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Effects of tree diameter and some working conditions on residual stump height following selective logging – Short Communication

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Abstract

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The forests in the north of Iran are located on steep terrains. The stump heights were measured in three compartments under selective management in Caspian forests. The objective of this study was to evaluate the effects of site characteristics on stump heights. The trees were felled with a Stihl chainsaw in the region. Each compartment included three slope categories (0–15, 15–30, and 30–60%) and three diameter categories (40–60, 60–80, 80–100 cm). Also, three snow depths were identified in the felling places (0–15, 15–30, and 30–45 cm) because of the felling season. The results of ANOVA test indicated that slope categories and snow depth had significant effects on stump heights (P < 0.01). In addition, the results proved that the stump diameter of harvested trees had no significant effect on residual stump heights (P > 0.05). Besides, there is a multiple linear relationship between stump height (dependent variable) and ground slope and snow depth as the independent variables.

Keywords: Caspian forests; stump category; slope classes; diameter category; snow depth

The forests in the north of Iran are located on steep terrain. Today, the uneven-aged forest management system with selection cutting (single and group selection method) and natural regeneration has been a dominant silvicultural regime in Caspian forests. This system provides the long-term benefits of sustainable forest management while being less obtrusive, and therefore it may be more acceptable to the general public (Behjou 2013). However, in general, selective cutting could be defined as a cutting regime based on certain defined criteria for the choice of trees that maintains or develops an uneven-aged forest structure over time (Lexerod, Eid 2006). On the other hand, the value of forest products of the Caspian hardwood region is growing with an increase in demand for quality hardwood logs. Herein, there have been substantial increases in demand for veneer type products from hardwood species such as beech (*Fagus orientalis* Lipsky) and elm (*Ulmus glabra* Hudson) (Behjou, Mollabashi 2013). A chainsaw is the most typical felling machine for felling commercial trees in the region. The range of using chainsaws is extensive for felling on gentle slopes and steeper ground. Generally, chainsaw felling has no tree size or ground slope limitations while maintaining a reasonable production rate. As the forest industry becomes increasingly competitive, and more strain is placed on the resource, it becomes important to analyse current harvesting methods to improve the value recovery (Han, Renzie 2005). A conventional chainsaw felling method that uses the face and back cut is commonly used in Caspian forests. Some studies have proved that when the chainsaw is used for felling, higher stumps may result. Murphy and Buse (1984) indicated that approximately 30% of the value loss that occurs during felling resulted from recovering less wood material left in high stumps. Boston and Dysart (2000) stated that even lesser improvements in value recovery could lead to high improvements in financial gains during felling operations. Holmes et al. (2002) evaluated conventional and reduced impact logging waste through high stumps at 0.28 and 0.10 $m^3 \cdot ha^{-1}$, respectively. Boston and Dysart (2000) found that higher stumps are left by chainsaw felling compared to mechanized felling. Poor felling practices belong to the main problems in Caspian forests, and the logging residue and waste standard requires stump height to be lower than 30 cm for all harvest sites, undoubtedly this tactic will result in more financial gains. Gerasimov and Seliverstov (2010) conducted a field-based study to evaluate the losses associated with the motor-manual and fully mechanized harvesting system in Russian forests. The observations were made for five harvesting systems. The results indicated that the fully mechanized and motor manual cut-to-length system provided the lowest loss during all stages of logging operation. Keivan Behjou et al. (2010) determined volume and value loss in logging operation in a Caspian hardwood forest site. The results indicated that in the shape of high stumps, the wood loss volume is 5.2% of harvested wood per hectare. Kärhä (2012) compared two stump-lifting heads in final felling in Norway spruce stands. The study suggested that all the stumps with the diameter less than 20 cm should be left on the harvesting site. Behjou (2013) applied an economic analysis of log damage during logging operations in Caspian forests. The results indicated that animal harvesting systems cause higher volume (40.5% of log volume) and value loss (89.5 $USD \cdot m^{-3}$) to logs than mechanized harvesting systems (13.9% and 6.0 $USD \cdot m^{-3}$). Behjou and Hashemian (2013) used an economic enterprise to calculate damage to forest wood products following selective logging. In this study, opportunity and replacement cost approaches were used to calculate damage to wood products. The results of the study proved that selective cutting can cause damage to residual trees as much as 303.65 $USD \cdot ha^{-1}$ and that some part of these losses resulted from high stumps.

