# Productivity and cost of manual felling with a chainsaw in Caspian forests

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**ABSTRACT**: A field production study was conducted for a manual harvesting system using a chainsaw in a Caspian hardwood forest site. A selective cut was performed on a 42-hectare tract with an average slope of 30 percent. Felling time per tree was most affected by diameter at breast height and by the distance among harvested trees. The gross and net production rate was 20.6 $m^3$ and 26.1 $m^3$ per hour/one person, respectively. The unit cost considering the gross and net production rate was 1.05 USD/$m^3$ and 0.81 USD/$m^3$, respectively. The significant variables included diameter at breast height ($D$) and distance among harvested trees ($L$) for the time expenditure model. This regression function is statistically significant at $\alpha = 0.01$.

**Keywords**: chainsaw; working efficiency; unit cost; felling

The area of natural forests in Iran is approximately 12.4 million hectares, equal to 7.5% of the total area of Iran. Approximately 1.9 million ha are commercial forests called Caspian forests, Hyrcanian or Northern forests (Limaei, Lohmander 2007). The commercial forests are located in the northern part of Iran, between north of the Alborz Mountains and south of the Caspian Sea. These forests are uneven-aged structures of varying species composition such as beech *(Fagus orientalis),* hornbeam *(Carpinus* sp.*),* maple *(Acer* sp.*),* oak *(Quercus* sp.*)* (Limaei, Lohmander 2007). In Iran, industrial logging is carried only in the Caspian forests. High-quality hardwood sawn timber is being harvested in these forests. Information on the productivity, cost and application of harvesting machines is a key component in the evaluation of management plans for the rehabilitation and utilization of Caspian forests (Behjou et al. 2008). Due to the higher initial costs of mechanized harvesting machines, larger diameters and crowns of hardwoods, and the relatively steep terrain in Caspian forests, manual felling with a chainsaw is still the most commonly used system in the region. Although, safety hazards increase, chainsaw felling is not as limited by the ground slope or tree size as is mechanized felling, manual felling is also used to meet management objectives such as pre-commercial thinning, salvage operations, and selective harvesting. Few previous studies addressed the production and cost of harvesting Caspian hardwood stands under different machine and harvest prescriptions. Many factors can affect the productivity of chainsaws. Jones (1983) conducted a time study on a 60-acre tract with three thinning treatments in northern West Virginia. The three treatments were defined as 45%, 60% and 75% of the residual stocking. The harvest consisted of manual felling with a chainsaw. Time studies showed that hourly felling production increased while skidding productivity decreased from the treatments 45%, to 60% and to 75% of residual stocking. Regression equations were later developed based on the above time-study data (Brock et al. 1986), which can be used for estimating production rates and costs for similar thinning operations. Some production/cost studies using manual harvesting systems have been conducted in harvesting planted pine stands in the south. KLUENDER and STOKES (1994) conducted a time study on a southern pine harvest consisting of manual felling, grapple skidding, and cable skidding. The harvest method ranged from clear cutting to single-tree selection and the proportion of basal area removed was used to measure harvest intensity. LORTZ et al. (1997) conducted a further analysis of southern pine felling with chainsaws and produced several equations for estimating felling times and productivity. WANG et al. (2004) developed a productivity model for chainsaw felling, which included variables such as diameter at breast height and the distance among harvested trees. HOLMES et al. (2002) conducted a time study on the forests of eastern Amazon, they found that the productivity and cost of manual felling were 20.46 $m^3$/h and 0.46 USD, respectively.

NIKOIE (2007) developed a productivity model for chainsaw felling in Caspian hardwood forests, which included variables such as diameter at breast height and the distance among harvested trees. The objectives of this study were to:

(1) Conduct a continuous time study on manual harvesting systems with a chainsaw model Stihl in a Caspian hardwood forest.
(2) Estimate the production rates and costs of chainsaw felling.

## MATERIAL AND METHODS

### Site of study

This study was carried out in compartment 231 in Chafroud forests in the north of Iran. The altitude ranged from 1,350 to 1,550 m above sea level and the average annual precipitation was 1,450 mm. The forest was an uneven-aged beech (*Fagus orientalis* Lipsky) stand with the average growing stock 320 $m^3$/ha. The slope of the compartment was 20 to 60% and the aspects of the slopes were northern. The total volume of production was 1,900 $m^3$ and the skidding of production was done from the stump area to the roadside landing by a ground-based skidding system. The skidder type used in this study was a Timberjack 450C wheeled skidder, with the power of 177 HP and the weight was 10,257 kg (BEHJOU et al. 2008). Table 1 shows the characteristics of the study area. Dominant canopy species include *Fagus orientalis*, *Carpinus betulus*, *Acer velutinum*, *Alnus subcordata* and *Ulmus glabra*. The canopy height averages approximately 26 m.

