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Survey of Directional Felling and Analysis of Effective Factors on Felling Error (Case Study; Iranian Caspian forests)

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ABSTRACT
Economic and environmental logging is important for sustainable wood production in the Caspian forests, north of Iran. Predetermination of the skid trail network and directional felling is a usual recommended method to reduce logging impact. The aim of this study was evaluation of directional felling and finding factors effective on felling error. Totally 135 trees were selected randomly for directional felling in mountainous forest in Nav watershed in the Caspian forest. Felling error was calculated for each observation in relation to lay deviation of ground slope, tree length, tree lean, the extent of rot on stump, and tree volume using multiple regression models. Tree volume, interaction of tree volume and terrain slope, and extent of rot in the stump were the most influencing factors on felling error. Results suggest that felling workers should be enough trained for proper use of tools and equipments. The most common tools and devices for manual felling are wedge and hydraulic jack which should be provided in advance.

Keywords*: Directional felling, Felling error, Caspian forests.*

INTRODUCTION

Sustainable timber production in the Iranian Caspian forests requires methods that cause less harvesting damage to the residual stand and soil (Nikooy *et al*. 2010). In order to decrease damage rate, harvesting can be organized in many ways depending on stand structure, tree size, topography, techniques and equipment available (Cedergren *et al*. 2002). Selection system is the most common harvesting method in the Hyrcanian forest (Marvi-Mohajer 2006). Tree selection is done by forest supervisor according to the forestry plan during harvesting season in summer. Damage to residual stand is considerable even in moderate wood removal (Naghdi 2004; Nikooy 2007). Felling trees and skidding logs to the landing are two main direct sources of harvesting damage (Jonsson & Lindgren 1990). Damages resulting from tree harvesting are inevitable but there are methods for decreasing them. Directional felling is the typically recommended method for reducing felling damage and it is mentioned in several studies (Pinard 1994; Bruenig 1996; Majnounian *et al.* 2008; Ershadifar *et al*. 2011). Directional felling means felling a tree in a predetermined direction in order to make skidding more efficient and to avoid damage to residual stands (Cedergren *et al.* 2002). Direction of fall is one of the influencing factors on production rate in skidding work phase. It is important especially in larger trees that make skidding operation easier and faster. It can also have impact on the residual stand. Proper planning and locating of skid trails is very important since it makes the job more productive and economically feasible (Simmons 1979). The implication of directional felling requires those sawyers are fully capable of felling trees in any predetermined direction (ITTO 1996). The impact of directional felling on reduce logging damage was investigated by Nikooy (2007) in Shafaroud forest; however the result was not statistically significant. In evaluation of directional felling in Nav district in Asalem forest, Shormage (2009) found out that with applying directional felling, felling error decreased by 50%. His study shows that using normal working techniques, it is possible to fell trees 30 to 45^o from their lean, if the lean is not heavy. With applying especial working techniques and equipment such as hydraulic jack and cable the range can be extended by 90^o and more (Conway, 1976). Study of Cedergren et al. (2002) in tropical rain forest about feasibility and usefulness of directional felling showed that directional felling can be used to save residual trees in steep terrain. The major concern among logger is minimum felling error especially in selective systems and applying accurate cutting surface (undercut, backcut, and holding wood) can reduce felling error. In this respect the potential of directional felling depends on the skill of forest supervisor to set guideline for choosing direction of felling and on the ability of the feller to fell trees toward desired path. Felling error and the effective factors on error is studied in this research in the broadleaf forest in Asalem in the Hyrcanian forest.

MATERIALS AND METHODS

This study was conducted in the 3700ha Nav timber district located in the Asalem forest region, Guilan province, Iran. The site is classified as mountain forest with a mean annual temperature of 18.8 and rainfall of approximately 1038.7 mm (Anonymous, 2006), the majority of which falls in a period from November to April, a peak of rainy season. Providing forestry plan for this district started in 2001 for logging of hardwoods like beech (*Fagus orientalis Lipsky*), oak (*Quercus castaneaefolia C. A. Mey. Subsp. castaneifolia*), maple (*Acer insigne Boiss. et Buhse*), hornbeam (*Carpinus betulus L*), andalder (*Alnus subcordata C. A. Mey*). The annual cutting area is 410 ha, harvested logs volumes are vary between 25-35 m^3/ha, and it is planned to be cut within 10-years intervals. Evaluating of directional felling performance was conducted in a 55 ha parcel located in the Nav District in Asalem watershed (48 39' and 48 44' east longitude and 37 20' and 37 61' north latitude) in an altitude between 550 to 750 m. Forest supervisor marked trees to be felled with a record number at breast height by red color six months prior to felling. Felling operation was conducted by six felling groups who have had sufficient experience and were trained for directional felling operation.

