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Tree regeneration following ground-base skidding in a Caspian forest

Farshad Keivan Behjou *

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Abstract

Tree regeneration after ground-based skidding was studied using paired scarified and unscarified plots as well as whole-gap surveys of scarified and unscarified areas in Caspian forests. More than a year following gap creation, variability in the density of regeneration among logging gaps was high, but commercial tree regeneration density tended to be greater in scarified areas than in unscarified areas within gaps for most species. Height growth was also significantly greater for trees in scarified compared to unscarified areas, despite a near quintuple of soil compaction in scarified areas. The principal species benefiting from soil disturbance by skidders was *Alnus subcor-*

* Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran,
Corresponding author: Farshad Keivan Behjou (fkeivan@gmail.com)

data and *Acer velotinum* which had nearly 35×higher density and 2×greater height growths in scarified compared to unscarified areas. Although initially devoid of vegetation and litter cover, scarified areas had vegetation and litter cover levels similar to unscarified areas after 12 months. Vegetation cover on scarified areas tended to be dominated by early successional tree species while unscarified areas were dominated by lately successional tree species.

1. Introduction

Caspian forests with an area of 2000 km² are located between -20 and 2200 m above sea level in north of Iran (south of the Caspian sea) (Tabari et al., 2007). The commercial forests have located in the northern part of Iran, between north of the Alborz Mountain and south of Caspian Sea (Limaei & Lohmander, 2007). These forests are uneven-aged structures of varying species such as: beech (*Fagus orientalis*), hornbeam (*Carpinus sp.*), maple (*Acer sp.*), oak (*Quercus sp.*) (Limaei & Lohmander, 2007). The type of forest management system is selection method (Marvimohajer, 2006). In Iran, Industrial logging occurs only in the Caspian forests. High quality hardwood saw-timber is being harvested in these forests, but in addition to timber production, these forests must be managed to produce a variety of non-timber goods such as flora, fauna, water, and aesthetic experience (Marvimohajer, 2006). Due to the higher initial costs of harvesting machines, larger diameters and crowns of hardwoods and the relatively steep train in Caspian forests, motor manual harvesting and a wheeled skidder are still the most commonly used system in this region (Behjou et al., 2008). Recruitment of commercial tree regeneration is fundamental to the sustainability of timber production in naturally managed Caspian forests. Logging activities can inhibit regeneration in Caspian forests. For example, soil compaction and displacement of topsoil due to logging is thought to be responsible for decreased potential for establishment and subsequent growth of tree regeneration in forests [Malmer & Grip, 1990, Jusoff & Majid, 1992., Gardingen et al., 1998].

Various studies in other areas have observed improved recruitment of seedlings and saplings in areas where soil had been scarified by logging equipment [Fredericksen et al., 1999., Fredericksen & William, 2000., Fredericksen & Mostacedo, 2000., Fredericksen et al., 2001]. Similar results have been reported in other types of forests [Ver Dickinson & issimo et al., 1992., Snook., 1996., Gullison et al.,1996., Whigham., 1999., Dickinson et al.,2000.,]. The objective of this study was to determine the impacts of ground-base skidding on tree regeneration within logging gaps in Caspian forests.

2. Methods

2.1. Study site

This study was carried out in compartment 231 in Chafroud forests in Guilan province in the north of Iran with 90ha area. The altitude ranged was from 1350 to 1550m above see level and the average annual precipitation was 1450mm. The average annual temperature is 11.6 degree centigrade. The forest was uneven-aged *Fagetum* (*fagus orientalis Lipsky*) with the average growing stock 320m³/ha. The slope of the compartment was 20 to 60% and the aspects of the slopes were northern. The total volume of production was 1900m³ that share of removed volume 10.6 percent of total volume. Around 10ha of compartment was harvested. The skidding was done from the stump area to the roadside landing by ground-base skidding system. The skidder type used in this study was wheeled skidder Timberjack 450C, with the power of 177HP and the weight was 10,257kg. Table 1 shows the characteristics of the study area. Dominant canopy species include beech (*Fagus orientalis*); hornbeam (*Carpinus betulus*); maple (*Acer velutinum*), alder (*Alnus subcordata*) and elm (*Ulmus glabra*). Some characteristics of remaining stand including stem number, basal area, height and diameter were shown in table 1.

