Caspian J. Environ. Sci. 2017, Vol. 15 No. 1 pp. 13~27

CJES
Caspian Journal of Environmental Sciences

[Research]

Comparison of damage to residual stand due to applying two different harvesting methods in the Hyrcanian forest of Iran: cut-to-length vs. tree length

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(Received: June. 26. 2016 Accepted: Dec. 18. 2016)

ABSTRACT

Damage to residual stand is unavoidable and it is one of the main important issues in the forest harvesting. Trees damage may occur in felling and skidding work phase or during skid trail construction. In any case, damage can be very serious to residual stand. Detailed study is necessary to find out the amount and severity of damage to trees; therefore district 14 of Kilesara in Guilan Province, Iran was selected for the study. The cut-to-length and the tree - length methods are practiced in the Hyrcanian forest. Applying any of these two methods is mostly related to dimensions of woody material, technical characteristics of skid trail, and machinery availability. A residual stand which is left after practicing such a method, is damaged in different way which needs to be studied in detail. The length of the winching strips and skid trails differed, but the width of them was kept constant at 6 m (3 m distance from centerline of winching strips or borderline of skid trails). All trees and regenerations around winching strips and skid trails are investigated for finding any sign of damage or injuries. The results showed that along winching strips, the percentage of damage to the residual stand was 19.5 and 18 %, while the damages along skid trails reached 25.4 and 31 % in the tree length and cut-to-length methods, respectively. The results of this study suggest that damage to the residual stand is considerable and should be reduced in order to improve the quality of stand at future.

Key words: Damage to residual stand, Post harvesting assessment, Skid trail, Winching strip, Iran.

INTRODUCTION

Nowadays, damage to residual stand is getting important due to increasing losing forest in many part of the world, therefore sustainable forest management become important. Defining and implementing sustainable forest management with aiming at low impact logging is one of the most critical challenges facing countries now. Forest managers are always under increasing pressure to meet the growing demands for all types of forest products and services, while need to consider environmental impact of their activities. The demands on the natural forests in Iran are numerous and increasing with demographic changes and changing land-use requirements. As a consequence of the increase in demand for forest products and services and the reduction of the forest resource base, concern has risen over whether the demands for forest products can be met in a sustainable manner.

Forest harvesting is always with damage to residual stand which can be direct to trees and indirect to future stand. Direct damage includes damage which is happened during harvesting and includes damage to the stem (scarring or removal of bark), crown (breaking), and root (exposed) (Mousavi Mirkala 2009). Damage to residual stand decreases potential of forest production. Indirect damage caused nutrition loses due to wood and branches removal, soil compaction, site condition changes, and other impacts which decreases potential of forest stand to present good and services to people (Nikooy 2007). In this research, direct damage is studied under comparing condition of the cut-to-length and tree length methods.

In the cut-to-length method, trees are felled, delimbed and bucked to assortments in the stump area. In this method, roadside landings are minimal since all processing is done in the cutting area and high roadside piles can be made. The method also allows for better sorting and storage of various wood assortments. This method is the most common method in many countries (Mousavi Mirkala 2009). In the tree length method, trees are felled, delimbed and topped in the cutting area. Delimbing and topping may occur in the stump area or at a point before roadside. Trees are mainly skidded to roadside with cable or grapple skidders. The tree-length method is most applicable to clear cutting, and can be used in row thinning (Pulkki 1997). In the Caspian forest, logging operation is generally performed using selective cutting methods including single and group selection systems.

In many developing countries, the main issues in harvesting were providing wood and material for wood industry without paying attention to the residual stand. In the last decades with increasing concern about losing forest due to overharvesting, scientists looking for a way to decrease negative effect of harvesting, therefore, FAO implemented code of practice in several developing countries such as South Africa, Malaysia and Indonesia (FAO 1998 a, b, c; FAO 2002 a, b, c) The extent of damage is highly related to the methods used. Ground-based skidding with skidder, which is used in primary transportation because of the low cost and high efficiency, highly influences the residual stand and forest soil (Najafi *et al.* 2004). For the post - harvesting assessment of a logging operation, getting an accurate measure of residual stand damage is important (Stephen & Craig 1997). An application for the residual stand damage study occurs when different harvesting systems are being compared for their ability to decrease damage to the residual stand (Stephen & Craig 1997). Damage to the residual stand is reduced significantly through the introduction of low impact logging in developing countries (FAO 1998 a, b, c; FAO 2002 a, b, c). Using techniques, such as pre-harvest inventory, pre-harvest planning of roads, skid trails and landings, as well as appropriate felling and processing techniques (directional felling) has led to a reduction in the level of damage to the residual stand (Hendrison 1990). Rotation lengths, cutting period, type of equipment used, operational plan, and operator skills influence the residual stand damage and also stand quality (Ostrofsky 2001).

