) in Bolivia. Logging damage to the residual trees is a consequence of any harvesting activity. In addition, Fajvan *et al.* (2002) claimed that minimizing the damage to residual trees is critically important for the maintenance of stand vigor and timber quality during skidding operations. Froese and Han (2006) observed that the frequency and extent of decay depend on the area, width, depth, and location of the wound, as well as on tree species, age, and vigor. Marvie Mohajer (2007) indicated that a critical step toward sustainable forestry in the region is the monitoring of the quality of residual trees following logging. Naghdi (2006) and Nikooy *et al.* (2010) considered the levels of residual tree damage in selection-managed stands and observed that 25% to 35% of the residual trees had been injured at some point in the course of logging. Similar researches have been carried out in tropical forests. Jackson *et al.* 2002 indicated that on average 44 trees were damaged for every tree extracted including 22 trees killed or severely damaged, six of them commercial species. Krueger (2004) showed that pre-harvest skidtrail planning and improved timber felling techniques yield short-term financial gains relative to conventional management. Holmes *et al.* (2002) indicated that reduced impact logging is less costly and more profitable than conventional logging under the conditions observed at the eastern Amazon study site. Panfil and Gullison (1998) indicated that both harvest intensity and total mortality were quadratic increasing functions of harvest intensity when expressed in terms of basal area. The main objective of this study was to evaluate the damage to residual trees resulting from selective logging.

EXPERIMENTAL

Site Description

The study was conducted in parcels 228, 231, and 232 in Chafroud forests in the North of Iran, located at coordinates of 37°25'N and 49°26'E. The altitude ranged from 1250 to 1450 m above sea level, and the average annual precipitation was 1450 mm. The forest was uneven-aged beech (*Fagus orientalis* Lipsky) with an average volume stock of 320 m^3/ha. The average slope of the parcels was 30 to 40%, and the aspects of the slopes were northwestern and northern. The total production volume was 2699 m^3, and the skidding was done from the stump area to the roadside landing with a ground-based skidding system. Beech (*Fagus orientalis*); horn beam (*Carpinus betulus*); maple (*Acer velutinum*), alder (*Alnus subcordata*), and elm (*Ulmus glabra*) are dominant canopy species.

Residual Tree Damage

The stands were harvested via manual felling with a chainsaw and semi-mechanized harvesting system with a rubber tired skidder throughout a 6-month period from the winter of 2010 to the spring of 2011. The chainsaw operator had 10 years of experience, whereas the skidder operator had 8 years. On our 152 hectare study site, data were collected after selective logging from the remaining trees to evaluate the amount of damage to residual trees. Damage to the residual trees was recorded according to the cause of damage (*i.e.* felling, winching, and skidding) and the location and severity of the wound.

Table1. Classification of Damages to Residual Trees along Skid Trails and Logging Gaps (modified from Krueger 2004)

Damage Type	Bole	Root	Crown
Severe	Snapped at Base, Bent, Or Severely Leaning	Uprooted	Loss of Entire Crown, Less Than Entire But More Than Two-Thirds of Crown
Moderate	Exposed And Damage Cambial Tissue	Exposed and damaged cambial tissue	Loss of less than two-Thirds But More Than one-Third of Crown
Minor	Exposed Cambial Tissue But No Damage, Bark Scrape	Exposed Cambial Tissue But No Damage, Root Scrape	Loss of Less Than One-Third of Crown

Assessing Tree Damage Associated with Felling Operations

Approximately 30 single tree fall sites were randomly selected in the region, and the tree damages incurred in each parcel were tallied. The damages to the residual trees were recorded according to the location and severity of the wound (Krueger 2004).

Assessment of Tree Damage Associated with Skidding Operations

All skid trails in each of the three parcels were mapped and delineated into four classifications: (1) primary skid trails, where more than 10 trees had been skidded, (2) secondary skid trails, where 2 to 10 trees had been skidded, (3) and tertiary skid trails, where only one tree had been skidded (Jackson *et al.* 2002). The lengths of individual skid trails were measured, and tree damages were tallied along the entire length of all primary, secondary, and tertiary according to cause of damage and the location and severity of the wound (Krueger 2004). In order to adjust the differences in pre-harvest tree density among stands and individual skid trail lengths, the percentage of damaged trees per unit length of constructed skid trail were calculated.

