The Influence of Operator Experience on Productivity of Mechanized Timber Harvesting From Windfall Stands

Jacek Brzózko, Witold Zychowicz*, Magdalena Bartosiewicz
Department of Agricultural and Forest Machinery, Warsaw University of Life Science
Nowoursynowska 164, 02-787 Warszawa, Poland
witold_zychowicz@sggw.pl

Abstract:
Wood harvesting from tree stands damaged by wind is harder than from undamaged mature trees stands or from thinning. It is mainly caused by the wide variety of damages of the trees, with demands different way of acquiring wood. Mechanized technology should be preferred in after-calamity conditions due to eliminating the risk of accidents at work and the higher productivity, allowing cleaning up the area of the calamity faster.
The factors that affect the mechanized harvesting from the after-calamity stands are similar to that characteristic for premature and mature tree stands. These are: volume and species of the trees, the density of the tree stand, formation of the terrain, the type and technical parameters of the machine which is used, but also the individual characteristics of the machine operator, mostly described as his experience. In case of after-calamity tree stands, especially the experience which manifests itself in the skill of harvesting trees with different kinds of damages, may have the deciding influence on achieved productivity. The goal of the investigation is to determine the operator's influence on the productivity of harvesting wood from after-calamity tree stands.
Preliminary studies were carried on at few after-calamity areas, where the work of the machine's operators with different experience was analyzed. It was determined what kind of trees' damages are characterized by the biggest dependence of the time of harvesting the wood from the operator's experience. To verify the obtained results the experiment were carried out to determine the productivity of experienced and inexperienced operator working on the same machine and same forest area damaged by the wind.
It was ascertained that the harder harvesting conditions were (the bigger amount of hard to precede mechanically damaged trees and the volume of these trees were bigger), the greater influence has the experience of the operator on the time which was needed to complete the task. Experience of the operator cannot be characterized only by the cumulative time worked on the machine, especially in case of after-calamity tree stands because this factor (worked out time), though important, is not the only one.

Keywords: harvester, productivity, operator, experience, windthrow

1 Introduction

Damages of forest trees caused by natural disasters (strong wind, heavy snow fall etc.) have intensified the in the recent years. Human interference in natural ecosystems and increased emission of pollutants contributed to the significant weakening of resistance of stands. The main factor causing damage to the stands in Poland is the wind. When the speed of wind exceeds 7 m/s it is able to damage the tree stand. Reaching the speed of above 25 m/s wind can cause catastrophic damage (Stathers et al. 1994). In most cases of disasters there is need for quick recovery of damaged wood. Failure to do so may result in intensification of disasters such as gradation of secondary pests. Typically, the time criterion is most important when planning wood harvesting from damaged tree stands. Timber harvesting from forest stands damaged by wind is more difficult than in the stands during typical thinning or felling. This is connected mainly with a large variety of types of damage to trees, which requires to apply a different technique of harvesting. Mechanized technology should be preferred in conditions of windfall stands due to the fact that this method in a large extent eliminates the risk of accidents at work and offer higher productivity (Suwała 2004, Brzózko 2009). The productivity of machines during harvesting from windfall stands is influenced by the same factors as during felling or thinning typical stands: such as the thickness of the harvested trees, their species, stand density, terrain, or the type and technical parameters of used machines, but also the individual characteristics of the operator usually referred to as his experience. In the case of damaged stands experience especially manifested in the proper technique of harvesting the trees with different types of damage may have a decisive influence on the achieved performance. The purpose of this paper is to determine the effect of operator experience on productivity of process of damaged tree stands harvesting.

2 Material and methods

2.1 Preliminary investigations

Preliminary investigations were conducted on several after calamity forest areas that occurring in Poland in 2007-2010, technique of work of operators of varying experience were analyzed. Productivity has been chosen as the main validating indicator of operator performance. The results of these investigations are presented in the studies: Brzózko and others 2009, Brzózko 2010, but have not yet given clear answer to the question how much experience the operator affects the productivity of damaged stands harvesting. Therefore was decided to conduct a research experiment that would allow, for specified and comparable conditions, to obtain reliable results.