Table1: Number of trees and volume harvested by tree species at the study site and Remaining stand characteristics

Species name	Number of harvested trees	Volume (m^3)	Remaining stand characteristics			
			stem number (per hectare)	basal area (m^2/ha)	height (m)	diameter (cm)
Fagus orientalis	388	1550	156	35	22	72
Alnus subcordata	97	212	27	9	19	62
Acer velutinum	27	72	9	5	28	67
Carpinus betulus	33	66	89	12	21	61

2.2. Statistical design

During March 2006, regeneration damage was assessed in 77 new logging gaps with average size of 282m². A sampling method with a fixed-circular plot was used to collect data for the survey. The radius of each plot was 1.78m, which covered 10 m² per plot with soil scarification; adjacent to each plot a 10 m² plot without soil scarification (control) was established, Note that the scarification created by skidding activities in the harvesting areas was assessed. The used harvesting system at study area was cut-to-length system. Scarified plots were located in areas impacted by logging machinery as close to the center of the gaps as possible. These plots were characterized by a near absence of vegetation cover (6.2±1.5%) and relatively sparse leaf litter cover (51.8±9.6%). Most areas had high litter cover (near 85%) during March. Control plots were located by tossing the sampling frame over the shoulder into unscarified areas of logging gaps that had otherwise similar light availability, water logging and topographic position as the paired scarified plots.

In March 2006 (immediately following harvesting), October 2006 (following the first rainy season), and April 2007 (approximately 1 year following plot installation), commercial tree regeneration density and the percent cover of ground-layer vegetation (<0.5 m tall) and leaf litter were visually estimated to the nearest 5% in all plots. In March 2006 and April 2007, the vegetation cover of major plant life forms (trees, shrubs, herbs) was also estimated. In April 2007, an index of soil compaction was obtained by the measurements of soil compaction using a soil penetrometer. One penetrometer reading was made at each of the four corners of each plot and the mean of the four readings was used in subsequent data analysis. Also in October 2006, new seedlings were tagged and their vertical height (from the ground to the apical bud) measured. The height of tagged seedlings was measured in April 2007. In April 2007, the relative frequency of dominant plants in each treatment was assessed by listing the three most abundant plant species or genera in each plot.

In order to supplement information gathered from the original 77 logging gaps, a count of all recruitment of commercial tree regeneration in scarified and unscarified areas of 77 logging gaps was conducted in April 2007 in another part of the same logging compartments which were harvested 13 months earlier. While vegetation had partially recolonized scarified areas, it was usually not difficult to discern where skidders had traveled within logging gaps. The areas of skidded and unskidded portions of the gap were measured and the number of commercial tree regeneration cm tall was counted and converted to a per hectare basis.

2.3. Data analysis

Most data were analyzed using a paired t-test or a Wilcoxon's signed rank test in cases of non-normally distributed data or data with heterogeneous variance between treatments. Individual plot means were used as replicates. For height data, a Student's t-test was performed using individual trees as replications. Differences were considered statistically significant at $P<0.05$.

3. Results

Commercial tree density in paired 10m² permanent plots within logging gaps differ significantly between scarified or unscarified areas during any measurement period of the study (Fig.1). However, tree densities measured in scarified and unscarified areas of entire logging gaps revealed significantly higher densities of commercial tree species in scarified compared to unscarified areas 12 months following logging (Table 2). Within these gaps, the average size of undisturbed areas was slightly, but not significantly, higher than the areas disturbed by skidders (0.07±0.001 ha compared to 0.03±0.004 ha). Gap sizes ranged from 660 to 790 m², with scarified areas occupying 4% of this area, on average. The higher total regeneration density in scarified areas was driven by the much higher (nearly 35×) densities of *Alnus subcordata* and *Acer velutinum* in scarified areas than in unscarified areas of logging gaps (Table 2). The majority of other commercial tree species had higher regeneration densities in scarified than in unscarified areas, although densities for the other species (*Fagus orientalis* and *Carpinus betulus*) were very low, with the exception of *Acer Velutinum* and *Alnus subcordata* (Table 2).