In addition to lower financial gains, high stumps in forest can cause negative effects on harvesting equipment, worker's safety and tree planting. To lower the stump height in any timber harvesting operations, it is important to clearly realize how harvesting attributes can affect the final stump height. In the present study, these attributes include working conditions (i.e. slope gradients and snow depth) and tree parameter (stump diameter). It is important to note that there are a few studies about the analysed wood waste associated with high stumps and variables determining stump height. The results of the present study should help maximize productivity and potential benefits that can occur from leaving lower stumps. The objective of this study was to determine and compare the stump height in different conditions and analysis of the relationship between the dependent variable (stump height) and the independent variables (ground slope, stump diameter, and snow depth).

MATERIAL AND METHODS

Material

The study was conducted in compartments 228, 231 and 232 in Chafroud forests in the north of Iran (Table 1). The altitude of the area ranged from 1,250 to 1,450 m a.s.l. and the average annual precipitation was 1,450 mm. The forest was uneven-aged *Fagetum* (*F. orientalis*) with the average growing

Table 1. Characteristics of the study area

	Compartment		
	228	231	232
Forest district	Chafroud	Chafroud	Chafroud
Altitude (m a.s.l.)	1,200	1,450	1,250
Aspect	northwestern	northern	northern
Area (m^2)	42	66	48
Average field slope (%)	40	30	30
Silvicultural system	selective cutting	selective cutting	selective cutting
Kind of timber	beech	beech	beech
Tree feller experience per year	14	14	14
Payment system	monthly	monthly	monthly

stock 320 $m^3 \cdot ha^{-1}$. The total volume of harvested wood was 2,699 m^3 and the skidding was done from the stump area to the roadside landing by a ground-based skidding system. Dominant canopy species include beech (*F. orientalis*), hornbeam (*Carpinus betulus* Linnaeus), maple (*Acer velutinum* Boissier), alder (*Alnus subcordata* C.A. Meyer) and elm (*U. glabra*). Table 1 shows the characteristics of the study area.

Methods

In each compartment, randomly 60 marked trees were selected. Two tree fellers with 14 years of experience carried out the felling operation. Then, in the place of each selected felled tree, stump height was measured from the ground level (from the bottom of the stump) to the highest portion of the stump cut face to the nearest centimetre. Average stump diameter was calculated to the nearest centimetre based on two measurements of the widest and the narrowest face of the stump surface. Then, the percentage of ground slope was calculated in the place of each sampled stump (sampling areas). Also, the depth of snow was calculated during the felling operation. Before implementing statistical data analysis, stump height data was evaluated to determine the outliers and normality by reviewing residual plots, scatter plots and histograms. A factorial experiment based on a completely randomized block design was performed in the study region; so the compartments were considered as blocks, and slope, snow depth, and stump diameter classes were considered as factors 1, 2 and 3 at three levels, respectively. The ground slope classes were defined as gentle (0–15%), intermediate (15 to 30%), and steep (30–60%). Also, the snow depth classes were defined as low (0–15 cm), intermediate (15–30 cm), and high (30–45 cm) as well as the diameter classes were defined as low (40–60 cm), intermediate (60–80 cm), and high (80–100 cm). ANOVA and Duncan's test were used to determine the significant differences (set at $P < 0.05$) in stump height between different ground slope, stump diameter, and snow depth classes. Also, a general linear model analysis using SPSS (Version 16, 2008) was performed to predict the average stump height. Stump height was considered as a dependent variable and stump diameter, snow depth, and ground slope were considered as independent variables in the form of categorical data with ordinal scale. Stepwise linear regression analysis was applied to predict a regression model.