Different studies about the damage to the residual stand have been conducted in Iran. For example, Rashidi (1995) studied mechanical damage to the residual stand in a *Fagus orientalis* stand in Emamzadeh Ebrahim, Guilan Province, Iran. Hosseini *et al.* (2000) analyzed the impact of two different timber extraction systems (cable and ground-based skidding systems) on the natural regeneration in two compartments of Hyrcanian forests in Northern Iran. The amount of damage to all stages of the regeneration was significantly higher in the skidding operation than in the cable system. Nikooy (2007) revealed that damage to the residual stand in conventional logging was 23.5 % higher than that of low impact logging. Mousavi Mirkala (2009), studied damage to residual stand due to applying two short-log and long-log methods under comparable condition in Hyrcanian forests. The results showed that damage to the residual stand in the long-log method was higher and heavier than in the short-log method. Also depth and severity of injuries were more considerable in the long-log method than those in the short-log method.

Globally there is a long history of research regarding damage to the residual stand which shows the importance of the issue. Westveld (1926) initially pointed out the significance of injury to coniferous reproduction due to logging operations. He studied the post - logging damage in all trees and seedlings with a diameter higher than 2.5 cm. Wales (1929) studied damage to residual stand due to skidding by tractor in the pine forests of Arizona, USA. He introduced guidelines, including 12 suggestions for driver and choker setter, in order to reduce damage caused by tractor skidder. Vasiliauskas (2001) compiled a comprehensive literature review of studies on damage to residual stand. Nikooy *et al.* (2010) considered the levels of the residual tree damage in selection-managed stands and observed that 25-35 % of the residual trees had been injured at some extent due to logging. Study about damage to residual stand continued by Badraghi (2013), Ezzati & Najafi (2010), Tavank**ar & Bonyad (2014) who reported various** issues about it.

The present study was conducted to complete the previous study about damage to residual stand due to practicing the short-log and long-log method (Mousavi Mirkala 2009) as well as damage to regeneration. The aim of the study was to determine intensity, occurrence and severity of damage due to applying the tree length and cut-to-length methods.

MATERIAL AND METHODS

Stand description

The study was conducted in Nav watershed, Hyrcanian forests, Northern Iran. The study area was located between 31°53′ and 31°56′ N, and between 41°72′ and 41°65′ E (Fig. 1). On the basis of the meteorological observations and according to Köppen's classification (Kimmel 2001), the climate of the area is temperate; the mean annual temperature is 12.6°C. In general, the relative humidity is high; with the annual rain fall varying between 1000-2000 mm per year.

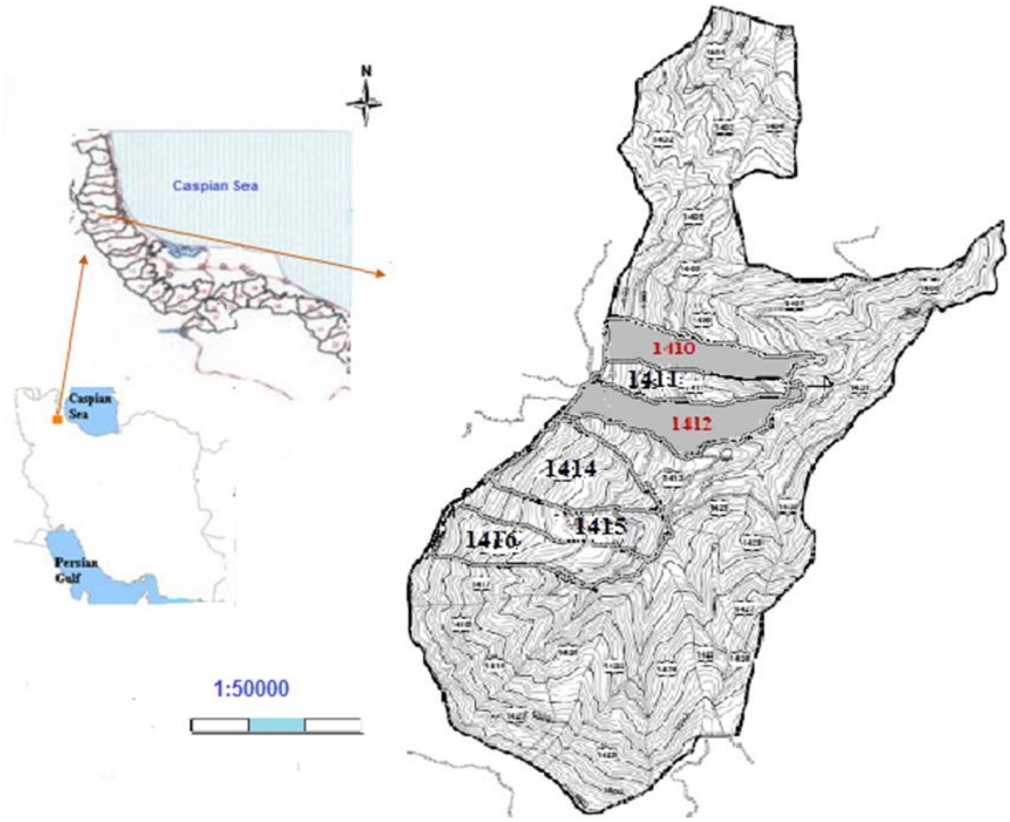


Fig. 1. Location of the study area.

