Ecological Engineering 83 (2015) 505–512

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Affective factors on residual tree damage during selection cutting and cable-skidder logging in the Caspian forests, Northern Iran

Farzam Tavankar[a,*], Amir Eslam Bonyad[b], Baris Majnounian[c]

[a] Department of Forestry, Khalkhal Branch, Islamic Azad University, Khalkhal, Iran
[b] Department of Forestry, Faculty of Natural Resources, University of Guilan, Somehsara, Iran
[c] Department of Forestry, Faculty of Natural Resources, University of Tehran, Karaj, Iran

ARTICLE INFO

Article history:
Received 26 January 2015
Received in revised form 21 June 2015
Accepted 27 July 2015
Available online 12 August 2015

Keywords:
Caspian forest
Harvest intensity
Logging damage
Selection cutting
Stand density

ABSTRACT

Although selection cutting has many advantages, its potential for damage to residual trees is a major challenge of forest management. The present study evaluated damage to residual trees during manual felling and cable-skidder logging operations in 18 instances of selection cutting in the Caspian forests of Iran. Data was collected from 100 m × 100 m systematic sample plots (0.1 ha) at each logging site. Harvest intensity ranged from 3.8 to 11 trees ha^{-1} and it averaged 7.3 trees ha^{-1}. Damage to residual trees was 10.5–23.6% with an average of 16.9%. There was a positive and significant correlation between amount of damage and harvest intensity ($R^2 = 0.65$, $P < 0.01$). The multiple regression analyses also indicated that there were statistically significant relation ($R^2 = 0.77$, $P < 0.01$) between amounts of trees damage and independent variables (harvest intensity, ground slope and stand density). Injury to the bottoms of tree boles 100–200 cm^2 in size was the most common types of damage. Damage was concentrated in small diameter trees (DBH < 40 cm). Most logging damage occurred during winching. Results suggest adherence to two silvicultural practices: (1) limit harvest intensity to 6 trees ha^{-1}, (2) limit selection cutting in slopes, less than 50%. Additional operational suggestions are implementation of felling direction and avoid log extraction through dense stands.

1. Introduction

The main goal of selection cutting management is provide the mixed and uneven-aged stands that are close to nature (Nyland, 2003; Marvie-Mohadjer, 2006). Uneven-aged management is one alternative that could generate sustainable harvests while maintaining continuous forest cover and protecting stands diversity (Guldin, 1996). In reality, this method is the practice of removing mature timber or thinning for release space for young trees to growth and improves the timber stand (Nyland, 1998; Donoso et al., 2000). In selection cuttings, harvested trees often need to be transported through the residual trees before reaching the skid trail. Residual stand damage is an unavoidable risk of selection cutting, but the level of damage should be minimized to assure future product quality (Tavankar et al., 2013). Residual tree damage during selection cutting has been reported to be a serious problem in the management of uneven-aged forest stands (Pinard et al., 1955; Whitman et al., 1997; Stehman and Davis, 1997; Sist et al., 1998; Naghdi et al., 2008; Nikooy et al., 2010).

The Caspian (Hyrcanian) forests of Iran are managed by selective logging and most timber is harvested in form of ground skidding. These forests are located on the southern border of the Caspian Sea and cover an area of about 1.92 million hectares (Heshmati, 2007). They are suitable habitats for a variety of broadleaf species (approximately 80 woody species) and include a lot of forest types (Marvie-Mohadjer, 2006). The stands in this area are the most valuable and economical. The main benefits of these forests are essentially twofold: on the one hand there is its wood production while on the other hand there are various physical and socio-economical effects frequently termed as forest influence. In many instances, the latter transcends is the significance of forests as producers of wood (Bonyad et al., 2012). In these forests, trees to be removed are felled, limbed and topped by chain saw, and primary transport of timbers is related to timber types, site characteristics, as well as, topography and access to forest roads. Wheeled skidders are used on the more gentle slopes and on skid roads on steeper terrain. Crawler tractors are used on steeper topography to skid direct to the landing. In steep terrains that are not accessible by ground-based machines, or the density of roads is not enough, felled trees

* Corresponding author at: P.O. Box 56817-31367, Iran.
E-mail address: farzam_tavankar@yahoo.com (F. Tavankar).

http://dx.doi.org/10.1016/j.ecoleng.2015.07.018
0925-8574/

are processed by chain saw into logs and lumbers and then hauled by mules (Jourgholami and Majnounian, 2011). The cable yarding technologies are still undeveloped in these forests. Wheeled skidders appeared in the early 1970s and are now the most widely-used harvester, in these forests.

Previous studies of Caspian forests have shown that residual tree damage ranges from 7% to 20% during each operation of selection cutting by cable-skidder logging in the managed unit (Parcel). For example, residual tree damages in the Caspian forests were reported 15.5% (Lotfalian et al., 2008), 19% (Naghdi et al., 2009), 7% (Majnounian et al., 2009), 19.7% (Nikooy et al., 2010), 14.1% (Tavankar et al., 2011) and 16.4% (Jourgholami et al., 2012). Not all tree species are equally susceptible to mechanical injury in the Caspian forests (Tavankar and Bonyad, 2014).