Experimental Design and Statistical Analysis

There was interest not only in quantifying the damage rooted from selective logging. The cause of damage was quantified and compared, too. A factorial experiment based on randomized block sampling was used in this study; the parcels were blocks and harvesting treatment (felling, winching, and skidding) and slope (0 to 20, 20 to 40, and >40%) were factors. Analysis of variance and Duncan multiple tests were employed to test the differences in residual tree damage among different logging operations and different slope classes within the forest.

RESULTS AND DISCUSSION

Statistical Analysis of Damage to Residual Trees

The total number of trees damaged per tree harvested, when tabulated according to damage classification and the cause of damage, showed that the most common types of damage to residual trees had happened in winching areas and skid trails. Types of damage included uprooted stems and damaged cambial tissue, while the most common types of damage to residual trees in logging gaps included crown damage (Table 1). Statistical analysis showed that for consideration of all damaged trees, skid trails and logging gaps accounted for a significantly greater number of damaged unharvested trees per tree harvested in comparison to winching areas (Tables 3, 4, and Fig. 1). On the other hand, the numbers of destroyed trees per one harvested tree were significantly different among logging treatments (Tables 3 and Fig 2).

Table 2. Total Number of Trees Damaged per Tree Harvested by Damage Classification and Cause of Damage

Bole Damage	Skid Trails			Winching Areas	Logging Gaps
	Primary	Secondary	Tertiary		
Uprooted	0.12	0.08	0.06	0.56	0.32
Snapped, Bent, Leaning	0.78	0.19	0.12	0.17	0.49
Damaged Cambial Tissue	1.03	0.60	0.34	0.29	0
Exposed Cambial Tissue	0.71	0	0.08	0	0.18
Bark Scrape	0.09	0.06	0.06	0.15	0.27
Crown Damage					
All	0	0	0	0	1.35
2/3<3/3	0	0	0	0	1.88
1/3<2/3	0	0	0	0	0.43
0<1/3	0	0	0	0	0
Root Damage					
Damaged Cambial Tissue	2.54	0.87	0.44	0.83	0
Exposed Cambial Tissue	0	0	0	0.11	0
Root Scrape	0.04	0	0.05	0	0.12

Table 3. Analysis of Variance (P values) of the Effect of Parcels, Logging Treatments, and Slope Classes on Residual Trees

Variable	Parcels (2 d.f.)	Logging Treatments (2 d.f.)	Slope Classes (2 d.f.)	Logging Treatments *Slope Classes (4 d.f.)
Number of Damaged Trees	0.075	0.000**	0.002**	0.699
Number of Destroyed Trees	0.849	0.000**	0.000**	0.010*

*P<0.05
**P<0.01

Results showed that logging gaps had a significantly greater number of destroyed trees per tree harvested than skid trails and winching area (Tables 3, 4). In addition, statistical analysis showed that steep slope class experienced significantly greater number of damaged trees per harvested tree compared to medium and gentle class (Tables 2, 3, and Fig. 3). Besides, the numbers of destroyed trees per one harvested tree were significantly different among slope classes (Tables 2, 3, and Fig. 4).