Study sites

They study area was located on Kilesara district belongs to Nav watershed in Northern Iran. Study on damage to winching strips was concentrated on parcels 1410 and 1412 and sparsely in the other parcels. Study areas are highlighted in the Fig. 1.

Total surface area of district are 1397 ha which is covered by several broad-leaved tree species such as Oriental beech, *Fagus orientalis;* hornbeam, *Carpinus betulus;* Caucasian alder, *Alnus subcordata;* Norway maple, *Acer platanoides;* Common lime, *Tilia rubra;* and European pear, *Pyrus communis.*

Table 1. General description of the study area.

Study area	**Kilesara district 14**
Silvicultural treatment	Single tree selection method
Elevation range (m)	700 (200-1600)
Aspect	Noth, North East, North West
district size (ha)	54
Slope (avg.)	0-30 % (11%), 30-60 % (38%), 60-80% (28%), 80-100% (14%), > 100% (9%)
Regeneration condition	Medium to good
Soil pH	4.8-5.7
Gross volume ($m^3.ha^{-1}$)	249.58
Crown cover	> 70 % (37.7), 40-70% (28.3), < 40% (34%)
Specie (volume precentage)	*F. oreintalis* (44%), *C. betulus* (22%), *A. subcordata* (5%), others species (29 %)
Avg. skid trail length *	750 m
Avg. winching strip length	33 m

*4800 m of skid trail is studied.

Data collection

Damage to the residual stand and regeneration along the winching strip was studied in sites randomly located within the working area.

The transect method was used to determine the percentage of damage and type of damage at log extraction stage along skid trails. Species, DBH and the tree growth stages including sapling (height less than 1.3 m), small thicket (DBH < 2-4 cm), thicket (DBH > 4-10 cm), and larger trees were recorded along the winching strips and skid trails and then, each tree was examined for any kind of damage. All injured saplings and trees were measured, recorded and then classified according to three 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 as well as 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 100 cm^2, between 100-1000 cm^2 and more than 1000 cm^2) and degree of injuries (deep and light) were recorded.

The length of the skid trail and winching strips differed, but the width of them was kept constant at 6 m (3 m distance from centerline of winching strips or borderline of skid trails).Because of the different surface area of the winching strips, the calculation of percentage damages was weighted as follows (Zobeiry 1994):

$$M_w = \frac{\sum_{i=1}^{n} g_i s_i}{\sum_{i=1}^{n} s_i} \qquad [i=1, 2,\dots n]$$

where M_w = average percentage of damaged trees along winching strip;

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.

A 2 × 3 factorial design were applied to elucidate the effects of harvesting method and the tree's growth stages on damage rates. Two–Way ANOVA and Tukey's HSD tests were applied for data analysis such as of Analysis of variance of damage to trees and regeneration in different harvesting methods. All analyses were performed using SPSS 18 statistical software package at the significance level of $P \leq 0.05$. All results were reported as Mean ± SE. The t-tests were used to measure whether there is a significant differences between the mean percentage of damaged trees in the two methods.

RESULTS

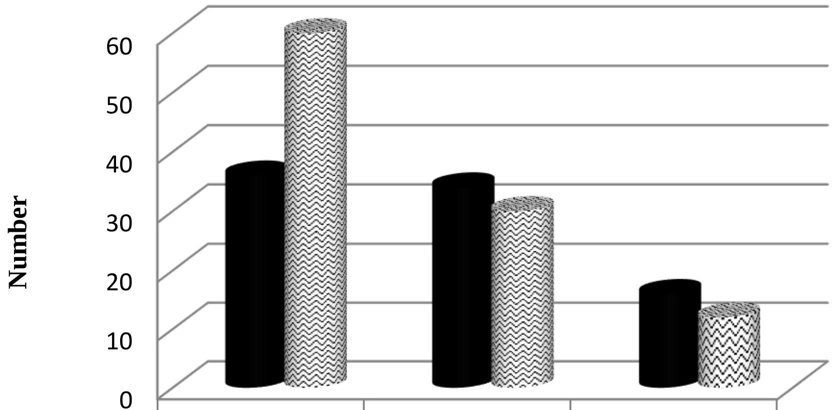
Damages along winching strips

According to the cut-to-length method, in 67 of the winching strips, 102 out of 369 trees were wounded as a result of the winching operation, while based on the tree length method, in 71 winching strips, 86 out of 342 trees were wounded as a result of this operation. The percentage of damage to the residual stand in the cut-to-length and tree length methods were 36% and 27%, respectively. Table 2 shows a summary of collected data in winching strips. 139 winching strips (in favor direction) are studied in both methods. All trees and regenerations were recorded in the predefined area.