2.2 Research conditions and methods

The aim of experiment was to determine the performance of experienced and inexperienced operators working with the same machine and on the same forest area damaged by the wind, in the areas with the same parameters of the stand (group selection harvesting). The research was conducted in Poland, at Wipsowo Forest District, located in the province of Warmia and Mazury (northeast part of Poland), where in July 2011 disaster windfall occurred. Through this Forest District the storm passed, which resulted in damage to the trees within area of about 600 ha, the total volume of damaged trees was about 50 000 m^3 (Fig. 1), age of damaged trees ranged from 40 to 130 years.

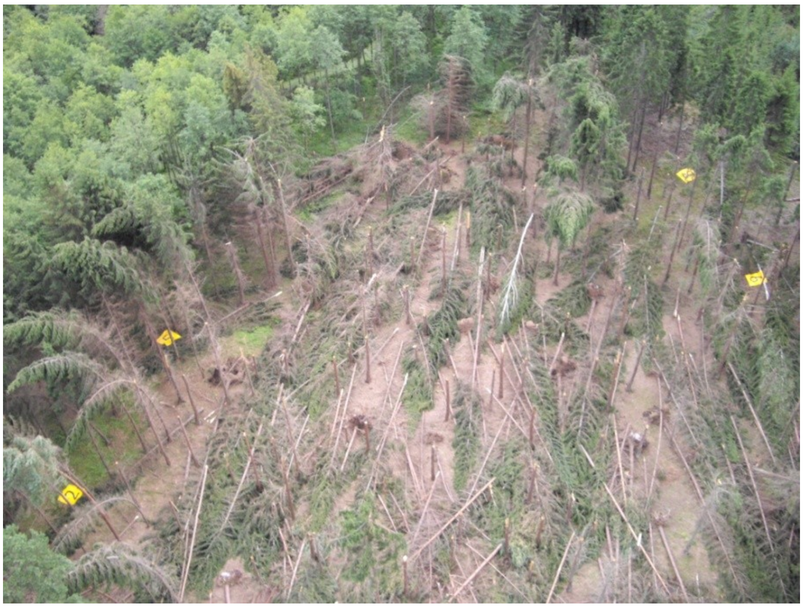


Figure 1: Research area in the Forest District Wipsowo

The study involved two operators with different experience. Length of service for an experienced operator of harvester was about 5 years. During this period he worked on five Valmet and John Deere harvesters of different class. He performed mainly clear cutting in coniferous stands. In 2007 he participated in the harvesting of stand damaged by wind. Professional experience of the second operator was considerably shorter and was approximately 1,5 years. The harvesting was carried out by the operators using the same harvester John Deere 1270D. The main parameters of the machine are presented in table 1.

Table 1: Main technical parameters of harvester John Deere 1270D

Parameter	Units	Value
Mass	kg	19 250
Crane	-	CH7
Crane reach	m	10
Engine power	kW	170
Lifting torque	kNm	197
Rotation torque	kNm	50
Angle of rotation	^{o}	220

The material for analysis was a video recording of timber harvesting from the damaged forest area. Recordings were made from the machine cab, in the period 8-12 August 2011.

For the purpose of analysis the working cycle of harvester is divided as follows:

$$t_c = t_s + t_o + t_p + t_d \quad [s] \qquad (1)$$

where

t_c - total time the harvester cycle, including one tree felling, delimbing, and cross cutting,

t_s - time of felling,

t_o -time of delimbing,

t_p -time of crosscutting,

t_d -execution time for additional activities which included: passage time to the next machine operation point, the time of removal of disturbing undergrowth, the time needed to remove the accumulation of trees, the time needed to lift and move the snags, entire trees or fragments thereof that disturb proper harvester operation, etc.

