# Influence of cutting form on the harvester productivity and costs

Tadeusz Moskalik
Faculty of Forestry, Warsaw Agricultural University

Abstract

*One of the principles of realization of sustainable forest management, in Polish conditions, is a reduction of forest area harvested on the clearcuts. Instead of that some kinds of other complex cutting forms are preferred. The aim of this paper is to present how different kinds of cuttings influence on the harvester productivity and what are the economical consequences of bringing of these balanced forestry guidelines into effect. Three Scots pine stands were taken under consideration, in which by harvesting Timberjack 1270B was applied. Each stand was cut other way: on the clear cut, in group cutting and in selection cutting. The reached harvester productivity was the highest on the clear cut, amounting 32,6 $m^3$/h. In two others cutting forms harvester productivity decreased adequately about 11,3 and 27,0%. This situation will affect an economic running of forest operations activity.*

Key words: productivity rate, harvester costs, clearcut, group cutting, selection cutting

## Introduction

Characteristically for forest economy in breakthrough in 20th and 21st centuries, especially in Europe are attempts of managing with continuous and a sustainable development. This concept coincides with contemporary multifunctional forestry model. It should be underlined that forest utilisation and at the same time timber harvesting as main forestry sector figures the most important part in multifunctional forest economy.
Forest harvesting machinery processes using harvesters and forwarders have vastly increased in forest utilisation in West Europe. It concerns mainly Scandinavia, where ca. 90% of total timber volume is harvested using these methods. Despite of certain attempts of machinery implementation from 70s last century, harvesting machinery involves in Poland only 1% of the total timber volume.
This time forest harvesting in Poland, in mature stands is done mainly on the clear cuts (59,6%). Complex fellings take up 28,2%; the rest of the area (11,2%) is harvested in other incidental fellings. Realization of sustainable forest management in Polish conditions assumes a reduction of forest area harvested in mature stands on the clearcuts. Instead of that some kinds of other complex cutting forms will be preferred. Thus, it is possible to expect an influence such choice decisions on the economic site of forest operations.

## Methods and material

In research Timberjack 1270B harvester was taken under consideration. Time studies of the harvester productivity and costs comparison were carried out in relation to different forest conditions: on the clear cut, in the group cutting and in the selection cutting. Main characteristic parameters of research plots are presented in table 1.

Table 1. Research plots

| Specification | Clear cut | Group cutting | Selection cutting |
|---|---|---|---|
| Forest district | Gidle | | |
| Logging unit | 184i | 95b | 138d |
| Area [ha] | 11,67 | 7,01 | 13,34 |
| Age [years] | 100 | 105 | 105 |
| Average mean-stem Volume [m$^3$] | 0,54 | 0,60 | 0,51 |
| Harvest intensity [m$^3$/ha] | 194 | 78 | 53,4 |

*Calculation of harvester productivity*

Hourly productivity ($W_t$), expressed in m$^3$/h, achieved by harvester describes the next formula (Moskalik 2004):

$$W_t = \frac{3600 V_5}{T_c} k \tag{1}$$

where:

$k$ - coefficient of effective working day (assumed k=0,8),
$T_c$ - time of tree process cycle in relation to the mean-stem volume $V_5$ [s],
$V_5$ - mean-stem volume [m$^3$].

$$Tc = \sum_{i=1}^{6} T_i = T_g + T_p \tag{2}$$

where:

$T_g = T_{g1}+T_{g2}+T_{g3}$ is a total time of process operations ($T_{g1}$ – tree felling, $T_{g2}$ – delimbing, $T_{g3}$ – bucking) [s],
$T_p = T_{p1}+T_{p2}+T_{p3}$ is a total of indirect times ($T_{p1}$ – preparing to work and ending, $T_{p2}$ - machine service, $T_{p3}$ – auxiliary time [s],
.
For Scots pine $V_5$ could be expressed by the next formula (Bruchwald, Dudek 1978):

$$V_5 = \frac{\pi}{40000} d^2 [h_g - (72,233 - 3,7 d_g - 6,275 h_g)(\frac{1}{d_g} - \frac{1}{d})] *$$
$$* [0,370305 + \frac{0,526942}{h_g - 1,3} - (\frac{0,0140985}{h_g} - \frac{0,6681325}{h_g^2})(d_g - d)] * \tag{3}$$
$$* [1 - (0,0208884 + \frac{26,360837}{d^2})^2]$$

where:

d – average diameter breast high of harvested trees (in bark) [cm],
$d_g$ – average diameter breast high of the stand (in bark) [cm],
$h_g$ – average height of the stand [m].
It has been assumed that the time of tree felling ($T_{g1}$) was a function of mean-stem volume –f ($V_5$). The delimbing time ($T_{g2}$) is expressed by the formula:

$$T_{g2} = \frac{L}{v_g} \tag{4}$$

where:

$L$ - total length of stem wood over 5 cm at the smaller end (merchantable timber from stem) [m],

$v_g$ - average harvester head travel speed [m/s], expressed as a function of mean-stem volume –f ($V_5$).

