journals.uoz.edu.krd
Available online at sjuoz.uoz.edu.krd
Science Journal of University of Zakho
Vol. 12, No.2, pp.215–220 April-June, 2024
p-ISSN: 2663-628X
e-ISSN: 2663-6298

THE EFFICENCY OF A MANUAL CHAINSAW PERFORMING UTILIZATION OPERATIONS OF POPLAR TREES IN ZAKHO, KURDISTAN REGION OF IRAQ

Mohammedamin Y. Taha
College of Agricultural Engineering Sciences, University of Duhok, Duhok-Kurdistan Region of Iraq
Email: mohammed.amin@uod.ac

Received: 5 Dec., 2023/ Accepted: 28 Jan., 2024 / Published: 30 May., 2024. https://doi.org/10.25271/sjuoz.2024.12.2.1224

ABSTRACT:

In Poplar plantations, manual tree harvesting techniques (using chainsaws) are still utilized, especially on gentle terrain or for smaller trees, where automated felling may not be a possible or safe option. The most important variables affecting the productivity of motor-manual felling, a global survey show that terrain slope, understory density, distance to trees, and diameter at breast height (DBH) are the most major variables influencing the productivity of manual tree felling. In harvesting activities like felling, delimbing, and bucking, skilled workers are required. Chainsaw use is associated with timber harvesting activities including felling, delimbing, and bucking in forest areas. The chainsaw felling hourly output was 0.4546 m^3/h, the delimbing hourly production was 0.482 m^3/h, and the bucking hourly production was 0.753 m^3/h. As tree DBH increased, chainsaw productivity also increased. In the present study, the utilization rate and chain saw productivity hours (PMH) were 8.25 hours and 71%, respectively. Regression models' calibration and validation procedures for many aspects of tree utilization were used to develop the mathematical models between the above-mentioned process included in utilization as dependent variables and both DBH and total height of trees as independent variables. The coefficient of determination was used to test the efficiency of the calibration and validation of the developed models in the estimation of the dependent variables, the most acceptable Equation No. 11 with a 91.86 coefficient of determination(R^2). Planning for sustainable harvesting can be influenced by the primary suggestions for improving motor-manual felling productivity.

KEYWORDS: Bucking Production**,** Delimbing, Chainsaw, Felling, Log, Regression model, Time study.

1. INTRODUCTION

Measured conditions and average cycle times have to be quantified in production studies. Undesirable sources of variance include delays, unmeasured situations, and variables that are randomly measured (Olsen *et al.*,1998).

Felling has the most important role affecting all subsequent harvesting stages (Abbasi *et al*., 2013). The proper felling and bucking will affect wood quality, efficiency, and felling costs, thus affecting income from selling timber (Garland, and Jackson,1997), and (Uusitalo *et al*., 2004). The effects of logging on forest ecosystem quality highly depend on the duration of operations and characteristic of this activity. The longer logging takes, the higher the logging costs increase, as is commonly known and is not accepted. This occurs particularly as a result of fixed costs Conway, (1982), and declining positive impacts (Ciubotaru,1998).

Through deliberate management measures, the many commodities and advantages that forests supply might be extracted and made accessible to a wider range of people. They include the creation of clean, high-quality water, energy, and mineral supplies, soil preservation, sustainable wood supply, wilderness, and scenic beauty, clean environments for recreation, and fish and wildlife habitats (Baskent & Keles, 2006). Documented that the creation of fish and wildlife habitats, clean, high-quality water, energy, and mineral sources, soil preservation, a sustainable wood supply, natural areas, and scenic beauty. Forest harvesting is the second phase of the wood processing method, typically referred to as mechanical production. Road construction, extraction, loading, primary transportation, bucking, and felling are the components of this expensive system (Lotfalian,2012). Harvesting involves several actions, such as bucking, bunching, falling, delimbing, positioning, and moving from tree to tree. Harvesting processes may be improved by evaluating each task component (Nakagawa *et al.*,2007a).