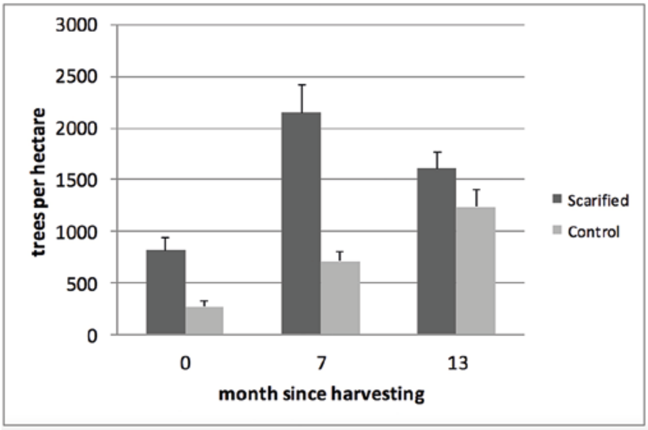

Fig.1: Mean density (no./ha) and one standard deviation of commercial tree regeneration in scarified and unscarified paired plots in canopy gaps 0, 7 and 13 months following logging in a Caspian forests in Iran

Table 2: Mean density (No./ha) ± standard deviation of commercial tree species in scarified and unscarified (control) areas throughout entire logging gaps (n=77) 13 months after harvesting in a Caspian forest in Iran.

Species	Scarified	Unscarified	P_{value}
All species	835.32±137.11	336.34±112.04	0.04
Fagus orientalis	78.43±38.24	176.43±88.13	0.03
Alnus subcordata	468.14±143.65	00.00±00.00	0.00
Acer velutinum	278.14±82.80	98.55±40.87	0.03
Carpinus betulus	10.76±20.20	112.23±25.32	0.03

The mean height of commercial regeneration was greater in scarified compared to unscarified plots (Table 3). Again, this trend was driven by the greater height of *A. subcordata* in scarified versus unscarified plots (Table 3). However, there was a trend for increased height growth of *Acer velutinum*, in scarified compared to unscarified plots. Sample sizes for other species were too small to make comparisons.

Table 3: Mean height (m) ± standard deviation of commercial tree species seedlings/saplings in scarified and unscarified (control) plots within logging gaps surveyed in a Caspian forest in Iran

Species		Time since harvesting (months)	
		7	13
All species	Scarified	0.26±0.13 (n=22)*	0.38±0.27 (n=29)*
	Unscarified	0.17±0.22 (n=28)	0.22±0.28 (n=27)
Fagus orientalis	Scarified	0.00±0.00 (n=0)*	0.07±0.03 (n=12)*
	Unscarified	0.14±0.10 (n=12)	0.28±0.03 (n=9)
Alnus subcordata	Scarified	0.26±0.06 (n=9)*	0.38±0.11 (n=11)*
	Unscarified	0.00±0.00 (n=0)	0.00±0.00 (n=0)
Acer velutinum	Scarified	0.23±0.07 (n=13)*	0.32±0.09 (n=6)*
	Unscarified	0.14±0.15 (n=10)	0.21±0.07 (n=13)
Carpinus betulus	Scarified	0.00±0.00 (n=0)*	0.00±0.00 (n=0)*
	Unscarified	0.18±0.07 (n=6)	0.22±0.09 (n=5)

At the time of plot installation (March 2006), mean vegetation cover in unscarified plots was 2× greater and litter cover was 1.5× greater than that in scarified plots (Table 4). After 7 and 13 months, vegetation and litter cover began to converge among treatments, but cover remained slightly higher in control plots, and control plots were dominated by herbaceous plant cover, while scarified plots were dominated by tree cover (Fig. 2a and b). There was a trend towards convergence among treatments in vegetation cover for all lifeforms after 13 months, although herbaceous cover remained significantly higher in control compared to scarified plots. The most frequent dominant plant species or plant groups occurring in control plots included ferns (*Pteridium spp.*), the forbs (*Rumex spp.*) and (*Rubus spp.*), and the grass (*Lamium spp.*). The most common dominant plant species or plant groups in scarified areas included the early successional tree species *Alnus subcordata* and *Acer velutinum*.