In order to assess the chainsaw operators, 135 trees were randomly selected. Felling groups were asked to indicate the specific direction in which they intended to fell (Krueger, 2004) according to skid trail direction, regeneration area, residual trees, obstacle, and tree lean, then direction of fall marked on trees bole by arrow. After felling operation, difference between the intended and actual direction of felled trees calculated for each observation, and an average felling error was calculated for each felling group, diameter classes and species. Ground slope, tree length, tree lean, the extent of rot on area of stump, and tree volume were made as assumed factors on felling error (Koger 1983; Krueger 2004; Ershadifar *et al*. 2011). Ground slope was estimated using a clinometer, tree height was measured after falling by tape, tree lean was assessed by manually constructed clinometer, tree volume was calculated using local volume Table, and extent of rot on stump area was estimated using of plastic net with equal cell. The present and extent of rot was visually assessed through inspection of the stump area then percentage is calculated. All factors which might have influence on felling error were studied with applying multiple regressions choosing backward selection (Cedergren *et al.* 2002).

RESULTS

Average diameter at breast height (D.B.H) of the 135 trees treated by directional felling was 62 cm, ranging from

25 to 102 cm DBH. Total height ranged between 10.2 and 29.1 m, with an average of 19.61 m, and average ground slope was 39 %, ranging from 6 to 61 % (Table 1). No hang-ups and splitting (Barber chairing) occurred during the directional felling. Buttresses were not found to cause any problems in directional felling. Rottenness was present in 26 % of the felled trees. A mean tree felling error of 31.26° (S.E. 1.99; S.D. = 19.09; n=135) was observed for felling operation in the study area. 52 % of trees felled within 20° of the desired lay and 38 % showed a lay deviation of 20-40°. Almost 6 % of the trees had felling error between 40-60°, and 4% of the trees had lay deviation more than 60° (Table 2).

Table 1. Basic information on the sample trees

Treatment	Number of tress	DBH range (cm)	Mean DBH (cm)	Height range (m)	Mean height (m)	Mean ground slope (%)	Ground slope range (%)
Directional felling	135	25-102	62	10.2-29.1	19.61	39	6-61

Table 2. Percentage of felling error in the total number of felled trees, n=135

Felling error	percentage
<20°	52
20-40°	38
40-60°	6
>60°	4

One-way analysis of variance revealed that there is no significant difference in mean felling error between the six felling groups employed (df=134, F=1.285, α=0.213). Mean felling error increased with observed DBH classes, but regression analysis showed that felling error was not strongly correlated to DB.H (R^2=0.133, p=0.013,) (Fig. 1).

Mean felling error was the highest for *Acer cappadocicum* (felling error=45.95, S.E. =5.54°; S.D. =16.63°; n=9) and followed by *Fagus orientalis* (felling error = 40.60 ° , S.E. =5.45°; S.D. =24.40°; n=82), *Alnus subcordata* (felling error, 38.35° for S.E. =2.96°; S.D. =26.86°; n=20), and *Carpinus betulus* (felling error = 22.11 °, S.E. =4.22°; S.D. =20.72°; n=24). Different variables were tested in order to find the most influencing factor on felling error by multiple regressions analysis. Tree volume, extent of rot, and interaction of tree volume and ground slope had significant effects (Table 3).