Bucking time - $T_{g3}$ depends on the number of crosscuttings made on the single tree and the tree volume.

The indirect times $T_{p1}$, $T_{p2}$, and $T_{p3}$ were calculated in relation to one harvested tree. Time $T_{p3}$ has been divided into three parts: $T_{p31}$ - harvester crane moving, $T_{p32}$ - work place harvester changing time, and $T_{p33}$ – time related to specific forest conditions, like displacement of timber or logging residues.

Time of the harvester crane moving was expressed in relation to the single tree distance from the strip road -$l_s$ [m] and the tree number per 1 ha – N [trees/ha], $T_{p31}$= f($l_s$,N).

Working place change time of harvester- $T_{p32}$, in relation to one harvested tree amounts:

$$T_{p32} = \frac{L_h}{n v_h} \tag{5}$$

where:

$L_h$ - distance between work places of harvester [m],

$n$ - number of harvested trees from $P$ area [trees],

$v_h$ - average harvester moving speed in the stand [m/s].

Number of harvested trees from one working place could be estimated by the formula:

$$n = \frac{V_p}{V_5} \tag{6}$$

where:

$V_p$ - volume of timber harvested from one harvester work place [$m^3$]

$$V_p = \frac{P V_0}{10000} \tag{7}$$

where:

$P$ - stand area processed from one harvester work place [$m^2$],

$V_0$ - harvest intensity, expressed as the timber harvested volume from 1 ha [$m^3$/ha].

Calculation algorithm of hourly Timberjack 1270B harvester costs - $K_g$, was adopted from Session’s method (Sessions J., Sessions J.B. 1992). Timber harvesting unit costs - $K_{jt}$, are presented by the formula:

$$K_{jt} = \frac{K_g}{W_t}$$

## Results

### *Felling*

Experimental research concerning tree felling time was carried out in different forest conditions. It was observed a high dependence of felling time on the mean-stem volume. The detailed statistical characteristics of this operation are presented in table 2 (Moskalik 2004). Changes in the felling time are varied from 6 s to 14 s. By comparable mean-stem volumes the shortest time was observed on clear cut, somewhat more in group cutting, and the longest one in selection cutting. In the last situation much time was needed for precision choice of felling direction.

Table 2 . Regression analysis of tree felling by Timberjack 1270B harvester

| **Specification** | **Equation** | ***r*** | ***df*** | ***p*** |
|---|---|---|---|---|
| Selection cutting | $f(V_5) = 4{,}81862 + 6{,}95388V_5$ | 0,64 | 563 | 0,0000 |
| Clear cut | $f(V_5) = 4{,}9689 + 4{,}72228V_5$ | 0,59 | 931 | 0,0000 |
| Group cutting | $f(V_5) = 5{,}06558 + 4{,}04121V_5$ | 0,48 | 935 | 0,0000 |

*r – correlation coefficient, df – degrees of freedom, p - measure of significance*

### *Delimbing*

Time necessary for delimbing depends on the total length produced assortments from one stem and on the harvester head moving speed. In mature forest, on analyzed plots, lengths were varied from 15 to 21 m. The harvester head moving speed was very varied, too. Reached results amount 0,4 -1,4 m/s. These parameters affect tree delimbing time, which lasts from 10 to 60-70 s (Figure 1).

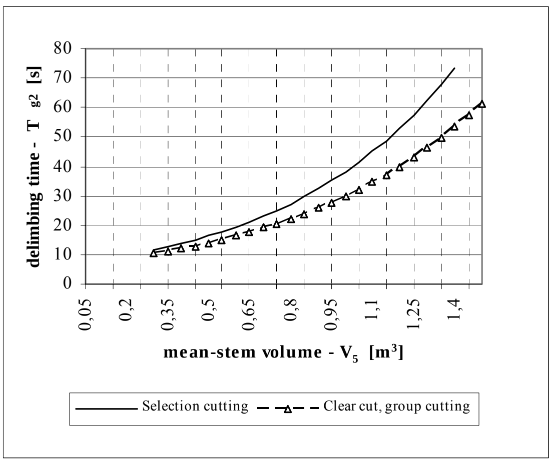


Figure 1. Tree delimbing time by Timberjack 1270B harvester in relation to mean-stem volume

*Bucking*

Number of crosscuttings made on one processed tree depends on the average length of assortments and tree diameter. Along with increase of assortments length decreases numbers of crosscuttings. Bucking time lasts relatively very short, from 1,5 to 7 s. Detailed values are presented in figure 2.