Time study is one of the most widely used techniques for evaluating work. It is used for determining how long a task will take to be finished in a variety of production circumstances all over the world (Björheden,1991). The study of time is the process of measuring, classifying, and then critically analyzing how much time is spent on work to improve study item efficiency by felling on unnecessary time consumed (Björheden *et al.*, 1995). Time consumption is investigated for a variety of purposes.

Assessing the primary factors affecting labor productivity and establishing a basis for cost estimating, wages, and other payments are the many important goals (Nurminen *et al*., 2006; Majnounian *et al.*, 2009).

This study aims to determine the cost and productivity of a chainsaw-using team that fells, delimbs, and bucks ‘of trees. in

* Corresponding author

the Zakho forest ′Poplar stand, Dohuk Governorate Kurdistan Region of Iraq.

2. MATERIALS AND METHODS

2. 1 Site of Study

The study was conducted in the Zakho forest *Poplus nigra* L. var. *italica* stand, Dohuk Governorate of Iraq. The height of this area is 433meters above sea level which takes at a latitude of 42˚36′22.33″E and longitude of 37˚11′12.34″N by GPS instrument, and the average rainfall is 560 mm/year. The slope of the Qarawila village varies from 0% to 10%, which takes Poplar stand having a different age of years. Harvesting operations were carried out using Stihl 070 Chainsaw with an individual selective-cut silvicultural system.

The time study technique has been used to carry out the time measurement operation. Bucking has been included in the observation of felling. Walking toward the tree to be felled, clearing the area around the tree, starting the chainsaw, cutting the base of the trunk, cutting the trees and branches, determining the log length and bucking, peeling the bark, quality marking with paint, measuring the diameter, marking with the slag hammer, and advising the forest products administration are all working elements of felling (Barokaha *et al*., 2017).

The factors of felling in previous studies included walking, identifying trees, felling, delimbing, and topping time. However, in the present study, in addition to the mentioned basics, the felling element was split into two parts: back-cut and under-cut.

The most important component of the harvesting process is the fell of trees (Conway,1982). Felling and bucking can be done manually, mechanically, or with the use of automated harvesters and feller-bunchers. Productivity evaluation and time studies are two popular methods used to investigate the economics of felling operations (Magagnotti *et al.,* 2012).

The duration of time spent on felling tasks was recorded using a stopwatch, and the slope of the forest was measured with a clinometer. A chainsaw with a 70 cm guide bar length and 6.5 horsepower (HP) was the felling tool used.

Stopwatches or timers were used to measure times and operational variables, and the results were recorded (Ledoux & Huyler,1997). There were certain fundamental tasks and variables in each operation's work cycle. Each function's duration and each factor's value were noted in the field. Walking to the tree, acquiring, under-cutting, and back-cutting were described as the essential time tasks for chainsaw felling.

Distance to tree, tree species, diameter at breast height (DBH), ground slope in the felling area, and ground slope between two trees are among the harvesting elements or operational variables for chainsaw felling that may be assessed in the field (Behjo *et al*., 2009).

2.2 Study Method

2.2.1 Equipment and Logging process

To carry out this stduy, the components of the work cycle were first identified, and the duration of each component was then recorded. For time studies based on the continuous time technique, a time recorder was utilized. To improve accuracy, the job was separated into subsections, the times for each subsection were then recorded. The tree's diameter (in centimeters), length (in meters), slope (in percentage), temperature, and environmental variables were all taken into account when determining when a tree would buckle. For conducting this study, a timer, a tape, a thermometer, a clinometer, and inventory forms were used. The following criteria were identified before doing the study: 1) walking to the tree; 2) preparing for felling (breast height diameter, and tree height was also measured); 3) felling; 5) delimbing (processing); bucking; and delays (avoidable and unavoidable). The time difference between a specific work stage was used to calculate each stage's duration, and a continuous stopwatch used to record the time at the beginning and end of each phase (continuous timing technique). All of them were recorded in a table. The time elements recorded for each Poplar tree calculated weremain working times of felling, main working times of processing (delimbing and bucking), total main working times of harvesting (the sum of felling, delimbing, and bucking times) as well as unavoidable delays as percentage (%) of main working times. In most available studies, delays are stated as a percent of the total scheduled time or scheduled machine (Spinelli & Visser, 2008). Equation No. (1) was used to calculate production in felling, delimbing, and bucking systems using chainsaws:

