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Productivity and cost of tree felling crew with a chainsaw in Caspian forests

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Abstract

Tree cutting is the most important component that affects all stages of harvesting. Tree cutting is included felling, cross-cutting (bucking), delimbing and topping. This study was carried out in the northern forests of Iran (i.e. Hyrcanian Forests) near the Caspian Sea in the Neka Chob Company, in order to evaluate subsections of tree felling. The main goals of this study are time study of tree felling, estimating and measuring productivity and costs of chainsaw as well as identifying regression model of tree felling time. Multivariate Regression of felling time was a function of tree diameter, distance among felling trees and air temperature. Hourly production of chainsaw felling was 44.61 m³/h (8 trees per hour). There was found a negative relationship between tree diameter and the Tree felling cost of production unit, so that when the tree diameter was increased the cost of Tree felling was being decreasing exponentially.

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Introduction

Harvesting begins at planning and it including Tree felling, delimbing, cross-cutting (bucking), primary transportation, loading, secondary transportation and unloading (Majnonian, 1989). Tree cutting is the most important agent that affects all stages of harvesting. Tree cutting is included felling, cross-cutting (bucking), delimbing and topping. Felling is the process whereby a standing tree is severed from its stump, so that subsequent logging operations may be undertaken. The severing point is made at a point on the trunk (stump) above the root collar. This activity is identified as felling and is carried out by a felling crew (Pearce and Stenzel, 1972).

In past, cutting, branching and timber processing in natural forests or afforestation were done by axes and saws but nowadays, handsaw has been replaced by chainsaw in our natural forest in north of our country, Iran. Uneven-aged management is used in most Iranian forests, which means that the harvesting methods used are single tree or group selection The time consumption in motor-manual felling and tree processing is studied for mainly finding out the most important factors influencing work productivity to rationalize work performance and to set a base for payment or for the cost calculation (Nurminen *et al.*, 2006).

Adverse weather such as trifle precipitation, high humidity, high and low temperature are some factors that can affect felling operation and this value may not completely cease felling operation but they can decrease efficiency (Lotfalian, 2012).

Time study is one of the most common practices of work measurements (Björheden, 1991). It is used worldwide, in many types of production, to determine the input of time in the performance of a piece of work (Björheden, 1991)

The aim of this study is an evaluation of Productivity and cost of tree Felling Crew with a chainsaw in Caspian forests.

Material and methods

Site description

The forest studied belongs to Neka Chob Company located in north forests of Iran. This forest originates from south to southeast of Neka city. This forest ranges from 36 ˚25ˈ to 36 ˚29ˈ N latitude and also originates from 53 ˚17ˈ to 53 ˚31ˈ E longitudes (Fig. 1.). This area covers 13565 hectares that about 1817 ha are farm lands and villages and 11694 ha belong to forest. The maximum and minimum altitude is 1430 and 350 m a. s. l. respectively.
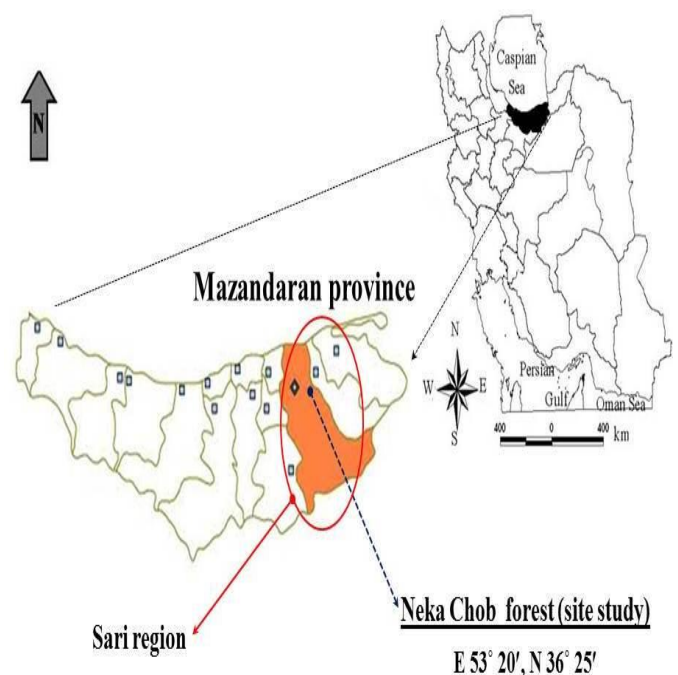
Fig. 1. Location of study area in Mazandaran province and Iran.