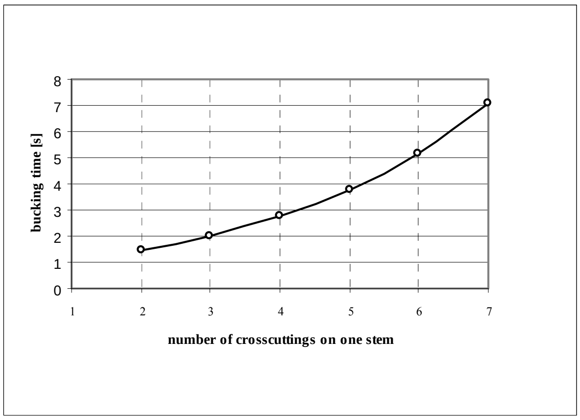


Figure 2. Bucking time in relation to the number of crosscuttings made on single tree

*Harvester productivity*

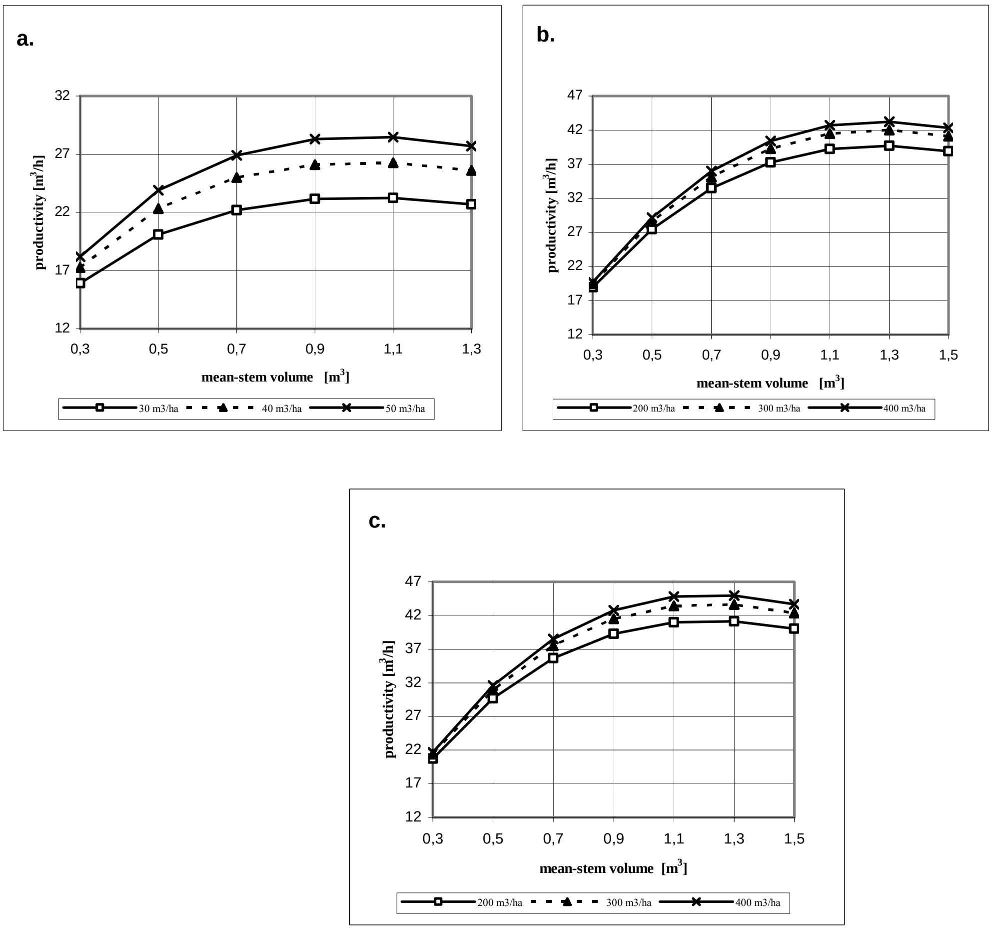

Figure 3. Hourly productivity of Timberjack 1270B harvester in relation to the mean-stem volume ($V_5$) and felling intensity ($V_0$): a. – Selection cutting, b. – Group cutting, c. – Clear cut.

During research work harvesting efficiency was varied and mainly depended on the cut single tree volume and different cutting treatment. Harvester average productivity reached 23,8 $m^3$/h in the selection cutting, 28,9 $m^3$/h in the group cutting and 32,6 $m^3$/h on the clear cut. Theoretical formulas (1-7) allowed to determine an influence of harvest intensity on Timberjack 1270B productivity. Calculated results are shown in figure 3 a, b and c. Along with higher harvest intensity level increased the harvester productivity.