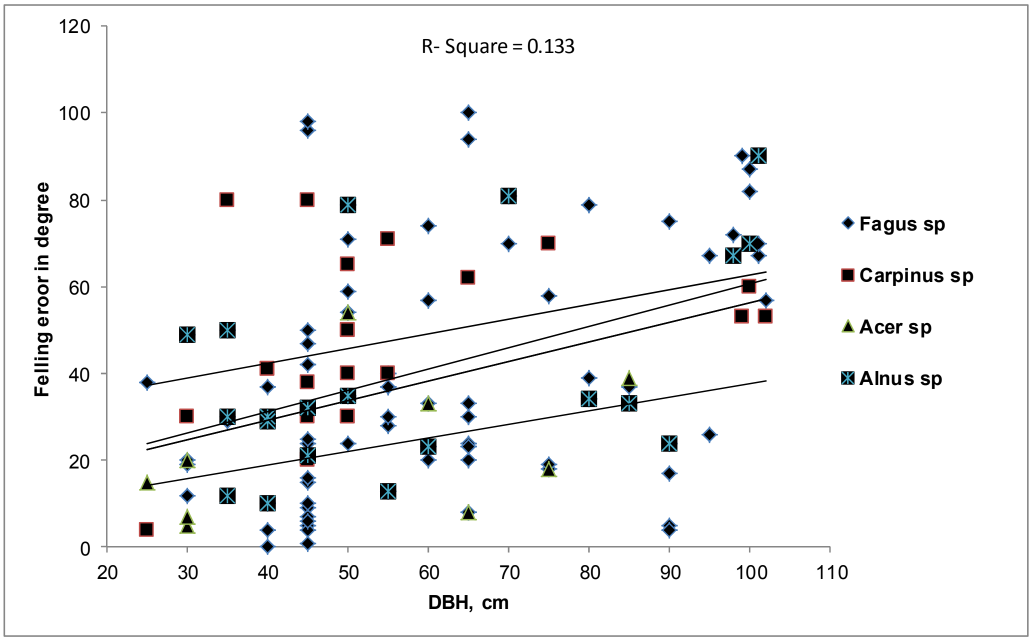
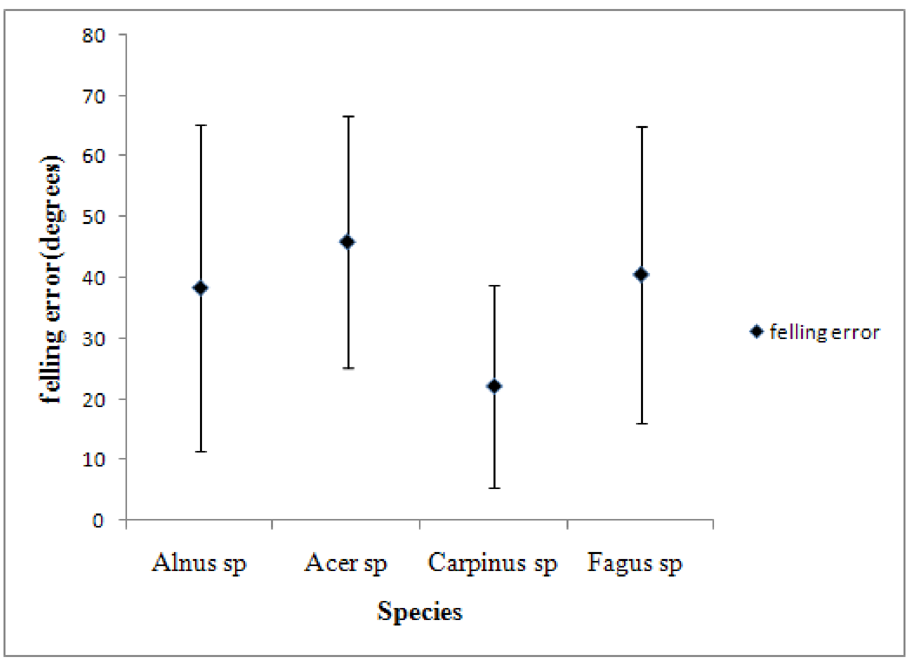


Fig. 1. Influence of tree diameter and grouped of species on felling error

Mean felling error was also found to vary by species (Fig. 2). Mean comparison between different species showed no significant difference (df =134, F=2.034, α=0.112).



Fi.g 2. Felling error by species groups.