Table 4: Mean ± standard deviation percent vegetation and litter cover 0, 7, and 13 months after harvesting in scarified and control areas of logging gaps in a Caspian forest, Iran

Variable	Treatment	Time since harvesting (months)		
		0	7	13
vegetation cover Percent	Scarified	8.9±2.7[a]	36.5±8.9[a]	99.8±12.1[a]
	Control	19.8±3.2[b]	47.4±9.6[b]	76.9±14.7[b]
litter cover Percent	Scarified	34.4±8.1[a]	86.1±10.7[a]	92.6±12.8[a]
	Control	57.9±7.8[b]	89.3±11.2[a]	97.9±13.4[a]

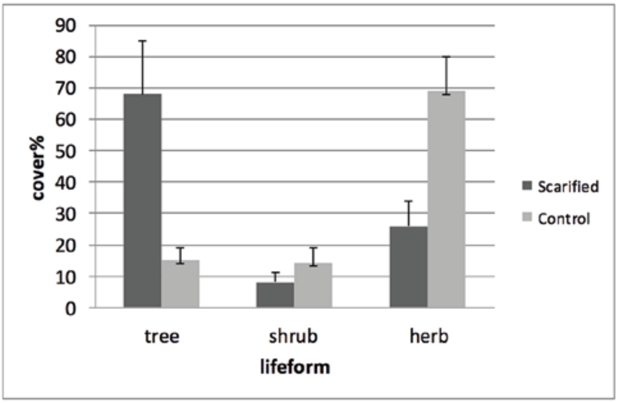

Fig. 2 a: Mean percent cover and one standard deviation of vegetation lifeforms in scarified and unscarified paired plots in canopy gaps 7 months following logging in a Caspian forest

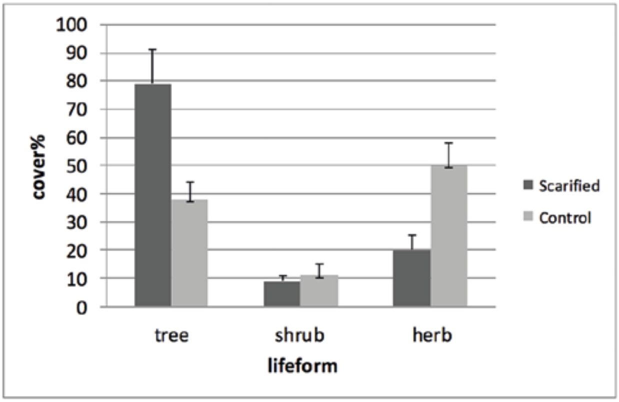

Fig. 2 b: Mean percent cover and one standard deviation of vegetation lifeforms in scarified and unscarified paired plots in canopy gaps 13 months following logging in a Caspian forest.

After 7 months, mean soil compaction was significantly higher on scarified plots (0.59±0.09 kg/m²) compared to control plots (0.11±0.02 kg/m²).

4. Discussion

A medium amount of regeneration of commercial species is pervasive in Caspian forests; the reason for this amount of regeneration is due to existing of livestock in these forests (Marvimohajer, 2006). Attempts to improve recruitment of commercial regeneration have included prescribed reforestation [Gunter., 2001., Fredericksen et al., 2001], mechanical weed control [Pinard et al., 1996., Pinard et al., 1998., Pinard et al., 2000], and seed tree retention guidelines [Lamb., 1996., Fredericksen et al., 2001]. All of these methods, however, have proved either too costly or only partially effective in providing adequate commercial tree regeneration. Several studies have reported increased regeneration for many species in areas disturbed by skidders [Fredericksen & Mostacedo., 2000., Doliveria., 2000., Pariona & Fredericksen., 2000]. Studies in other types of forests have suggested that commercial regeneration may be improved by increased soil disturbance [Whitman et al., 1997]. In Brazil, D' Oliveira (2000) suggested that the success of underplanting may also be enhanced by plantings in log landings and other scarified areas.

The results of this study confirm that commercial regeneration is enhanced by soil disturbance in logging gaps, although other factors, besides soil scarification, are undoubtedly important in securing regeneration in logging gaps and the degree of benefit varies among species. For example, the disturbance-adapted species, *A. subcordata*, clearly benefits from soil disturbance in logging gaps, but only when seed trees are located near gaps. This species does not exist in the forest understory and regenerates almost exclusively from seed rather than root sprouts.