RESULTS

Totally, 180 stumps were measured from 3 compartments (Table 2). Comparison of stump height among 3 slope classes and 3 snow depths showed that there is a significant difference in stump height ($P < 0.01$). The results from statistical analysis indicate that the average stump height from chainsaw felling in steeper slope classes was significantly higher than the average stump height from chainsaw felling in moderate and lower slope classes ($F = 112.92$, $P < 0.01$), and the average stump height from chainsaw felling in higher snow classes was significantly higher than the average stump height from chainsaw felling in moderate and lower snow classes ($F = 52.47$, $P < 0.01$). Also, the results indicate that there was no significant difference in the average stump height from chainsaw felling between higher, moderate and lower diameter classes ($F = 0.92$, $P > 0.05$). Besides, there was no significant difference between compartments regarding the stump height ($F = 1.07$, $P > 0.05$) (Table 3).

Table 2. The descriptive statistics of measured stump height (cm) in 3 compartments (felling method: manual with chainsaw, number of sampled stumps in each compartment: 60)

Compartment	Mean	SD	Range	Minimum	Maximum
228	36.64	3.67	13.90	31.50	45.40
231	36.67	3.71	15.00	30.50	45.50
232	36.54	3.62	13.70	31.60	45.30

SD – standard deviation

Table 3. The results of ANOVA test regarding stump heights

		Compartments (df = 2)	Classes (df = 2)		
			slope	diameter	snow depth
Stump height (cm)	mean square	4.39	462.76	3.75	215.02
	F-value	1.07	112.92	0.92	52.47
	P-value	0.346^{ns}	0.000^{**}	0.403^{ns}	0.000^{**}

df – degree of freedom, ns – not significant, $^{**}P < 0.01$: highly significant

Ground slope versus chainsaw felling

The consideration of the effect of the slope on stump height with Duncan's test showed that there is a significant difference between slope categories ($P < 0.05$) and in addition, stump height in steeper ground slope class (class 3) is significantly larger than in gentle and intermediate ground slope classes (class 1 and 2) (Fig. 1a) (Eq. 1):

$$y = 26.02 + 2.78x_1 + 2.39x_2 \qquad (1)$$

where:
y – stump height (cm),
x_1 – ground slope class (1: 0–15%, 2: 15–30%, 3: 30 to 60%),
x_2 – snow depth class (1: 0–15 cm, 2: 15–30 cm, 3: 30 to 45 cm),
R^2 = 64.6%.

Stump diameter versus chainsaw felling

A multiple comparison analysis by Duncan's test was performed to evaluate a statistical difference between stump diameter classes. Comparisons showed that there is no significant difference between diameter categories ($P > 0.05$) (Fig. 1b).

Snow depth versus chainsaw felling

Evaluation of the effect of the snow depth on stump height was performed using a multiple comparison analysis. A statistical difference between snow depth classes was observed. Besides, there was a significant difference between diameter categories ($P < 0.01$). The results of Duncan's test proved that stump height in higher snow depth class (class 3) is significantly larger than in lower snow depth classes (class 1 and 2) (Fig. 1c).

The results of the multiple linear analysis indicated that there is a linear relationship between stump height (dependent variable) and the independent variables, i.e. ground slope and snow depth (Table 4).