The manual harvesting system examined consisted of felling with a chainsaw. Felling was performed using a Stihl chainsaw with 3-horsepower (hp) engine and bar length of 80 centimetres. The field study was conducted in March 2006 in Chafroud forests, in the north of Iran.

## METHODS

Times and operational variables were measured using a stopwatch and recorded on paper (LEDOUX, HUYLER 1997; BEHJOU et al. 2008). The work cycle for each operation consisted of certain elemental functions and factors. The times for each function and the value of each factor were recorded in the field. Elemental time functions for chainsaw felling were defined as: walk to tree, acquire, undercut, back cut.

Harvesting factors or operational variables for chainsaw felling measured in the field include distance to tree, tree species, diameter at breast height (dbh) and ground slope in the felling area and ground slope between two trees.

A total of 129 cycles for chainsaw felling was observed in the field. The number of observations varied depending on the amount of time required for collecting time study data. Each felled tree was measured for dbh/butt diameter to the nearest centimetre. Local volume equations were used to compute the volume of felled trees (ZOBEIRY 1994).

SPSS 14 was used to analyze the data. The response variables were tested by Duncan's multiple range test at 0.05 levels. Regression techniques were also employed to develop models for elemental times, cycle time, and productivity of chainsaw felling.

dbh of felled trees ranged from 40 to 273 cm and averaged 87.62 cm (Table 1). The distance among

Table 1. Characteristics of the study area

| Characteristics | Study aspect | Characteristics | Study aspect |
|---|---|---|---|
| Forest district | Chafroud | Number of workers | 3 |
| Compartment number | 231 | Average field slope (%) | 30 |
| Altitude (m a.s.l.) | 1,412 | Silvicultural system | selection cutting |
| Aspect | Northern | Kind of timber | beech, alder |

Table 2. Statistics of operational variables of the chainsaw felling in the study area

| Variable | mean | Standard deviation | minimum | maximum |
|---|---|---|---|---|
| **Harvest conditions** | | | | |
| Diameter (cm) | 87.62 | 28.07 | 40.00 | 273.00 |
| Slope 1 (%) | 32.86 | 15.72 | 0.65 | 89.00 |
| Slope 2 (%) | 25.23 | 9.68 | 0.00 | 60.00 |
| Distance among felled trees (m) | 35.63 | 49.36 | 0.00 | 385.00 |
| **Felling cycle time and elemental times** (min) | | | | |
| Walk to tree | 0.49 | 1.13 | 0.16 | 5.16 |
| Acquire | 0.06 | 0.04 | 0.03 | 0.27 |
| Undercut | 0.94 | 1.01 | 0.11 | 4.62 |
| Back cut | 0.73 | 1.17 | 0.09 | 6.57 |
| Delay | 0.81 | 2.18 | 0.48 | 68.67 |
| Total felling time* | 4.57 | 2.14 | 0.00 | 11.94 |

*Total felling time per tree does not include delays

harvested trees varied from 0 to 385 m with an average of 35.63 m (Table 1). In addition to the total felling cycle we must consider delay time. The delay times and the reasons for the delays were also recorded. Three categories of delays were used in the delay analysis: personal delay, mechanical delay and operational delay, which represent delays associated with the principle operating functions of the system.

It was assumed that the skidding time per cycle is a function of the above mentioned variables. The stepwise regression model was applied to develop a model. In this method, if any variable has a significant effect on the RMS (Residual Mean Squares) of the model, it would be used in the model.

Table 3. Average time and share of time segments

| Elemental times of working cycle | | Time (min) | Time (%) |
|---|---|---|---|
| Walk to tree | | 0.49 | 16 |
| Acquire | | 0.06 | 2 |
| Undercut | | 0.94 | 31 |
| Back cut | | 0.73 | 24 |
| Felling | | 0.81 | 21 |
| Delay | | 0.18 | 6 |
| Total felling time | | 3.85 | 100 |
| Delays | personal | 0.22 | 27 |
| | mechanical | 0.44 | 54 |
| | operation | 0.15 | 19 |

## RESULTS AND DISCUSSION

Table 2 presents the statistics of the operational variables of wheeled skidding in the study area. Table 3 shows the average working time and the share of elemental times of working cycle obtained in the Chafroud logging area with the Stihl chainsaw model.