$Pt = V \div t$ (Eq. N. 1)

where, Pt = felling, delimbing, and bucking productivity (m^3/hour);

V = volume of timber, (m^3);

t = felling, delimbing, and bucking duration (hours)

Due to delays caused by factors such as mechanical failures, lack of staff, bad weather, etc., scheduled operating time and productive time for logging equipment are seldom equivalent (Miyata,1980). Scheduled machine hours included all time the chainsaw is scheduled to work, SMH can be calculated by Equation No. (**2**).

$$SMH = PMH + Hmech + Hop + Hot$$

(Eq. N. 2)

where:

SMH = scheduled machine hours, PMH = productive machine hours, *Hmech* = hours of mechanical delay,

Hop = hours of operator delay, and

Hoth = hours of other delay.

SMH can be calculated from above Equation.

While productive machine hours reflect the amount of time the machine is really in use. The following Equation illustrates how time lost due to mechanical and non-mechanical delays is excluded by Equation No. (3):

$$PMH = SMH – Mechanical\ Delays – Non\text{-}mechanical\ Delays$$

(Eq. N. 3)

The chainsaws productive machine hour (PMH) and scheduled machine hour (SMH) are considered as 1214 and 1700 hours respectively. Utilization measures the percentage of scheduled time that the machine is productive, Equation No. (4).

Util(%) = PMH /SMH Eq. N.(4).

A total of 65 samples of Lombardy Poplar (*Populus nigra* L.) wood stand were randomly used from the Qarawila village, Zakho district, and Dohuk Governorate of which 55 samples were for calibration and the rest for validation of the developed model. The process included felling, delimbing, and bucking of trees using the chainsaw. The time required for each practice in the whole process was measured and recorded separately. However, the data about the tree attributes, including the breast height diameter, height, and volume of trees were gathered to use with the other dataset in model development. These recorded data will constitute the raw data and will be transferred to a computer for the development of the required models. For such a purpose, the Statgraphic Centurion package was used for estimating the model parameters. It aimed to use both simple and multiple regression analysis in generating the regression models. DBH of felled trees ranged from 24 to 40 cm and averaged 33.65 cm (Table 1).

Table 1: Score means of the operational variables of the chainsaw felling, delimbing, and bucking in the Zakho

Variables	Height of Trees(m)	Diameter at Breast Height(cm) (cm)	Volume (m^3)	Temperature (c˚)	Slope (%)	Felling Time(min)	Delimbing Time(min)	Bucking Time(min)
Minimum	10	23	0.13	25	10	0.67	0.61	0.36
Maximum	16	39	0.97	35	12	0.91	0.89	0.6
Average	13	33.44	0.77	30	11	0.77	0.72	0.46

The distance among harvested trees varied from 0 to 385 m with an average of 35.64m (Table 1). In addition to the total felling, delimbing, and bucking cycles, the delayed time was not taken into account. The stepwise regression model was applied to develop a model. All the variables with a significant effect were included using RMS (Residual Mean Squares) of the model.

RMSE=$\frac{\sqrt{\sum(yi-\hat{y}i)^2}}{n-p-1}$

where;

p= is the number of independent variables.

n= is the number of observations.

So if y=b° $+ b1x$

RMSE=$\frac{\sqrt{RSS}}{n-2}$

3. RESULTS

3.1.1. Chainsaw production of the tee felling system

A total of 17.5612m^3 by Huber's formula for volume calculation of felling trees were used in the production as shown in Equation No. (5).

$Hourly\ production\ \left(\frac{m^3}{H}\right) = V/T$ Eq. No. (5).

hourly production=17.5612/38.63=0.4546 m^3/h

In this investigation, 0.4546 cubic meters of trees were felled with chainsaws each hour.