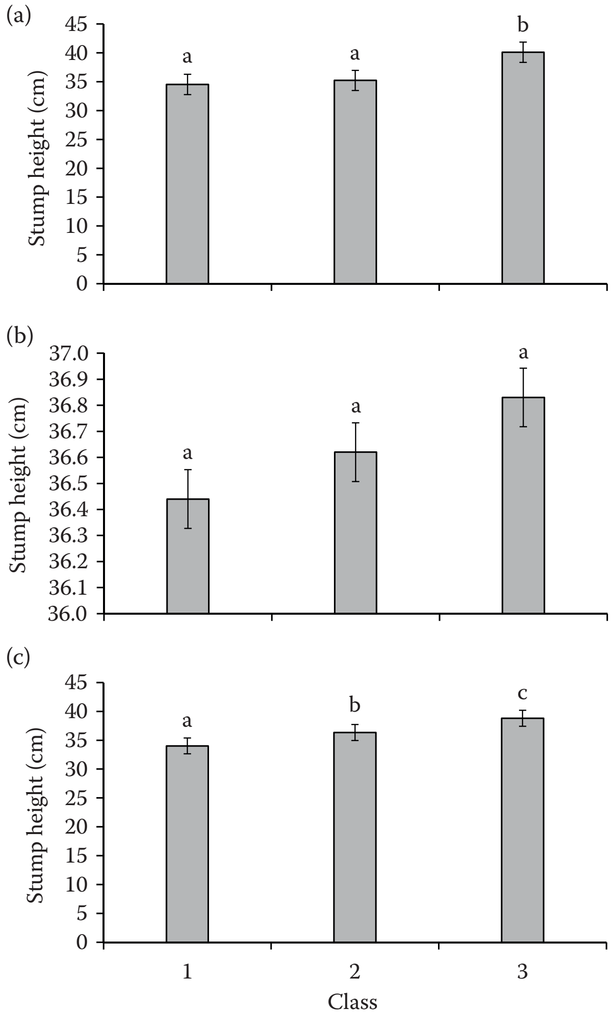

Fig. 1. Stump height in different classes of ground slope (1: 0–15%, 2: 15–30%, 3: 30–60%) (a), stump diameter (1: 40–60 cm, 2: 60–80 cm, 3: 80–100 cm) (b), snow depth (1: 0–15 cm, 2: 15–30 cm, 3: 30–45 cm) (c)

DISCUSSION AND CONCLUSIONS

Harvesting and use of stumps as a raw material in pulp production and energy generation have increased too rapidly in the 21st century (Kärhä 2012). Except for a few cases, the operational and economic benefits of lower stump heights outweigh those of high stumps (Holmes et al. 2002). The results of the present study indicated that chainsaw

Table 4. ANOVA table for a regression model of stump height

Sources of variation	Sum of squares	*df*	Mean square	*F*-value	*P*-value	R^2
Regression	1,538.15	2	769.07	161.16	0.000	64.6
Residuals	844.68	177	4.77			
Total	2,382.82	179				

df – degree of freedom, R^2 – correlation coefficient felling led to higher stumps on steeper slopes (Keivan Behjou et al. 2010) and higher snow depth. On the one hand, it is possible to minimize the volume loss through lower stumps in forest stands (Boston, Dysart 2000; Behjou 2013). On the other hand, stump height was significantly affected by ground slope classes (Han, Renzie 2005) and snow depth.

In addition, the results proved that stump diameter has no significant effect on stump height. Chainsaw felling in gentle and intermediate terrain conditions left lower average stump height relative to the steep terrain; and it was statistically different between lower, intermediate, and high snow depth classes ($P < 0.01$). The results of the multiple regression analysis indicated that slope gradient and snow depth have significant and positive effects on stump height ($y = 26.02 + 2.78x_1 + 2.39x_2$, $R^2 = 64.6\%$). Harvesting of trees close to the ground level not only improves the potential value recovery, but also allows higher operational efficiency for the follow-up tasks such as felling in future and log extraction activities (Han, Renzie 2005). An effective approach to increase value returns of harvesting is to maximize wood use through improvements such as minimizing stump height. Wood waste associated with large stump heights can be prevented through the proper selection of suitable felling methods (Murphy, Buse 1984; Behjou 2013).

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