The harvested trees are characterized by: type of damage, specie, type of trunk (straight or cooked) and volume calculated on the basis of butt diameter and trunk length. Harvested damaged tree stand consisted of the following tree species: spruce - 76%, pine - 21% birch and 3%. The time of performance of working cycle can be affect by the shape of stems. In investigated stand share of straight trees was equal to 69.3% and share of trees with crooked trunks was 30.7%. Butt diameter of undamaged trees was measured by a harvester. For trees with damaged lower part, butt diameter was estimated on the base of maximum diameter measured by the harvester and the lengths of the damaged and undamaged parts of the tree. Percentage distribution of diameters of harvested trees is presented in figure 2. Each harvested tree was identified and classified into one of the types of damages presented in the table 2. Trees with damages of other types, due to the presence on the surface in small amounts, were not included in the analysis. Figure 3 shows the percentage distribution of individual damages to trees registered on the area of investigation.

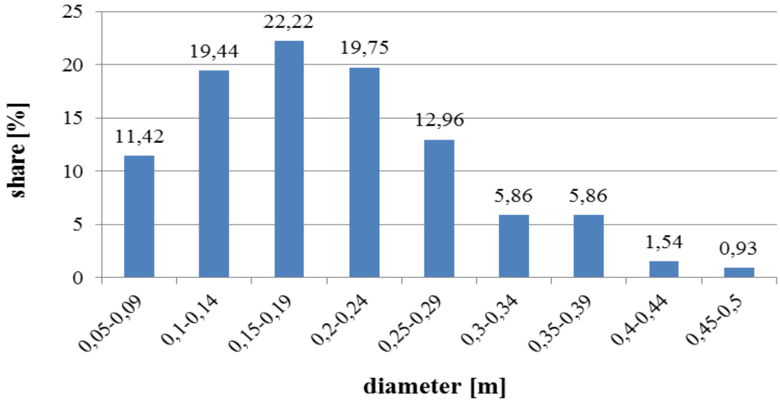
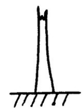
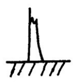
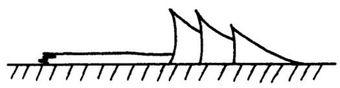
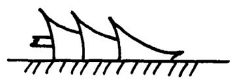
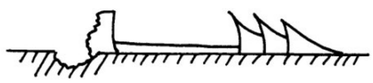
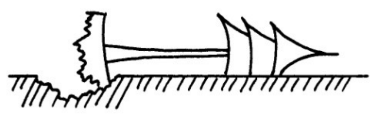


Figure 2: Percentage distribution of diameters of harvested trees

Table 2: Types of damaged trees analyzed in the paper

Designation	Type of damage	Pictogram
DSK	Not damaged standing tree (with crown)	
DCZw	Standing part of broken tree - high	
DCZn	Standing part of broken tree - short	
LCZn	Detached lying part of the fully broken tree	
LK	Lying top part of tree (crown)	
WLn	Low-lying overthrown tree with roots	
WLw	High-lying overthrown tree with roots	
SL	Easy accumulation of trees (trees can picked up from the top of the stack)	
ST	Difficult accumulation of trees (there is a need to draw trees from the dump)	

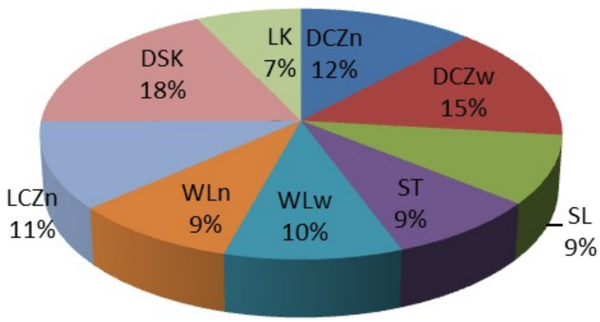


Figure 3: Percentage distribution of damages to trees registered at the area of investigation

3 Results and analysis

Putting together the results of the study allowed to establish the relation between the time of working cycle of harvester $t_{(c)}$ and the volume of the trees for the operators in question (figure 4). Because distributions of the analyzed time of harvester operating cycles is skewed, comparison of time of cycles obtained by the two investigated operators was performed with a nonparametric Wald-Wolfowitz test of series. Statistical analysis showed significant difference ($Z = -5.698$, $p = 0.00$, $\alpha = 0.05$) between the operating cycles, in the cases of operator experienced and inexperienced. The volume of the tree is therefore decisive factor for the productivity of timber harvesting from damaged stands as well as from intact stands, that was shown earlier by Gingras 1990, 1996, Moskalik 2004, Więsik and others, 2005.