Mechanisms driving the regeneration of other species are less understood. There is some observational evidence from these forests that regeneration of beech (*Fagus orientalis*) only occurs when peak seed production is reached during masting cycles (4 - 6 years) and when this high seed production coincides with disturbances (wind, fire, or flooding) that open the canopy and provide both germination sites and removal of competing vegetation to enhance survival and the accelerated growth of seedlings included the early successional tree species *Alnus subcordata* and *Acer velutinum*.

Maybe light availability is not a big issue. Yet it can be explained why there are more light-demanding species (Alder, maple) in scarified plots. In particular, alder could also benefit from water logging by skidding activities. If the soil is compacted, it is more likely that there is water abundance, and alder in Austria likes these conditions. On the other hand, beech and hornbeam are more frequent in unscarified gaps which are smaller and the top-soil is less disturbed. According to results in some cases the height increment between scarified and unscarified is not so different, because of similarity in the light conditions in some sample plots.

For a few other species (*Alnus subcordata* and *Acer velutinum*), seed production tends to be consistent and abundant each year, but regeneration nearly always occurs in areas with high soil disturbance such as abandoned logging roads [Quevedo & Fredericksen, 2000]. Interestingly, the regeneration characteristics of beech (*Fagus orientalis*) reported from the Northern Iran literature and other parts of world [Gunter., 2001] appears to have a regeneration strategy similar to oak (*Quercus spp.*), but, *A. subcordata* seems to be able to regenerate in areas that have severe soil disturbance and has high light availability (Marvimohajer, 2006). The reason for this difference is unclear, but further studies of the dependence of alder (*Alnus subcordata*) regeneration species on soil scarified areas and/or light availability in this forest is recommended.

In addition to increasing the regeneration density for most species, height growth of seedlings established on scarified areas was higher than those established on unscarified areas. The lower initial cover of competing vegetation on scarified areas is a potential factor for this increased growth because competing vegetation cover was only about 19% of that on unscarified areas at the beginning of this study. Another possibility is that the absence of litter cover allowed for rapid establishment of seedlings on scarified areas resulting in a head start on growth. Greater soil compaction on scarified sites did not seem to negatively affect the initial growth of seedlings, or at least did not offset the other growth advantages due to soil scarification.

5. Conclusions

The results of present study proved that scarification substantially changes the species composition of the regeneration, which is very interesting and important. Potentially by a combination of scarified and unscarified patches it can be established a nicely mixed forest stand. Also, the results of this study show an overall positive effect of skidder disturbance on commercial tree regeneration in logging gaps of Caspian forests; results that are supported by an increase in regeneration in other soil-scarified areas of logging compartments such as primary and secondary skid trails outside of logging gaps [Quevedo & Frederickson., 2000., Jackson et al., 2002]. Scarification by skidders may not significantly increase regeneration of many species, and very high levels of soil disturbance may eventually be counter-productive to regeneration due to severe soil compaction. However, it is possible that soil disturbance by skidders could be used as an inexpensive silvicultural tool to improve conditions for germination or resprouting of several commercial tree species in logging gaps of this forest and increase the subsequent growth of seedlings established due to control of competing vegetation. This soil scarification could be carried out just prior to extraction of the log during harvesting operations. Several silvicultural treatments are currently being studied on an operational scale at the study site to improve regeneration. One of these treatments is increased soil scarification with skidders in logging gaps, including the movement of logging slash to the borders of gaps, in order to increase areas free of obstructions that may inhibit the germination, establishment, and growth of commercial tree seedlings. Regarding to 77 samples represent in the study area, there is both light-demanding and shade-tolerant species with a stem number of about 600 per hectare (average of scarified and unscarified). This is below suggestions for Austria, where we would like to have at least 1600 per hectare for oak, maple, etc and more than 5000 per hectare for shade-tolerant beech (Weinfurter 2013). It will be expected that the number of regeneration should be more than. For such a low number of regeneration, it is suggested high costs to reach satisfactory quality in the final stand.

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