*Harvesting costs*

Hourly Timberjack 1270B harvester costs, calculated by Session's method, in Polish conditions amounts 321,0 ZL. Cost structure indicates that almost 50% of the costs is a machine price. Labour costs are insignificant and do not exceed 10%. Such a structure is different from traditional harvesting based on chain saws, because in this case salary is the main cost element and in Poland it is 60-70%. Inevitable salary increasing in the future will cause that fully mechanized harvesting will be relatively commercially valuable.
Reached productivity influences on harvesting unit costs. The direct unit cost amounted 13,5 ZL/$m^3$ in the selection cutting, 11,1 ZL/$m^3$ in the group cutting and 9,8 ZL/$m^3$ on the clear cut. Figure 4 shows a diversity of unit costs adequately to above presented productivity data. It can be clearly observed that the cutting form exerts an influence on the economic site of forest operations.

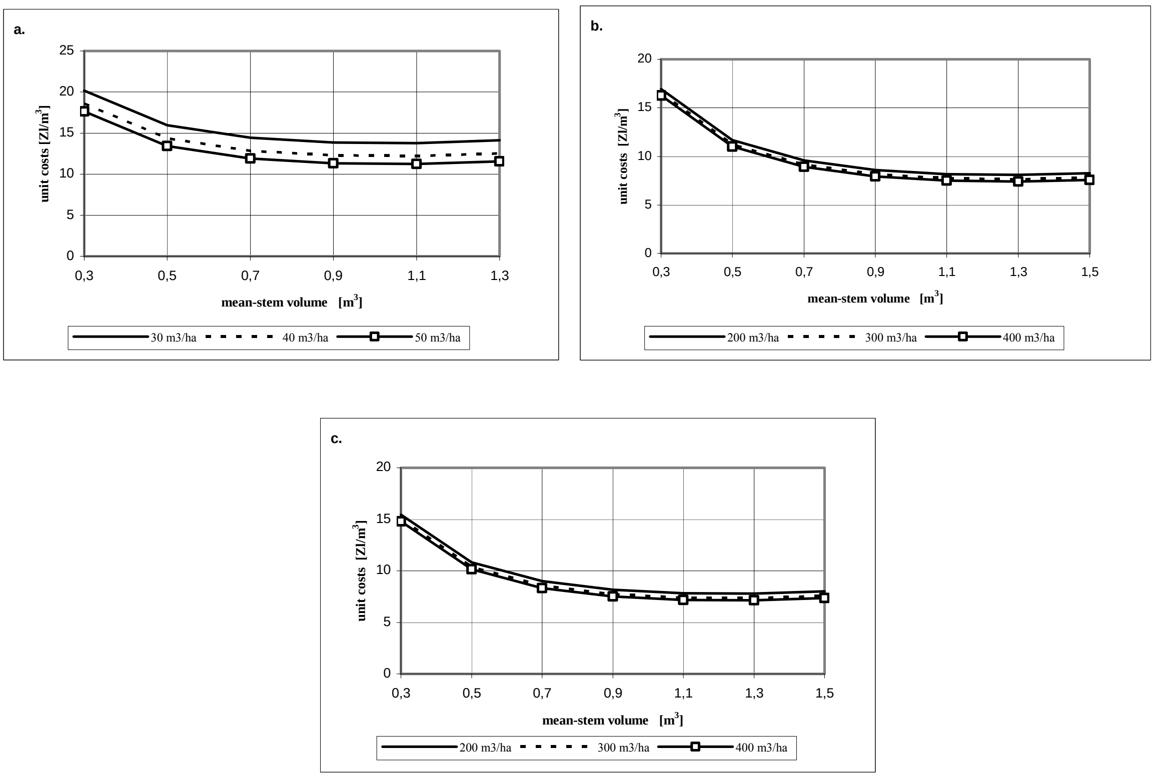

Figure 4. Direct unit costs of timber harvesting by Timberjack 1270B: a. - Selection cutting, b. - Group cutting, c. - Clear cut

## Conclusion

Forest utilisation according to sustainable forest development is one of the basic forestry targets. Following rules of permanent and balanced forest economy is crucial. Timber harvesting based on harvesters is able to fulfil these requirements where the work is effective, safe and at the same time low damaging growing forest level.
Presented in this paper results show that a high significance in forest activity is connected with the choice of cutting form. A contemporary attitude to the forest management is conductive to the creation of mixed and varied age forests. In mature stands are preferred complex cutting forms instead of clear cuts. Such changes, bring out a harvesting productivity decrease because of a high work complication level. In relation to the clear cut, in the group cutting harvester productivity decreases about 11,3% and in the selection cutting about 27,0%. This situation will affect an organizational running of forest operations and forest economy.

## References


1. Moskalik T., 2004: Model maszynowego pozyskiwania drewna w zrównoważonym leśnictwie polskim. Wydawnictwo SGGW Warszawa.
2. Sessions J., Sessions J.B., 1992: Cost control in forest harvesting and road construction. FAO Forestry Paper, Rome.