Table 2. Summary of collected data in winching strips.

Method	Number of winching strip	Sum of strip length (m)	Sum of area (ha)	Number of trees in all strips	Number of regeneration		
					Sapling	Small thicket	Thicket
Tree length	71	2060	1.24	342	599	280	187
Cut-to-length	67	2166	1.30	369	653	293	191

Totally, 3 or more wounds per stem were found to be the least common, for both methods. Percentage of two wounds and 2-3 wounds per stem in the cut-to-length method were 9.7 % and 9.1 % less than those in the tree length method, respectively. The percentage of one wound per stem in the cut-to-length method was higher than that in the tree length method by 18.1 % (Fig. 2).



	1 wound	2-3 wounds	> 3 wounds
Tree length	36	34	16
Cut-to-length	60	30	12

Fig. 2. Percentage of number of wounds in the damaged tree along winching strips in the tree length and cut-to-length methods.

Overall, in both methods, 17 % of the damage was located on the roots, 71 % was located up to a height of 1 m on the bole, while 13 % was located above 1 m.

In the cut-to-length method, the percentage of damage on root and up to 1 m was higher than in the tree length method by 2%. Adversely, the percentage of damage observed above 1m in the cut-to-length method was found to be 4 % less than that found in the tree length method (Table 3). Both in the cut-to-length and in the tree length methods, in 39 % of the cases the surface area of the wounds were less than 100 cm^2, in 46.5 % between 100-1000 cm^2, while in 14.5 % more than 1000 cm^2. In the cut-to-length method, the percentage of wounds with a surface area less than 100 cm^2 was higher than in the tree length method by 4%, while the percentage of wounds with surface between 100-1000 cm^2 and more than 1000 cm^2 was less than in the tree length method by 1% and 3%, respectively.

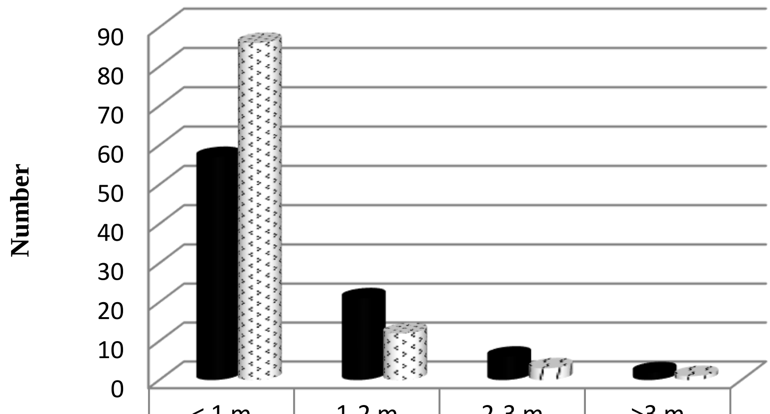
Finally, the percentage of deep wounds in the cut-to-length method was higher than in the tree length method by 1 %. Fig. 3 shows the percentage of wound in a distance from winching strips. The most of damaged trees was located up to 1 m and the damaged trees decreased with increasing distance from winching strips.

Damage to regeneration along winching strips

Table 4 shows damage to regeneration at three stages inducing sapling, small thicket and thicket. The results showed that damage to regenerations in the tree length method was less than in the cut-to-length method. The number of stem from sapling stage to small thicket and thicket stage decreased 53 % and 68 % in both methods, respectively. Table 5 shows different types of damage to regeneration in winching strips. In all three classes, the highest damage was related to sapling, followed by small thicket and thicket.

Table 3. Summary of damage to trees in winching strips.

Tree length method	Wound place	On root	14 (16%)
		Up to 1 m	60 (70%)
		>1 m	12 (14%)
	Wounds area	<100	33 (37%)
		100-1000	40 (47%)
		>1000	13 (16%)
	Degree of wounds	Deep	71 (82%)
		Light	15 (18%)
Cut- to-length method	Place of wounds	On root	18 (18%)
		Up to 1 m	73 (72%)
		>1 m	11 (10%)
	Wounds area	<100	42 (41%)
		100-1000	47 (46%)
		>1000	13 (13%)
	Degree of wounds	Deep	70 (81%)
		Light	32 (19%)



	< 1 m	1-2 m	2-3 m	>3 m
Tree length	57	21	6	2
Cut-to-length	86	12	3	1

Fig. 3. Damage to trees in winching strips in distance from centerline in the tree length (a) and cut-to-length (b) methods.

Table 4. Percentage of damaged regeneration in winching strips.

Harvesting method	Tree length method			Cut-to-length method		
Regeneration stages	Sapling	Small thicket	Thicket	Sapling	Small thicket	Thicket
Number in strips	599	280	187	635	293	191
Number of damaged	76	58	40	102	70	53
Percentage of damage	12.7	20	21	15.6	23.1	27.7

Table 5. Different types of damage to regeneration in winching strips.