3.1.2.Chainsaw production of the tee delimbing system

A total of 17.5612m^3 of bucking trees were used in the producti on.

$$Hourly\ production\ \left(\frac{m^3}{H}\right) = V/T$$

hourly production=17.5612/36.43=0.482 m^3/h

In this investigation, 0.482 cubic meters of trees were delimbed with chainsaws each hour.

3.1.3.Chainsaw production of the tee bucking system

A total of 17.5612m^3 of bucking trees were used in the producti on.

$$Hourly\ production\ \left(\frac{m3}{H}\right) = V/T$$

hourly production=17.5612/23.28=0.753 m^3/h

In this investigation, 0.753 cubic meters of trees were cross cut with chainsaws each hour.

3.1.4. A total of 5.8419m3 of felling trees were used in the production.

$$Hourly\ production\ \left(\frac{m^3}{H}\right) = V/T$$

hourly production=5.8419/13.75=0.4248 m^3/h

In this investigation, 0.4248 cubic meters of trees were felled with chainsaws each hour.

3.2.1.A total of 5.8419m^3 of bucking trees were used in the p roduction.

$$Hourly\ production\ \left(\frac{m^3}{H}\right) = V/T$$

hourly production=5.8419/12.75=0.469 m^3/h

In this investigation, 0.469 cubic meters of trees were delimbed with chainsaws each hour.

3.1.4.Chainsawproduction of the tee bucking system(Validation)

A total of 5.8419m^3 of bucking trees were used in the prod uction.

$$Hourly\ production\ \left(\frac{m^3}{H}\right) = V/T$$

hourly production=5.8419/8.19=0.7132 m^3/h

In this investigation, 0.7132 cubic meters of trees were cross cut with chainsaws each hour.

Based on the above mentioned, it was presumed that trees were operated per hour. According to productivity studies, as tree diameter raised, so did production times increased.

3.2. The cost of tree felling, delimbing, and bucking operations

The instruction of forests and rangelands office was used for costing the system) Sobhani & Rafatnia,1997). According to finding instruction, system cost belongs to the chainsaw and personnel costs. The cost purchase price 1000 US$, also the machine utilization71.41 % were considered. The total machine life in hours given in Table (9) is 10,000 hours. Assume that the machine is scheduled for 1,700 operating hours per year (200 shifts averaging 8 hours), but it actually operates 6 hours for each 8-hour shift. Then estimated productive time per year is:

1,700 hr./yr. × (6 hr. - 8 hr.) = 1,275 hr./yr.

Total life in year = total machine life in hour actual machine hours per year Total life in year = 10,000 hr. ÷ 1,275hr./yr. =7.843 or approximately 8 years.

Normally delays are presented as a percentage of SMH.

For instance, the chainsaw would have 9-0.5=8.5 SMH per day if the logger in this study worked from 7 a.m. to 4 p.m. with a 30-minute lunch break.

Rodriguez (1986) described planned operating time as the time allotted for the equipment to carry out its intended function. Days when a machine is not in use are not included in the scheduled operation time. These days may also include weekends, holidays, days with inclement weather, and so on (Miyata,1980).

If 200 shifts are predicted and the usage of logging equipment is scheduled for 8 hours each shift, then;

SMH = 8.5 hr./day x 200 days/yr. = 1,700 hr./yr

If the chainsaw spent the following time: 45 minutes preparing for tree felling, delimbing, and backing of the tree to be felled; 20 minutes adjusting a hydraulic fitting; and 10 minutes moving to another landing, its PMH would be PMH = 9.5- (0.75) - (0.33) - (0.17) =8.25 hours.

UT =PMH÷ SMH × 100= 71% as shown in Table No. (2).