Study Method

First the parts of work cycle were determined and then time of each part was recorded in order to curry out this research. The time recorder was used for time study base on continuous time method. Work was divided in subsections in order to better accuracy of work and then time of each subsection was recorded. Time parts regarding to work cycle of felling include Walk to tree (finding tree), time of decision for felling lean of the tree, time of clearing surround the tree, Undercut time, back cut time, wedging time and also

cease or delay times were separately recorded. The affective factors on the time of a Tree felling include the tree diameter (cm); the distance between two trees (m), the slope (percent), temperature and atmospheric conditions in the environs of the tree were recorded. A time recorder, a tape, a thermometer, a clinometer and inventory forms were applied for doing this research.

The production in felling system with chainsaw is obtained by following formula:

Production: $\dfrac{the\ tree\ quantity\ (\ the\ stock\ of\ felling\ trees)}{total\ net\ time}$

(1)

Determining samples quantity

Basic studies with recording 23 primary samples were done in order to determine the number of samples for time study to create predictable mathematic model of felling time and also the standard deviation of net times (without delay times) were recorded. Regarding to 95 % of accuracy, 10 percent of a cycle must be considered in felling phase.

The number of samples needed for our research was determined by this formula:

$$n = \frac{t^2 \times (s_x\%)^2}{(E\%^2)}$$ (2)

n: The number of samples

t: The index that depends the number of samples and validation and extract of T student table

S_x: Standard deviation acquired of fundamental inventory

E: Accuracy that is 10 percent of a felling time

For doing this research 190 samples were recorded to determine felling mode of tree with chainsaw. Finally 3 samples were measured for validating the model, so that wholly 193 samples were used in this study. When the data were collected the measured cycles of cut were being measured in the stands. Therefore, mathematic method of felling -time prediction was prepared by SPSS. After entering collected data, the normality of data distribution were done by Normal Plots and Anderson- Darling. The relationships between measured factors and their binary interactions with felling time without considering delay time were defined. Stepwise and Multivariate Regression were applied For defining variable and fixed indexes of the predictable model of felling time (Jourgholami and Majnonian, 2010).

Results

The predictable model of felling time with chainsaw The mathematically predictable model of felling time is multivariate linear regression that appears as a function of tree diameter and distance between two trees as well as air temperature.

$$Y = -1.208 + 0.109x_1 + 0.035x_2 - 0.124x_3$$ (3)

Y: Time of the Tree felling (min)

x_1: Tree diameter (cm)

x_2: Distance between two trees

x_3: Air temperature

Table 1. Summarizes analyze of variance Table 1. of model (3). The amount of F in Table 1. shows significance at 0.01 level and variables of model show differences by 87 percent.

Table 1. Analyze of variance of the predictable model of felling time with chainsaw.

	Sum of squares	df	Mean square	$F= \frac{MSK}{MSe}$	(%) R^2	r	P
Regression	2077.418	3	692.472	225.932	0.78	0.88	0.000
Residual	570.082	186	3.064				
Total	2647.501	189					

Qualifying validation of the model

In order to qualify validation of the mathematic model, the information of 3 samples acquired in timing were randomly collected and they were used to valid after applying regression model.

Table 2. shows the information of measured amount, estimating by model and the maximum and minimum of predictable range at 95% significance level . The results indicated regression model of Tree felling has the statistical validation.

Table 2. Observation sample, parameter acquired by regression model and the maximum and minimum of predictable range at 95% significance level.

| sample	X_1	X_2	X_3	Measuring time	estimating time	Confidence Limits	
						Lower Bound	Upper Bound
(1)	35	34	9	2.06	2.68	0.39	4.93
(2)	65	24	15	5.14	4.85	1.92	7.78
(3)	95	28	21	8.59	7.52	3.84	11.18

The production of tee felling system with chainsaw

The stock of felling trees was 1053.5853 m³ that was applied for the production.