Tree length method	Leaned	Sapling	40 (65.6%)
		Small thicket	18 (29.5%)
		Thicket	3(4.9 %)
	Wounded	Sapling	38 (43%)
		Small thicket	27 (30%)
		Thicket	24 (27 %)
	Roots off the ground	Sapling	27 (51%)
		Small thicket	13 (24.5 %)
		Thicket	13 (24.5 %)
Cut-to-length method	Leaned	Sapling	33 (55 %)
		Small thicket	22 (36.7%)
		Thicket	5 (8.3%)
	Wounded	Sapling	28 (32.9 %)
		Small thicket	25 (29.4%)
		Thicket	32 (37.6%)
	Roots off the ground	Sapling	15 (27.8%)
		Small thicket	23 (42.6%)
		Thicket	16 (29.6%)

Damages along skid trails

Damage to the residual stand along the skid trails occurs during the construction of the trails, as well as during log skidding. The results obtained from the cut-to-length method showed that 248 out of 1065 trees and regenerations were injured as a result of the skidding operations (23.3 %). In the tree length method, of 239 out of 1056 trees and regenerations, were injured as a result of the skidding operations (22.5 %).

Overall (in both methods), 36.1 % of trees had 1 wound in the stem, 43 % had 2-3 wounds, while only 20.1 % had more than 3 wounds (Fig. 4). The number of one wound per stem in the cut-to-length method was higher than in the tree length method by 16.3% while the number of 1-2 wounds and more than 3 wounds per stem in the cut-to-length method was higher than those in the tree length method by 2.8% and 13.5 %, respectively.

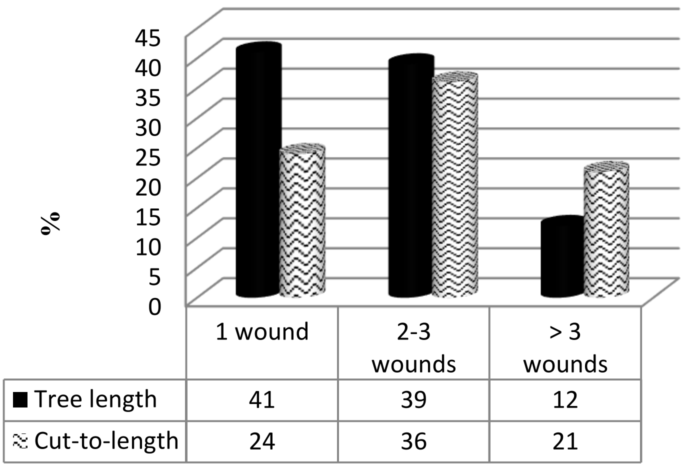


Fig. 4. Number of wounds as percentage on the damaged tree along skid trails for the tree length and cut-to-length methods.

The number and percentage of damaged trees at various diameter classes at skid trails is shown in Table 6.

Table 7 shows a detailed data on damage to trees in the skid trail. Most of the recorded damage was deep and was located up to 1 m. The wound surface area was mostly 100-1000 m^2. In total, 21% of the trees' wounds were located on the roots, 71.6 % on up to 1 m and 7.5 % on above 1m. The number of damage on the roots in the cut-to-length method was higher than in tree length method by 3.7 %. The numbers of damage on a height 1 m above the ground and higher than 1 m in the tree length method were higher than in the cut-to-length method by 2.4 % and 1.3 % respectively. Overall (in both methods), 27.6 % of the wounds had a damaged area less than 100 cm^2, 49.8 % were between 100-1000 cm^2, and 23 % were more than 1000 cm^2. Percentage of wound area less than 100 cm^2 and between 100-1000 m ^{2} in the tree length method was higher than in the cut-to-length method by 1.8 and 1.1 %, respectively. However, the number of wound area between 100-1000 cm^2 in the cut-to-length method was 4 % higher than in the tree length method. In the tree length method, the number of deep wounds was higher than in cut-to-length method by 2.2 %.

Fig. 5 shows the distribution of damaged tree in associated with distance. By increasing distance from border of skid trails, damage decreased. So, the most damaged trees (84 %) were located less than 1m away from border of skid trails or 3m from centerline of skid trails.

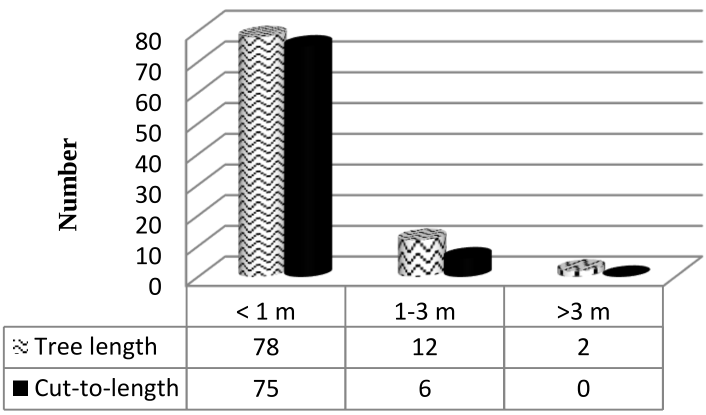


Fig. 5. Damage to trees around skid trail at different distance from borderline of skid trails in the tree length and cut-to-length methods.