Table 3. Analysis of factors assumed to influence on felling error

Variable	Regression coefficient	Significance of *t*	Adjusted r^2
Included			
Tree volume (cubic meter)	3.633	6.348	0.652
Extent of rot at stump level (%)	0.850	2.957	
Tree volume × ground slope (%)	-0.033	-2.111	
Constant	13.634	5.072	
Excluded			
Tree diameter (centimeter)		ns*	
Tree length (meter)		ns	
Ground slope (%)		ns	
Tree lean (degree)		ns	

*not significant
P_{out} = 0.05

DISCUSSION

Directional felling is an important factor to achieve the goals of sustainable forest management that will be realized through falling tree in the specified direction. Mean felling error increased with each DBH class observed, but regression analysis showed that felling error was not strongly correlated to DBH (Fig. 1). Diameter increasing exponentially increases the volume of trees and increasing the volume along with the slope and extent of rot increased felling error. Results showed that felling groups felled only 52 % of trees within 20º of the specified direction. Although falling path was determined and experienced workers were employed, results were not desirable. Result of other studies suggests that trained felling group should usually be able to fell trees within 20º of the desired lay (Cedergren *et al.* 2002; Pinard *et al.* 1995). The inability of chainsaw operator to fell tree in right direction will be increased future crop trees damage, wood waste, and inefficiencies during logging (Gerwig *et al.* 1996; Johns *et al.* 1996; Barreto *et al.* 1998; Nikooy 2007). The observed influence of tree volume, extent of rot at the stump and interaction of tree volume and ground slop on felling error suggests that extra care must be taken deciding whether to fell broadleaves trees in steep slopes (Table 3). Large mean felling error associated with *Fagus orientalis*, *Acer cappaoicicum* and *Alnus subcordata* is likely due to the larger size of these trees and irregular crowns which make it difficult for felling groups to assess the natural weight distribution and ground slope. The results of this study suggest that the performance of directional felling needs auxiliary tools such as wedges or hydraulic jacks. Dent (1974) and ITTO (1996) have reported the same results in their studies. Since felling group rarely use such tools, felling of trees causes unnecessary residual stand damage, wood waste, and operational inefficiencies despite of training chainsaw operator. Experienced felling worker could select desired direction themselves in felling area. The feasible range was mostly around 180º and trees could generally be felled towards the skid trail, while considerations were taken to residual stand (Cedergren *et al.* 2002). When high felling error occurs for felling group, damage level increases. Several proposed adjustments have been recommended to reduce the damage level. These suggestions mainly consider two important phases of harvesting including tree felling and extraction (Mattson-Marn & Jonkers 1981, Appanah & Weinland 1990; Vanclay 1993). Tree should be felled in a direction which facilitate subsequent phase of harvesting (wood extraction). Although the extent of felling error in this study was less than error reported in other operations (Nikooy 2007; Shormage 2009), this could be further reduced through stricter implementation of directional felling techniques. Results of this study indicate that unnecessary felling error from felled trees could have been reduced significantly with more efficient training of workers, using auxiliary tools, rewarding payment system and applying other forms of remuneration (Johns *et al.* 1996; Cedergren *et al.* 2002).

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بررسی قطع هدایت شده و آنالیز عوامل موثر بر خطای قطع(مطالعه موردی: جنگل‌های خزری ایران)

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خلاصه

بهره‌برداری مطابق با معیارهای اقتصادی و زیست‌محیطی برای تولید چوب پایدار در جنگل‌های شمال از اهمیت بسزایی برخوردار است. طراحی مسیرهای چوبکشی قبل از قطع درختان و انجام قطع هدایت شده از روشهای توصیه شده معمول برای کاهش خسارات بهره‌برداری می‌باشد. هدف از این مطالعه ارزیابی قطع هدایت شده و تعیین عوامل تاثیرگذار بر آن بود. برای این مطالعه در مجموع 135 درخت به طور تصادفی برای قطع هدایت شده در حوزه ناو در جنگل‌های هیرکانی انتخاب شد. خطای قطع برای درخت قطع شده در ارتباط با شیب مسیر افت،ارتفاع درخت، تمایل درخت، وسعت پوسیدگی در محل کنده و حجم درخت با استفاده از مدل‌های چندگانه رگرسیونی محاسبه شد. حجم درخت، اثر متقابل حجم و شیب مسیر افت و وسعت پوسیدگی در محل کنده از مهم‌ترین عوامل تاثیرگذار در خطای قطع بودند. نتایج نشان داد که کارگران گروه قطع باید از آموزش‌های لازم در استفاده از ابزار و وسایل کمکی قطع برخوردار باشند و لازم است برای پیشرفت کار وسایل متداول برای قطع با اره‌موتوری مانند گوه و جک‌های هیدرولیکی در اختیار آنان قرار گیرد.

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