The hourly production (M³/H)

$$= \frac{1053.5853}{23.6135} = 44.61$$

The hourly production of trees with chainsaw in this study was 44.61 cubic meter per hour. It indicated about 8 trees per hour were operated. Studying the amount of production showed that when the tree diameter was increased the production times was being increased (Fig. 2.).

y = 0.6612x - 3.282
R² = 0.65
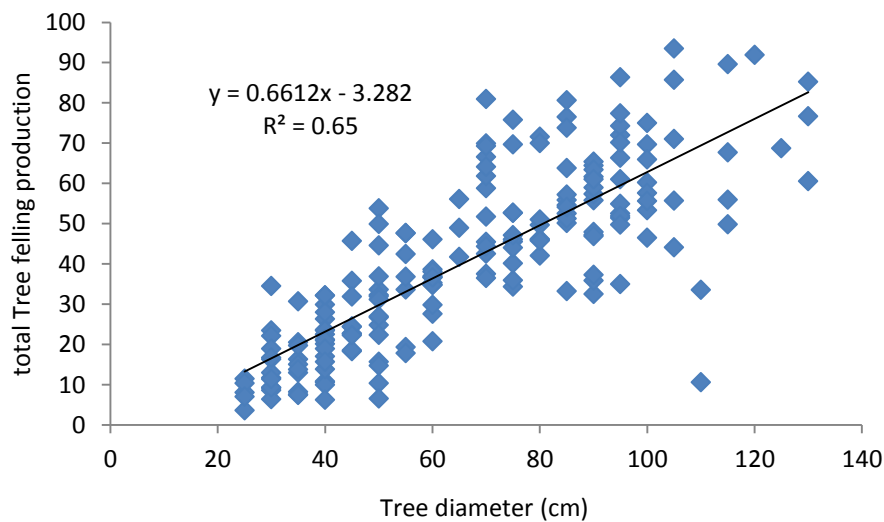
Fig. 2. The variations of total Tree felling production with chainsaw with Tree diameter (cm).

Analyzing the sections of Tree felling with chainsaw

As there is shown in the Fig. 3., time study of a felling cycle in considered parcels indicated that the time applied for feeding and resting, Undercut and back cut were 18.54%, 1652%, 1358%, respectively. The other agents for this value including technical delay, personal delay, operational delay, providing fuel,

Walk to tree (finding tree) and determining felling trend were 79.94%, 12.02%, 9.35%, 2.07%, 9.88% and 4.81%, respectively. The average net time of a felling cycle and the average time of a felling cycle with delay time were 6.21 and 12.41 min, respectively. Marking trees base on single-selecting method has caused to devote 9.88% of time of a cycle on finding the

marking tree. Feeding and resting and also personal and operational delay have allocated much time of a

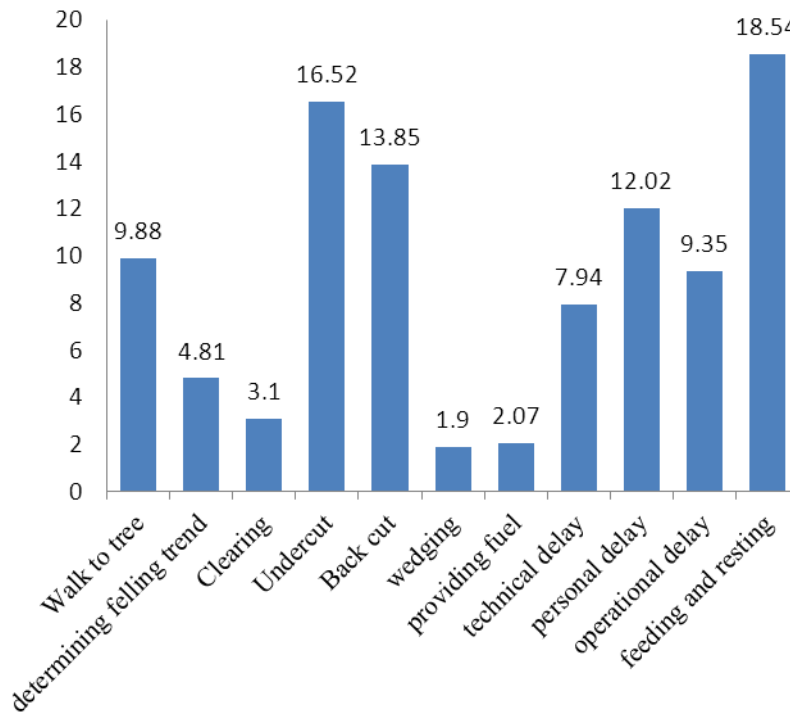cycle and this value can be managed correctly in order to increase efficiency.