Table 6. Number and percentage of damaged trees at various diameter classes in skid trail.

Diameter classes (cm)		Number of trees	Number of wounds	Wound in each classes/total wounded trees (%)	Wound in each classes/total trees in each class (%)
<35	Tree length	145	42	45.6	29.0
	Cut-to-length	138	32	39.5	23.0
35-50	Tree length	63	29	31.5	46
	Cut-to-length	62	20	24.7	66.7
50-70	Tree length	31	15	16.4	48
	Cut-to-length	30	14	17.3	32.6
>70	Tree length	14	6	6.5	43
	Cut-to-length	19	15	18.5	51.7
Total	Tree length	253	92	100	46.9
	Cut-to-length	249	81	100	42.4

Table 7. Summary of damage to trees in skid trails.

Tree length method	Wound place	On root	17 (18.5%)
		Up to 1 m	67(72.8%)
		>1 m	8 (8.7%)
	Wounds area	<100	26 (28.2)
		100-1000	44 (47.8%)
		>1000	22 (23.9%)
	Degree of wounds	Deep	10 (11%)
		Light	82 (89 %)
Cut-to-length method	Place of wounds	On root	18 (22.2%)
		Up to 1 m	57 (70.4%)
		<1 m	6 (7.4%)
	Wounds area	<100	22 (27.1%)
		100-1000	42 (51.8%)
		>1000	17 (22.1%)
	Degree of wounds	Deep	8 (9.8%)
		Light	73 (91.2%)

Table 8 shows damage to regeneration along skid trails.

Similar to winching strips, the most damaged trees was related to sapling, followed by small thicket and thicket.

Two-Way ANOVA test revealed that neither interaction of harvesting method and the tree growth stages nor harvesting methods affect damage rate. However, the tree growth stages significantly affected the damage rate (Table 9 and Table 10).

Turkey's HSD test depicted that sapling significantly differed from small thicket and thicket, showing the lowest damage rate (Fig. 6). In both methods, there were not significant differences on the number of tree damages between the winching strips (p-value = 0.76) and skid trails (p-value = 0.5).

Table 8. Different type of damage to regeneration in skid trails.

Tree length method	Leaned	Sapling	27 (64%)
		Small thicket	13 (31%)
		Thicket	2 (5%)
	Wounded	Sapling	34 (40%)
		Small thicket	21 (25%)
		Thicket	28 (12%)
	Roots off the ground	Sapling	10 (44 %)
		Small thicket	7 (30%)
		Thicket	6 (26%)
Cut-to-length method	Leaned	Sapling	19 (63%)
		Small thicket	10 (34%)
		Thicket	1 (3%)
	Wounded	Sapling	42 (42%)
		Small thicket	30 (30%)
		Thicket	27 (28%)
	Roots off the ground	Sapling	19 (49%)
		Small thicket	11 (28%)
		Thicket	9 (23%)

Table 9. Analysis of variance of damage to regeneration (winching strips) in different harvesting methods and tree growth stage.

Source	Sum of Squares	df	Mean Square	F	Sig.
Harvesting method	254.15	1	254.15	0.57	0.451
Tree growth stage	8060.62	2	4030.31	9.03	<0.001
Harvesting method × tree growth stage	381.82	2	190.91	0.43	0.652
Error	180771.85	405	446.35		
Total	189456.33	411	0		

The highest damage rate was recorded in the cut-to-length method as well as small thicket and thicket stages, while the lowest observed in the tree length method as well as sapling and small thicket stages (Fig. 7).

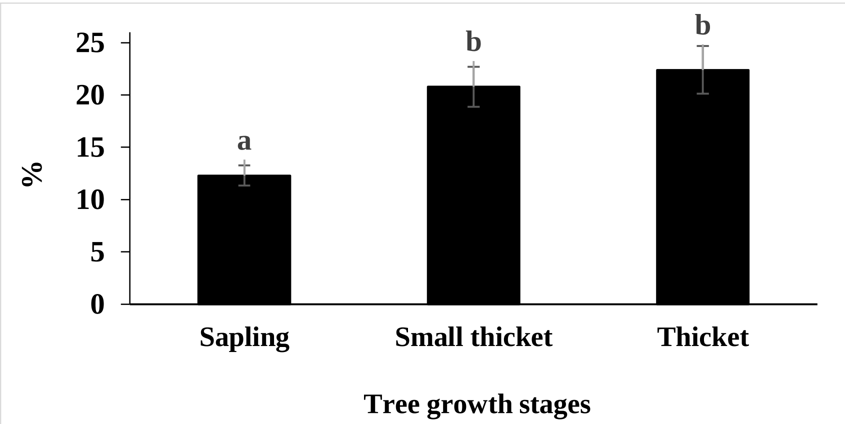


Fig. 6. Damage rate at different tree growth stages in winching strips. Different letters on columns depicted statistically significant differences.