The gross and net productivities of chainsaw for different diameters were 26.1 $m^3$ and 20.6 $m^3$ per hour/one person, respectively. Estimates of hourly costs of the chainsaw were computed using the machine rate method (Miyata 1980). The unit costs with and without delay times were 1.05 USD/$m^3$ and 0.81 USD/$m^3$, respectively. The average lost time is

Table 4. ANOVA model

| | Sum of squares | df | Mean square | *F*-value | *p*-value |
|---|---|---|---|---|---|
| Regression | 841.20 | 2 | 420.60 | 350.64 | 0.00 |
| Residual | 151.14 | 126 | 1.20 | | |
| Total | 992.33 | 128 | | | |

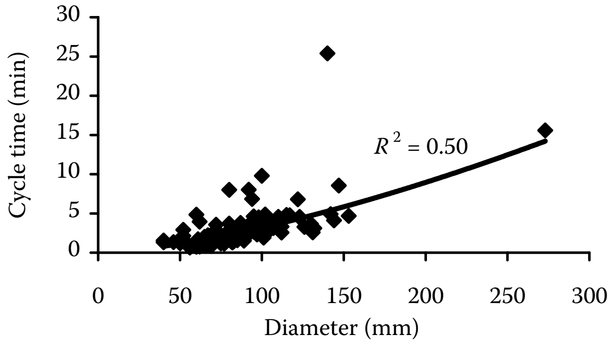


Fig. 1. Effects of tree diameter on felling time per cycle

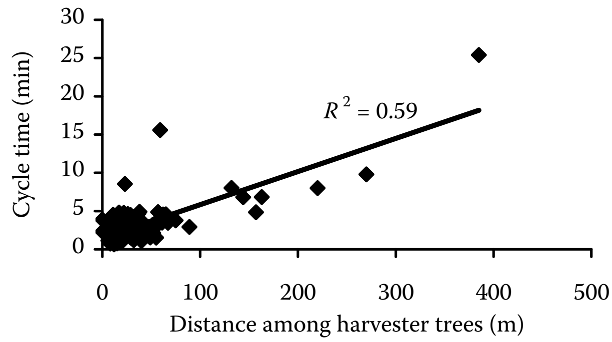


Fig. 2. Effects of distance among harvested trees on felling time per cycle

0.81 min per working cycle, lost times (delays) were taken from different places in the working area. The stepwise regression analysis was applied to the time study data base to develop a delay-free cycle time equation. The significant variables included diameter at breast height ($D$) in centimetres (Fig. 1) and distance among harvested trees in m ($L$) (Fig. 2). The cycle time equations calculated for the chainsaw took the following form:

$$t = -2.80 + 0.051D + 0.039L \qquad (1)$$
$$R^2 = 84.5\%$$

This multiple correlation coefficient of 0.92 is interpreted as the 84.5% of total variability, which is explained by the regression equation. The significance level of the ANOVA table (Table 4) shows that the model is significant at $\alpha = 0.01$. The SPSS 14 statistical program was applied according to its series of phases in Table 2.

## CONCLUSION

The variables such as distance between harvested trees, diameter at breast height (dbh), slope in the stump area, and slope between two harvested trees were entered into the general model for predicting felling time as significant variables, which can be applied in harvesting planning. The felling cycle time per tree and felling productivity were mostly affected by dbh of the tree being felled but they were also affected by the distance between harvested trees. Increasing distance between harvested trees will increase felling time, but if dbh increases, the felling time decreases. The average productivity of 26.1 $m^3$ per productive machine hour (PMH)/one person or 20.6 $m^3$ per schedule machine hours (SMH)/one person provided the weekly production of 470.58 and 371.1 $m^3$ with chainsaw felling. Its total hourly cost was 0.81 USD/PMH and 1.05 USD/SMH per cubic meter, respectively.

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.

The mean of delay times was 0.8l min per turn, which was 0.22, 0.44 and 0.15 min per turn for operational, mechanical and personal delays, respectively. Obviously, mechanical delays are the most frequent. After the mechanical delays, operational delays were the most frequent. In order to prevent a decrease in their efficiency and to reduce delay times the maintenance of machinery must be performed according to the technical specification.

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Received for publication July 15, 2008
Accepted after corrections October 5, 2008

## Výkonnost práce a ekonomické náklady při motomanuální těžbě s motorovou pilou v kaspických lesích

**ABSTRAKT**: Časovou studii pro analýzu produktivity práce při motomanuální těžbě dříví s motorovou pilou v listnatých lesích jsme realizovali v kaspických lesích. Výchovný zásah byl vyznačen a následně prováděn na ploše 42 ha s průměrnou sklonitostí terénu 30 procent. Závislost těžebního času byla nejvíce ovlivněna výčetní tloušťkou kácených stromů a vzdáleností mezi vyznačenými stromy, určenými k těžbě. Průměrná výkonnost práce byla se zohledněním časových ztrát během směny 20,6 $m^3$/h a 26,1 $m^3$/h v operativním čase. Průměrné výrobní náklady činí 1,05 USD/$m^3$ s ohledem na vznikající časové ztráty. V případě nezapočtení ztrátových časů se náklady snižují na 0,81 USD/$m^3$. Nezávislé proměnné zahrnují v modelu spotřeby času výčetní tloušťku stromu ($D$) a rozestup mezi těženými stromy ($L$). Regresní model je statisticky významný na hladině významnosti $\alpha = 0{,}01$.

**Klíčová slova**: motorová pila; pracovní výkonnost; výrobní náklady; motomanuální těžba

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