Fig. 3. Statistical characteristics of time study on Tree felling operation.

Table 3. Statistics of operational variables of the chainsaw felling in the study area.

Variable	Diameter (cm)	Slope (%)	Temperature (°c)	Distance among felled trees (m)	Walk to tree (min)	determining felling trend	Clearing (min)	Undercut (min)	Back cut (min)	Wedging (min)	providing fuel (min)	technical delay (min)	personal delay (min)	operational delay (min)	feeding and resting (min)
mean	66.86	22.74	14.46	54.74	1.22	0.59	0.38	2.05	1.72	0.23	0.25	0.98	1.49	1.16	57.28
Standard Deviation	26.46	13.64	3.71	46.35	1.44	0.43	0.48	1.59	1.43	0.37	0.56	2.95	2.86	7.48	7.34
maximum	130	70	24	209	7.91	2.2	2.73	7.2	7.6	1.89	3.26	18.46	22.13	31.45	67
minimum	25	2	9	1	0.05	0	0	0.13	0.18	0	0	0	0	0	51.5
total	12705	4321	2749	10400.9	233.15	113.43	73.23	389.7	326.83	44.87	48.94	187.38	283.69	220.7	437.46

The cost of Tree felling system
The instruction of forests and rangelands office was used for costing the system (Sobhani and Rafatnia, 1997). According to this instruction, system cost belongs to the chainsaw and personnel costs. The cost of production unit can be accounted with system cost

divided by total production. Accounting costs of machines and other tools were based on costs of 2013. Regarding to local climate and also working labors on other works, the number of working days was considered 155 days. Economic life 5 year and Purchase price 3125 US$, also the Machine utilization

70 % were considered. Productive Machine Hour (PMH) and Scheduled Machine Hour (SMH) for the chain saw are considered to be 775 hours and 1085 hours, respectively (Table 4.).

Table 4. Summary of detailed chainsaw cost calculation parameters.

| Cost factors	Felling (chain saw)
Purchase price (US$)	3125
Salvage value (US$)	312.5
Economic life (year)	5
SMH (hour)	1085
PMH (hour)	775
Utilization (%)	70
Total fixed cost (US$/m³)	0.03
Total variable cost (US$/m³)	0.06
Total machine cost (US$/m³)	0.09
Total labor cost (US$/m³)	0.07
Total cost (US$/m³)	0.16

The cost of Tree felling with chainsaw

The cost of Tree felling was acquired by the system cost divided by the production. The unit cost of chainsaw felling was 0.168 USD/m³ (0.93 USD per tree). Results showed that there was a positive relationship between tree diameter and the cost of Tree felling so that when the tree diameter was increased the cost of Tree felling was being amplified exponentially (Fig.4.). There was a negative relationship between tree diameter and the Tree felling cost of production unit, so that when the tree diameter was increased the cost of Tree felling was being decreasing exponentially (Fig. 5.).
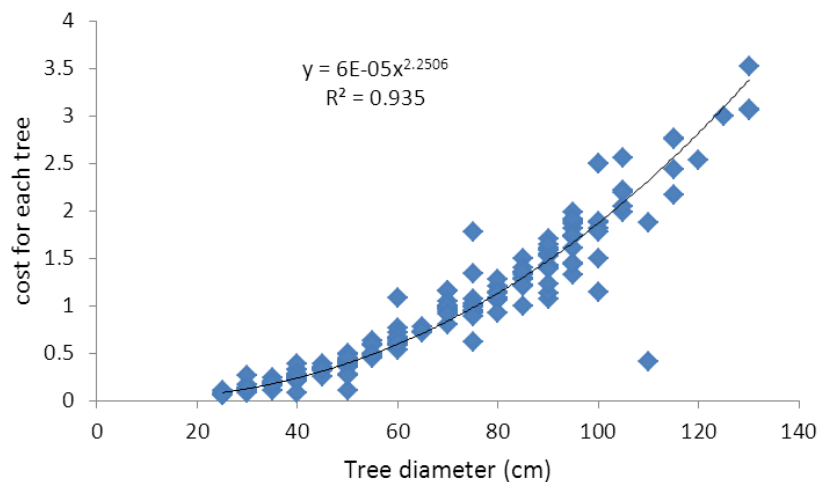
Fig. 4. The effects of tree diameter variations on the cost of Tree felling.