Ficklin et al. (1997) found that wheeled skidders damaged about 22% of residual trees. Hartsough (2003) studied forests in the northeastern California and found that 23% of residual trees were damaged during ground-based logging and that smaller trees were more likely to be damaged. Froese and Han (2006) studied about damage to residual trees in a conifer mixed stand and concluded that 37.4% of the residual stand was damaged. Iskandar et al. (2006) reported that 9–15% damage in eastern Kalimantan forests in Indonesia. Yilmaz and Akay (2008) studied forests in Turkey and showed that 14% of residual trees were damaged during felling and skidding operations. Marchi et al. (2014) studied environmental impacts of thinning by semi-mechanized logging systems in an Austrian pine (*Pinus nigra* A.) plantation of central Italy. Their results indicated that the frequency of wounded residual trees was highest when applied winching without snatch block (49.7%), and decreased when used cable yarders (36.3%), especially if equipped with a semi automatic carriage (35.1%).

Damage to the residual stand in forest operations often occurs during timber extraction (Vasiliauskas, 1993; Han, 1998; Froese and Han, 2006; Kosir, 2008; Picchio et al., 2012). Nikooy et al. (2010) assessed the percentage of damaged residual trees after felling, winching and skidding in the Caspian forests. They found that the percentage of damaged residual trees during winching and skidding operations increased in comparison with felling. The same results reported by Tavankar et al. (2013) in the Caspian forests.

Damage usually occurs right after treatment, but sometimes develops over time (Meadows, 1993; Legere, 2001; Ezzati and Najafi, 2010). Damage to residual trees during selection cutting may decrease quality of the residual trees and increase stand mortality from insect and disease infestations (Vasiliauskas, 1993; Han et al., 2000; Camp, 2002). The wound size and location on the bole greatly affects healing and future timber values. Vasiliauskas (2001) suggested 25–50 years healing period for a 10 cm wide wound in Norway spruce. Welch et al. (1997) recommended 15 years period for complete healing of wounds size <60 cm^2 in Sitka spruce. Wounds caused by ground-based logging usually occur on the lower parts of residual tree boles (Bettinger and Kellogg, 1993; Athanassiadis, 1997; Naghdi et al., 2008; Jourgholami, 2012). Han et al. (2000) reported that the frequency of infection and amount of decay decreased as wound height increased. The lowest sites for wounds on the stem have detrimental effects on stem quality (Ezzati and Najafi, 2010).

The most common damage to residual trees is wounding, which accounts for more than 90% of total damage (Vasiliauskas, 2001; Hartsough, 2003; Yilmaz and Akay, 2008; Naghdi et al., 2009). The injuries often become an input port for fungal decay (Vasiliauskas, 2001). The effect of bole injuries on the future stand structure and quality depends on the intensity, location, and size of the injuries (Meadows, 1993). Since logging injury usually occurs on the lower parts of a trunk, wound decay in a tree affects the most valuable timber (Meadows, 1993; Han, 1998).

Table 1
Technical characteristics of the rubber-wheeled Timber Jack 450 C.

Machine	Timber Jack 450 C
Weight (t)	9.8
Length (m)	6.4
Width (m)	3.8
Length of the winch cable (m)	50
Engine power (hp)	177

Logging damage to residual trees can be a consequence of harvesting activity and has been tied to several variables besides the logging system, including logging intensity (Fjeld and Granhus, 1998; Sist et al., 1998), logging machines (Han and Kellogg, 2000), season of logging (Limbeck-Lilienau, 2003), road density (Gullison and Hardner, 1993; Iskandar et al., 2006), level planning of logging operation (Pinard and Putz, 1996), site condition, and skill of operators (Bragg et al., 1994; Pinard et al., 1955). Ground slope has also been correlated with increased logging damage (Bragg et al., 1994; Pinard and Putz, 1996). Sist et al. (1998) reported that level of residual tree damage had positive correlation with harvest intensity. Stand density (stem ha^{-1}) is one of the important stand features and level of residual tree damage depends on it (Pinard et al., 1955; Bettinger et al., 1998).

A literature review shows that minor damage to the stem of residual trees during logging can have a major impact on the final stand volume of future saw logs (Han et al., 2000; Vasiliauskas, 2001). In the context of selection cutting management, limiting logging damage to residual trees must therefore remain one of the major objectives (Tavankar et al., 2013). Estimating residual stand damage caused by logging can assist logging managers in evaluating the overall success of harvesting in sustainable forest management. However, many studies have been done on the residual tree damage during selection cutting in the Caspian forests, but researches about affective factors are poor.

Our hypothesis in this study was that the level of residual tree damage during selection cutting and cable-skidder logging is correlated to the ground slope, stand density and harvest intensity in the Caspian forests. The objective of this study was to quantify level and type of damage caused by selection cutting and cable-skidder logging and effect of ground slope, stand density and harvest intensity on the level of damage in the Caspian forests of Iran.

2. Materials and methods

2.1. Study area

The study area was located in a mountainous area of Caspian forest, northern Iran (37°3834″–37°42′21″ N and 48°48′44″–48°52′30″ E). Damage to residual trees was evaluated on 14 logged parcels from 2000 to 2012. Four parcels had been logged twice during this period. The elevation of study area ranged from 850 to 1350 m a.s.l. The vegetation of this area is an uneven-aged mixed forest dominated by *Fagus orientalis* Lipsky and *Carpinus betulus* L., with the companion species *Alnus subcordata* C.A.M., *Acer platanoides* L., *Acer cappadocicum* Gled., *Ulmus glabra* Huds., and *Tilia begonifolia* Stev. Harvesting of these forests is generally done by selective cutting. Chain saws and cable skidders are the main machines used for felling and timber extraction in these forests. Timber is extracted mostly in logs of long-length (7.8 m), or seldom in logs of short-length (5.2 m). The most common skidder is the rubber-wheeled Timber Jack 450 C. The main technical characteristics of the rubber-wheeled Timber Jack 450 C are shown in Table 1.