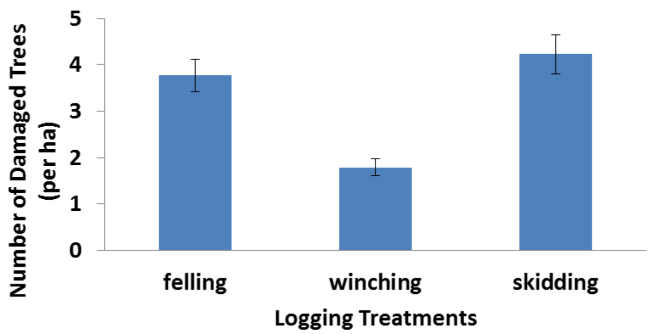

Fig 1. Number of damaged residual trees in different logging treatments

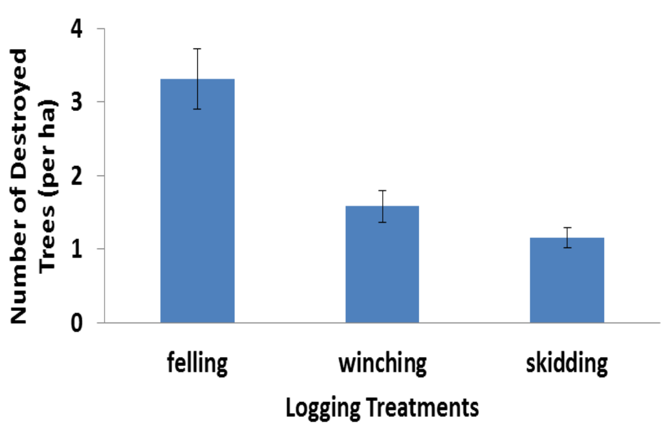

Fig 2. Number of destroyed residual trees in different logging treatment

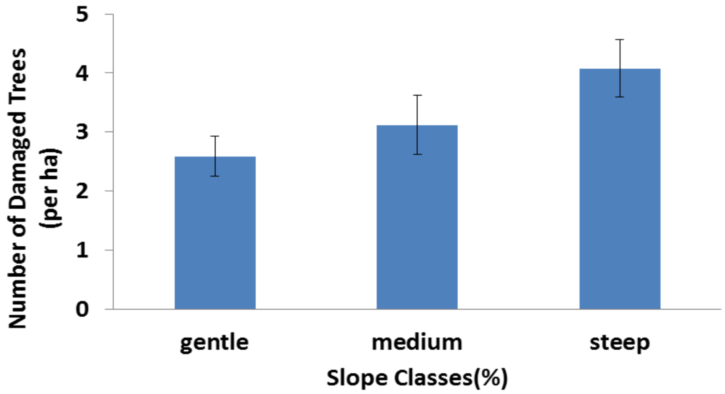

Fig 3. Number of damaged residual trees in different slope classes

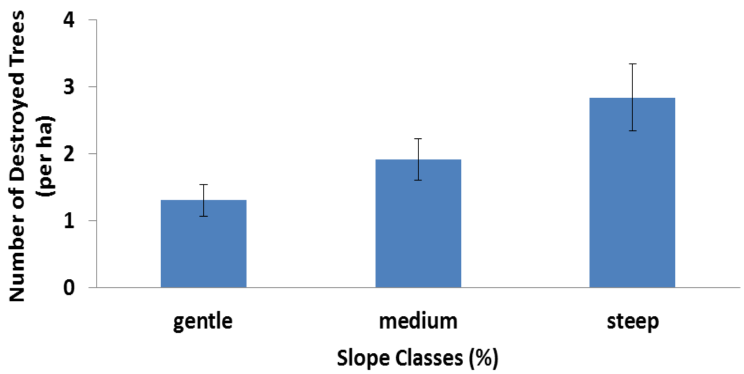

Fig 4. Number of destroyed residual trees in different slope classes

Comparison among logging gaps, winching areas, and skid trails revealed that although more trees were damaged along skid trails (Fig 1), fewer trees were destroyed along skid trails. On the contrary, in felling areas, almost all trees that had been damaged, were judged to be on their way to destruction (Figs. 1 and 2). The results of this study showed that one of the potential difficulties of selective cutting in any stand is logging damage to residual trees that can result in reduction of the tree wood value. Absolutely, much of this damage could be avoided through more careful logging procedures. The results indicated that most of the instances of bole damage were caused by skidding, during which tree-length logs scraped against the boles of standing trees on primary and secondary skid trails, but most of the crown damage occurred as a result of felling operations; so, better felling procedures, such as directional felling, could inhibit some of the crown damage.

The number of trees that were destroyed by the selective logging operation ranged from 1.15 along skid trails to 3.32 in felling gaps per harvested tree. Some damages to residual trees are greater. It was found, in general, that the lowest log of a residual tree decreased by one grade point. The bottom log is the most valuable log in the tree. This devalues the remaining trees within the residual stand, since the damaged trees probably will not heal over nor increase to a better log grade in a foreseeable future. The logging wounds provide opportunities for fungi to enter and rot the trees, eventually diminishing their value (Shigo 1979; 1986). The results showed that logging treatments and slope gradient had significant impact on residual trees (P = 0.000) following logging operations.

CONCLUSIONS

1. More careful logging would have reduced the amount of residual stem damage associated with selective logging in Caspian forests.
2. The unplanned logging operations increased the chance of bole and crown damage to residual trees.
3. Preserving the quality of residual trees during selective logging is necessary to achieve sustainable forest management in Caspian forests.
4. Selective logging has many potential advantages, including reducing stand density, favoring certain species, increasing diameter growth, and having more pleasing aesthetics compared to clear-cutting. However, the potential detrimental effect, due to damage to residual trees should be considered in selective logging.

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