Table 2: Detailed chainsaw cost calculation parameters for felling, delimbing, and bucking

Rf	Cost factors	Felling, delimbing, and bucking (chain saw)
1	Purchase price (US$)	1000
2	Salvage value (US$)	100
3	Economic life (year)	7.834 or 8
4	SMH (hour)	1700
5	PMH (hour)	1214
6	Utilization (%)	71.41
7	Total fixed cost (US$/m^3)	0.64
8	Total variable cost (US$/m^3)	1.75
9	Total machine cost (US$/m^3)	2.39
10	Total labor cost (US$/m^3)	6.36
11	Total cost(US$/m^3)	8.75

The operation of tree felling, delimbing, and bucking are influenced by a variety of factors. Many of these elements are impossible to quantify. Tree diameter and tree length were the factors in this study that had the greatest impact on tree felling, delimbing, and bucking time. These results are comparable to those from (Lortz *et al.*,1997), (Rummer, and Klepac, 2002, Wang *et al.*, 2004, and Majnounian *et al.*, 2009).

The collected data were entered to the computer and the Statgraphic Centurion was used for developing the regression models for different parts of tree utilization as follows:

The following model was developed for regressing the felling time as dependent variable on both diameter of breast height and total height as independent variables.

$FT = 0.3277437 + 0.000238669D + 0.0336637H$ Eq. No. (6)

Where:

FT: Time of the tree felling (min)

D: Tree diameter (cm)

H: Tree height(m)

Table (3) shows the developed felling time regression model using ANOVA. It shows that there is a statistically significant effect of the independent variables and felling time based on F-value (39.45) which is higher than tabulated F – value.

Table3: Score meansof the predictable model of felling time with chainsaw

	Sum of squares	Df	Mean squares	R^2(%)	F-Ratio	P-Value
Regression	0.0573271	2	0.0286636	84.83	39.45	0.000
Residual	0.0102494	47	0.000732097			
Total	0.0675765	49				

2-The development of relation model for delimbing time

The delimbing time was regressed on diameter and height and the following equation was developed:

$DT = 0.270715 + 0.000447905D + 0.0358339H$ Eq. No. (7)

Where:

DT: Time of the tree delimbing (min)

Table No. (4) shows delimbing time model (7) using ANOVA. Table (4) shows that the diameter and height have a statistically significant effect on delimbing time.

Table 4: Score means of the predictable delimbing time model (7)

	Sum of squares	Df	Mean squares	R^2(%)	F-Ratio	P-Value
Regression	0.164122	2	0.082061	80.2152	95.28	0.000
Residual	0.04048	47	0.000861277			
Total	0.204602	49				

3- The development of relation model for bucking time

The following regression model was developed for bucking time:

$BT = -0.0906547 + 0.00342427D + 0.03574H$ Eq. No. (8)

Where,

BT: Time of the tree bucking (min)

Table (5) shows ANOVA analysis of model (8).

Table (5) shows that the diameter and height have a statistically significant effect on bucking time.

Table 5: Score means of the predictable model of bucking time with chainsaw

	Sum of squares	Df	Mean squares	R^2(%)	F-Ratio	P-Value
Regression	0.224522	2	0.112261	71.5422	59.08	0.000
Residual	0.0893097	47	0.00190021			
Total	0.313832	49				

3.2.1. Model validation

The dataset of 17 samples that were obtained throughout time was randomly collected and utilized to validate the developed model. The findings showed the statistical validity of the tree- felling, delimbing, and bucking regression model. R^2 is used to measure the precision of equations for the calibration and validation. The higher value of. $R^{2,}$ the better is the equation. It is ranged between (0-1) according to R^2 for calibration and validation it can be noted that the calibration equation was in a higher precision compared with validation equation. However, the difference is not significant:

84.83-71.54= 13.29 which is about 13.29/84.83=15.6% which is acceptable.

$$FT = 0.321331 + 0.000633D + 0.0214604H \quad \text{Eq. No. (9)}$$

Table (6) shows developed time regression model using ANOVA. It shows there is a significance effect of the independent variables and felling time based on F- value (39.15) which higher than tabulated F – value of felling time (*FT*).