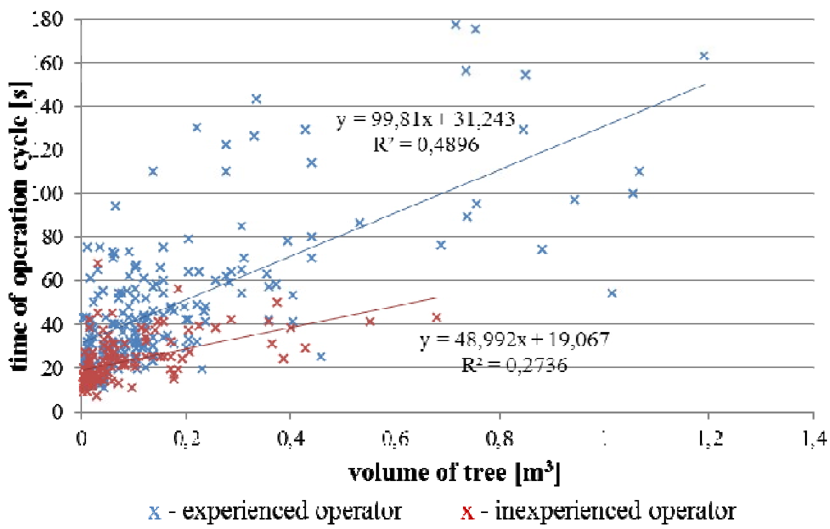


Figure 4: Relation between the time of working cycle of harvester and the volume of the trees for two operators: experienced and inexperienced

However, the question is whether factors such as type of damage and shape of trunk of harvested trees affects the harvester working cycle in the cases of the experienced operator and not experienced? Dependence of time on the volume of harvesting of trees for different types of tree damages for both operators are presented in table 3, that present also the results of statistical analysis conducted to check significance of the regression equations obtained. In all cases examined, obtained cycles time for an inexperienced operator are higher and more uneven than for experienced operator.

Table 3: Statistical analysis of significance of regression equations for different types of damage to trees

Type of damage	Operator	Number of trees	Equation of the line	R^2 calculated	R^2 observed	Significance
DCZn	Experienced	19	y = 134,97x + 13,046	0,2146	0,197	+
	Inexperienced	16	y = 115,32x + 25,959	0,3115	0,232	+
DCZw	Experienced	10	y = 46,878x + 16,755	0,0686	0,362	-
	Inexperienced	33	y = 81,394x + 27,749	0,373	0,121	+
SL	Experienced	16	y = 38,272x + 19,439	0,2674	0,232	+
	Inexperienced	10	y = 69,712x + 34,263	0,7659	0,362	+
ST	Experienced	11	y = 84,492x + 21,017	0,5603	0,332	+
	Inexperienced	14	y = 58,856x + 27,549	0,6398	0,264	+
WLw	Experienced	6	y = 11,814x + 22,332	0,0847	0,569	-
	Inexperienced	23	y = 46,749x + 51,573	0, 2307	0,163	+
WLn	Experienced	11	y = 42,489x + 22,431	0,6224	0,332	+
	Inexperienced	16	y = 143,2x + 29,267	0,747	0,232	+
LCZn	Experienced	7	y = 68,008x + 22,748	0,2045	0,499	-
	Inexperienced	26	y = 104,15x + 25,488	0, 2867	0,145	+
DSK	Experienced	37	y = 44,867x + 17,511	0,2646	0,106	+
	Inexperienced	15	y = 188,54x + 17,512	0,7258	0,247	+
LK	Experienced	7	y = 429,46x + 11,966	0,607	0,499	+
	Inexperienced	14	y = 44,068x + 41,982	0,0084	0,264	-

For damaged trees WLW, DSK, ST and SL difference between operators performance is higher, although for trees DSK and ST it disappears for low volumes. For trees DCZn, the performance difference is smaller and has a constant value, independent of the volume of harvested trees. For LK trees no significant dependence were obtained. Type of tree damage has significant impact on the performance of individual harvester operators.