Table 10. Analysis of variance of damage to regeneration (skid trails) in different harvesting methods and tree growth stage.

Source	Sum of Squares	df	Mean Square	F	Sig.
Harvesting method	127.23	1	127.32	18.46	<0.001
Tree growth stage	99.75	2	49.87	7.23	0.006
Harvesting method tree growth stage	50.93	2	25.46	3.68	0.048
Error	110.34	16	6.89		
Total	8866	22	0		

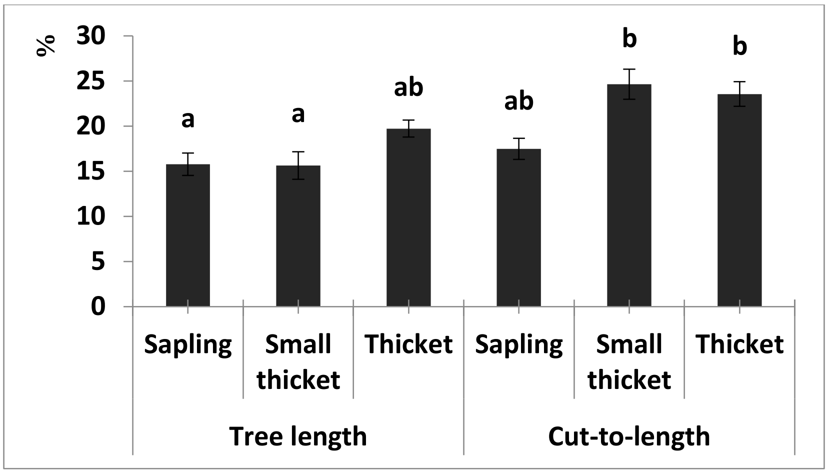


Fig. 7. Damage rate at different tree growth stages in skid trails. Different letters on columns depicted significant differences.

DISCUSSION

One of the most important issues in harvesting, except when clear-cutting is used, is logging damage to residual stands. Usually in the harvesting procedure, tree damage is to be expected and unavoidable, especially in mature, fully stocked stands. Many researchers worked on finding differences between traditional harvesting and well organized harvesting under comparable conditions. The results of all of these studies showed that in well-organized harvesting system, damage to residual stand decreased significantly (Hedin 1980; Garland 1997, Sist *et al.* 1999; Pinard 2000; Sobhani 2001; Jackson 2002).

The results of this study showed that the harvesting operation may cause significant damages to the remaining trees and regenerations. By the well-designing and constructing skid trails before harvesting operation, only limited area will be ready for wood extraction, while by applying directional felling, trees are winched along strips. The risk of damage to the boundary trees is low on such trails. In the skid trails, straight line and higher curve radius is an important issues.

Han and Kellogg (2000) stated that dimension of skidder and the load size were the most significant variables in the damage to residual stand. Therefore, they recommended that the width of skid trails should be between 3.6-4.2 m which depends mostly to the harvesting methods. In the study, the width of the skid trail was considered 4 m for both methods. Therefore it need to be considered wider skid trail besides being straight and higher curve radius.

The present study showed that damage to residual stand as well as regeneration in winching strips and also skid trail in the tree length method was less than those in the cut-to-length method. This may related to the higher number of skidded logs in the cut-to-length method in comparison with tree length method. In both methods, the amount of damage to sapling was less than in thicket and small thicket. The main reason for that was the higher flexibility and ability to be leaned against higher pressure in sapling. Overall, damages to winching strips were 18% and 28% in the skid trail which were higher than the results of Nikooy (2007), Mousavi Mirkala (2009) and Tavankar & Bonyad (2012).

Many scientists showed that features such as location of wound on standing trees, wounds area, and deepness of wounds are the most important factors for measuring damage to residual stand (Stone & Coulter 1975; Wasterlund 1992; Bettinger & Kellogg 1993; Han & Kellogg 2000). Therefore, in the present study, evaluations of damage due to cut-to-length and tree length methods on the residual stand were compared applying the same factors. The present study showed that in both methods, the number of wounds on the trees in winching strip and skid trail in a height less than 1 m were higher than those in roots and over one meter height. These wounds have negative effect on residual stand due to increasing chance of decay (Shea 1960).