Table 6: Score means of the predictable model of felling time with chainsaw

Validation	Sum of squares	Df	Mean squares	R^2(%)	F-Ratio	P-Value
Regression	0.0573271	2	0.0286636	84.8329	39.15	0.000
Residual	0.0120241	14	0.000732027			
Total	0.257	16				

3.2.2. The predictable model of delimbing time with chainsaw:

The mathematically predictable model of delimbing time is multivariate linear regression that appears as a function of tree diameter and tree length of delimbing time(*DT*).

$$DT = 0.260387 + 0.000648777D + 0.0360107H \quad \text{Eq. No. (10)}$$

Table (6) shows developed time regression model using ANOVA. It shows that there is a statistically significant effect of the independent variables on the delimbing time for validation based on F- value (136.22) which is higher than tabulated F – value of delimbing time.

Table 7: Score means of the predictable model of delimbing time with chainsaw

Validation	Sum of squares	Df	Mean squares	R^2(%)	F-Ratio	P-Value
Regression	0.215878	2	0.107938	81.7	136.22	0.000
Residual	0.0483353	61	0.000792383			
Total	0.264211	63				

3.2.3. The mathematically predictable model of bucking time is multivariate linear regression that appears as a function of tree diameter and tree length.

$$BT = -0.0719417 + 0.00286542D + 0.0362958H \quad \text{Eq. No. (11)}$$

Table 8: Score means of the predictable model of bucking time with chainsaw

Validation	Sum of squares	Df	Mean squares	R^2(%)	F-Ratio	P-Value
Regression	0.0795916	2	0.0397958	91.856	78.97	0.000
Residual	0.00705546	14	0.000503961			
Total	0.0866471	16				

Table (8) shows developed time regression model using ANOVA. It shows that there is a statistically significant effect of the independent variables of both diameter and height on the bucking time for validation based on F- value (78.97) which is higher than tabulated F – value.

The results of this study will assist loggers in selecting the most effective technique for a particular stand and harvest cases. They may also be utilized to assess the production and cost of different harvesting techniques and equipment that are presently in use in the region.

The overall felling, delimbing, and bucking times would have been impacted by the unrecorded delay times. Due to the longer felling, delimbing, and bucking cycles, these timings would have eventually increased by the total cut and bucking cost per m^3. The extended periods needed for bucking, delimbing, and felling would have raised logger expenses, lengthened the time required for cutting the tract, and decreased productivity.

The investigation additionally demonstrates the advantages of wood utilization efforts. Better utilization efforts in the Zakho black Poplar stand. however, would have resulted in larger limb and top timings.

I already compared my results with other previous studies as Forest managers and researchers may utilize the study's findings and costs to determine acceptable silvicultural methods in same locations in our study. These results are in line with those of Wang *et al.* (2004), Majnounian *et al.* (2009), Rummer and Klepac (2002), and Lortz *et al.* (2007).

DISCUSSIONS

Regression models were used to create theoretically the different components of tree utilization, with use as dependent variables and both DBH and total height of trees as independent factors. The calibration and validation procedures of the regression models were applied to these processes.

The measured parameters are the only factors that affect the time needed for any process dealing with tree operations which were the diameter and height of trees.

The coefficient of determination was used to assess how well the developed models' calibration and validation performed in the estimation of the dependent variables. The most appropriate Equation was (11) with a 91.86 coefficient of determination (R^2) which was utilized to assess the effectiveness of the calibration and validation of the produced models in the estimation of the dependent variables.

REFERENCES

Abbasi, E., Lotfalian, M. , Hosseini, S. (2013). Productivity and cost of tree felling crew with a chainsaw in Caspian forests. J. Biodivers. Environ. Sci. 2013, 3, 90–97.

Azarnoush, M. R., & Fathi, J. (2014). Efficiency Economic of Chainsaw and Timber Jack 450C Skidder Evaluation in Felling Operation and Ground-Base Skidding System Journal: JOURNAL OF ADVANCES IN BIOLOGY Vol 4, No.3

Barokaha, S.M., Matangaranb, J. R., & Santosa, G. (2017). Cost Analysis of Felling with Chainsaw and Skidding with Farm Tractor in KPH Saradan. International Journal of Sciences: Basic and Applied Research (IJSBAR) ISSN 2307-4531

Bas¸kent, E. Z. & Keles¸, S. (2006). Developing alternative wood harvesting strategies with linear programming in preparing forest management plans. Turkish Journal of Agriculture and Forestry, 30(1), 67–79.