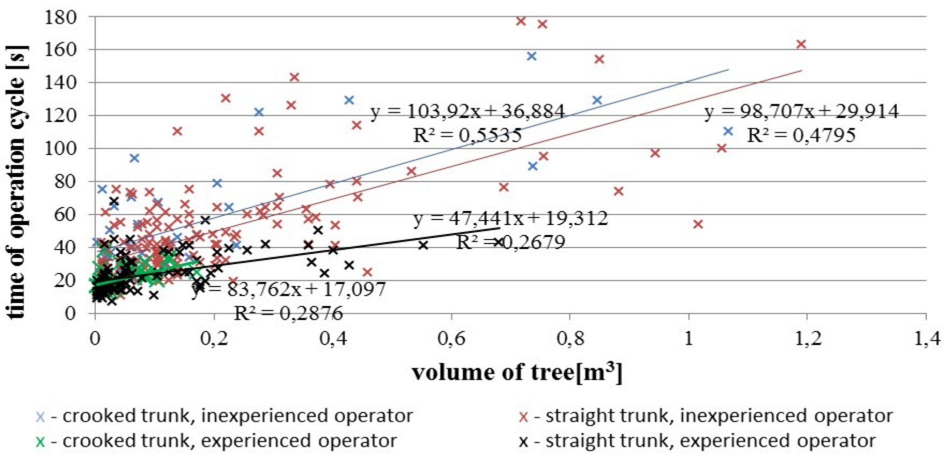


Figure 5: Relation between the time of working cycle of harvester and the volume of the trees for crooked and straight trunks for two operators: experienced and inexperienced

Of all the trees harvested by an inexperienced operator 19.8% of the trees had crooked trunks and in the case of experienced operator this figure was 22%. Figure 10 shows the dependence of harvester operation cycle time on volume of the trees harvested by both operators. For an inexperienced operator the difference between the harvesting productivity of trees with crooked and a straight trunks is significant (Z = 2.097, p = 0.03) and has a constant value. For an experienced operator, there was no significant difference in productivity of harvesting trees with straight and cooked trunks (Z = 1.724, p = 0.08). Presented dependencies don't confirm that trunk shape effect on the harvester cycle time in the case of experienced operator. Comparing the times achieved by two operators, the times obtained by an experienced operator are much shorter, regardless of the type of trees.

4 Conclusions

The experience of the operator of harvester has an impact on the growth of productivity of operation. Multiannual work as harvester operator and previous experience in harvesting wood from the damaged stands, helps to shorten time of harvesting of damaged trees. The cycle time for an experienced operator is in the range from 7 to 68 seconds, and for an inexperienced is more than twice as long and ranges from 11 to 177 seconds.

Type of damage to trees has an impact on productivity of harvester. In any case of damage, there is another level of difficulty of obtaining, thus affecting the cycle time. The greatest difficulty for the inexperienced operator to harvest trees caused WLW damaged trees, where the cycle time for 65% of the trees ranged from 50 to 163 seconds, and WLn from 50 to 177 seconds for 56% of the trees. In the case of DSK damaged trees when harvesting technique is similar to normal conditions, the cycle time for experienced operator varied from 9 to 38 seconds, and for an inexperienced from 21 to 129 seconds.

Shape of trunk (straight or crooked) does not affect the productivity of harvester in damaged treestand in the case of experienced operator. Harvester operation cycle time increases with increasing volume of the tree, for both cases of trees trunks shapes.

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