$$y = 47.423x^{-1.303}$$
$$R^2 = 0.6725$$
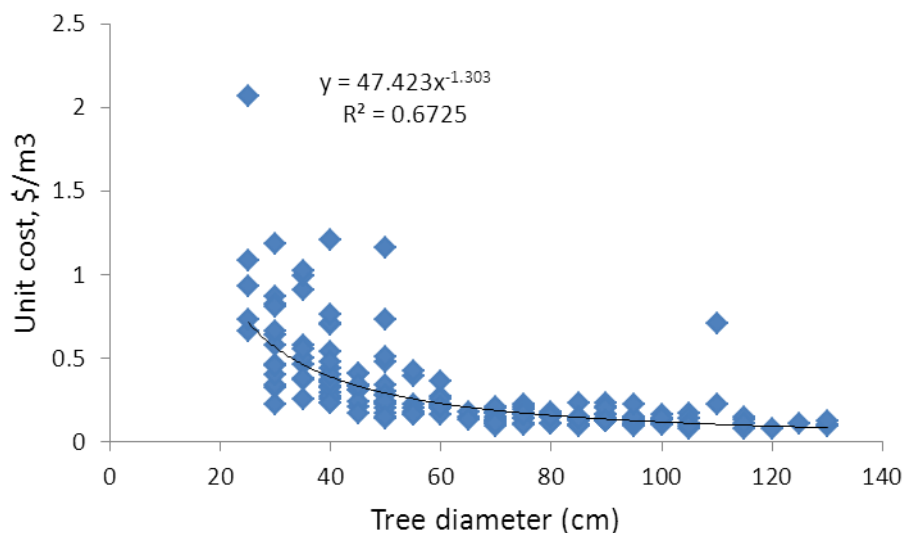
Fig. 5. The effects of tree diameter variations on the production unit cost.

Discussion and conclusion

There are many factors that effect on Tree felling operation. Some of these factors cannot be identified and even many of them cannot be quantified. In this research the variables that have the most effect on Tree felling time were tree diameter and distances among trees. These values are similar to those obtained by Lortz *et al.*, 1997, Rummer and Klepac 2002, Wang *et al.*, 2004, Lee *et al*, 2004, Sessions *et al.*, 2007, Nikoie 2007, Rizvandi and Jourgholami 2012.

Chainsaw man should waste time for finding trees and this value regarding to the silviculture method is different. For example in single selected method this value would be amplified.

In this study, Tree felling split in two sections known Undercut and back cut.The values are comparable to those done by Rizvandi and Jourgholami, 2012 and Fathi *et al.*, 2011. In some studies four sections were applied for Tree felling that our results have not been similar to those obtained by Lortz *et al.*, 1997, Rummer and Klepac 2002, Wang *et al.* 2004, Lee *et al.* 2004. It is noteworthy in this research that Undercut and back cut operation did not performed along with Tree felling operation.

Results showed that there was found a positive relationship between tree diameter and the

production without delay of Tree felling so that when the tree diameter was increased the production was being amplified exponentially. This result is similar to those obtained by Lortz *et al.*1997, Wang *et al.* 2004, Lee *et al.* 2004, Rizvandi and Jourgholami, 2012 and Fathi *et al.* 2011.

The mean of delay times was 3.63 min per turn, which was 1.16, 0.98 and 1.49 min per turn for operational, technical and personal delays, respectively. Obviously, personal delays are the most frequent.. After the personal delays, operational delays were the most frequent.

The results of this study can be used to compare the production and cost of other harvesting machines or systems used in the region and will be helpful for the loggers in selecting an appropriate system under certain stand and harvest circumstances.

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