BehjouK., Majnounian B., Dvořák J, Namiranian M, Saeed A, & Feghhi J.(2009). Productivity and cost of manual felling with a chainsaw in Caspian forests. Journal of Forest Science 2009; 55(2): 96-100.

Björheden R., Apel K., Shiba M., & Thompson M.A. (1995) IUFRO forest work study nomenclature. Swedish University of Agricultural Science Department of Operational Efciency, Garpenberg, p 16

Bjorheden, R. (1991). Basic time concepts for international comparisons of time study reports. Journal of Forest Engineering, 2(2), 3339.

Ciubotaru A. (1998). Exploatarea pădurilor. [Forest Harvesting]. Editura Lux Libris, Braşov, 351 p.

Conway, S. (1982). Logging practices: principles of timber harvesting systems. Miller Freeman Publications, San Francisco, 432 p.

Garland, J. & Jackson, D. (1997). Felling and Bucking Techniques for Woodland Owners (Issue January); The Woodland Workbook; Oregon State University: Corvallis, OR, USA, 1997.

Huyler, N.K. & LeDoux, C.B. (1997). Cycle-time equation for the Koller K300 cable yarder operating on steep slopes in the Northeast. Res. Paper NE-705. USDA Forest Service. Lortz, D., Kluender, R., McCoy, W., Stokes, B., &Klepac, J., (1997). Manual felling time and productivity in southern forests. Forest Prod J 47(10): 59–63.

Lotfalian M (2012) Forest utilization. Aeizh Press, Tehran, p 488 (in Persian).

Magagnotti N., Spinelli R., Acuna M., Bigot M., Guerra S., Hartsough B., Kanzian C., Kärhä K., Lindroos O., Roux S., Talbot B., Tolosana E., F. & Zormaier ? (2012). Good practice guidelines for biomass production studies, COST Action FP-0902, WG 2 Operations research and measurement methodologies.Fiorentino (FI),

Majnounian B, Jourgholami M, Zobeiri M, &Feghhi J, (2009). Assessment of forest harvesting damage to residual stands and regenerations - a Case Study of Namkhaneh district in Kheyrud forest. Iran J Environ Sci 7(1): 33-44.

Miyata, E. (1980). Determining Fixed and Operating Costs of Logging Equipment.

Olsen, E., Hossain, M., & Miller, M. (1998). Statistical Comparison of Methods Used in Harvesting Work Studies. Forest research Laboratory, Oregon State University, 8 – 21.

Nakagawa T., Kurose T., Hino T., Tanaka K., & Kawamukai M. (2007a). Development of series of Gateway binary vectors, pGWBs, for realizing efficient construction of fusion genes for plant transformation. J Biosci Bioeng 104: 31–41

Nurminen T., Korpunen H., & Uusitalo J. (2006). Time consumption analysis of the mechanized cut-to-length harvesting system. Silva Fenn. 40:335–363. doi:10.14214/sf.346

Rodriguez, E. Otava. (1986). Wood Extraction with Oxen and Agricultural Tractors. Food and Agriculture Organization of the United Nations. 92p.USDA Forest Service General Technical Report NC-S 5. l6p.

Rummer, R., &Klepac, J., (2002). Mechanized or hand operations: which is less expensive for small timber? Published in Small Diameter Timber: Resource Management, Manufacturing, and Markets proceedings from conference held. 268 p

Spinelli, R, &Visser, R (2008). 'Analyzing and Estimating Delays in Harvester Operation"International Journal of Forest Engineering, vol.19 , no.1, pp. 36-41.

Uusitalo, J., Kokko, S., Kivinen, V.P. (2004). The effect of two bucking methods on Scots pine lumber quality. Silva Fenn. 2004, 38, 291–303.

Wang, J., Long, C., McNeel, J., Baumgras, J., (2004). Productivity and cost of manual felling and cable skidding in central Appalachain hardwood forests. Forest Prod J 54(12): 45–51.