The wounds on the injured trees are located in different areas. In most of the cases, the injuries were situated up to 1 m above the stem which represents the most valuable part of the tree. 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 (Vasiliauskas 1993). In this study, about 88% of wounds were located up to 1 m (wounds on root are also included). The number of wounds on the damaged trees varied considerably; hence they were classified into three categories. Overall (along skid trails and winching strips in both methods), 44 % of all the damaged trees had 1 wound, while 38.0 % had 2-3 wounds, with the remainder (18.0 %) having more than 3 wounds. For all the damaged trees, 18.6 % of damages were located on the roots, 71.0 % below 1 m of the stem excluding roots, while 10.4 % located above 1 m.

The sizes of the logging wounds reported in several ways. In the North American conifer forests, scar sizes on damaged trees ranged from 0.13 cm^2 to 2968 cm^2 (Bettinger & Kellogg 1993). In the study by Vasiliauskas (1993), the size of logging wounds on Norway spruce *Picea abies* reached 1000-3500 cm^2. In the present study, overall (along skid trails and winching strips in both methods) 33 % of wound areas covered less than 100 cm^2, 48 % varied between 100 and 1000 cm^2, while 19% were larger than 1000 cm^2. Comparing the methods showed that the tree length method leads to larger wound than the cut-to-length method.

The distribution of different damage size showed similar results with previous studies (Nikooy 2007; Mousavi Mirkala 2009). Most trees wounded during forest operations are not randomly distributed within a stand, rather they are situated close to the skid trails and winching strips (Bettinger & Kellogg 1993; Nikooy 2007). Siren (1982) noted that 90% of wounded stems located less than 5m away from the centerline of the extraction route. In the present study, in both methods, wounds were mostly (around 80%) up to 1m away from borderline of skid trail or centerline of winching strip.

As a conclusion, damage to residual stand was significant in the study and was lower in the tree length method than in the cut-to-length method. The most reason for higher damage in the cut-to-length method may be associated with the higher number of winched or skidded logs in each cycle which increases the chance of strike to border trees.

ACKNOWLEDGEMENTS

I would like to thank to Dr. Ramin Naghdi (Faculty of Natural Resources, University of Guilan) for their help and arrangement the study area. Thanks to Dr. Nikooy (Faculty of Natural Resources, University of Guilan) for providing related material for the research. The study was not financially supported by any individual, group or organization and was done as my personal interest for completion of my previous study in the area. Thanks to Agnese Priede for editing the text and improving the English in the manuscript.

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آسیب به توده باقی‌مانده در اثر عملیات بهره‌برداری با دو روش مختلف بهره‌برداری در جنگل‌های شمال ایران: روش تبدیل به بینه در مقابل تمام تنه

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(تاریخ دریافت: ۹۵/۰۴/۰۶ تاریخ پذیرش: ۹۵/۰۹/۲۸)

چکیده

آسیب به توده باقی‌مانده اجتناب‌ناپذیر بوده و یکی از مهم‌ترین مسئله در بهره‌برداری جنگل می‌باشد. آسیب به درخت ممکن است در هنگام قطع و چوب‌کشی و یا در زمان احداث محل دپو و یا مسیر چوب‌کشی اتفاق بیفتد. در هرحال، آسیب به توده باقی‌مانده ممکن است بسیار جدی باشد. به منظور تعیین میزان و شدت آسیب به توده باقی‌مانده و زادآوری، مطالعه دقیق ضروری می‌باشد و به همین منظور سری ۱۴ کیله‌سرا در استان گیلان برای این مطالعه انتخاب شد. روش تبدیل به بینه و تمام تنه روش‌های متداول خروج چوب در جنگل‌های شمال می‌باشد. به کارگیری هر کدام از این روش‌ها عمدتاً به ابعاد چوب‌آلات، خصوصیات فنی مسیرهای چوب‌کشی، و دسترسی به ماشین‌آلات بستگی دارد. توده باقی‌مانده بعد از عملیات خروج چوب با هر کدام از این روش‌ها نیاز به مطالعه دقیق دارد. طول مسیرهای چوب‌کشی و مسیرهای خروج چوب متفاوت بوده، اما عرض آنها ۶ متر ثابت در نظر گرفته شده است (۳ متر فاصله از وسط مسیرهای جمع‌آوری چوب و یا از کناره‌های مسیر چوب‌کشی). تمام درختان و زادآوری‌ها در داخل مسیرهای جمع‌آوری چوب و مسیرهای چوب‌کشی برای یافتن هر گونه آسیب بررسی شده است. بررسی‌ها نشان داد که در امتداد مسیرهای خروج چوب درصد آسیب به درختان و زادآوری‌ها ۱۹/۵ و ۱۸ درصد بوده است در حالی‌که در امتداد مسیرهای چوب‌کشی ۲۳/۳ و ۲۲/۵ درصد بوده به ترتیب در روش‌های تمام تنه و گرده بینه بوده است. نتیجه این مطالعه پیشنهاد می‌کند که آسیب به توده باقی‌مانده قابل ملاحظه بوده و باید به نحوی کاهش یافته تا توده آینده کیفیت بالاتری داشته باشد.