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# Structure of the harvester's operation time utilization under conditions of Polish forests

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**Abstract:** *Structure of the harvester's operation time utilization under conditions of Polish forests.* Achievement of beneficial economic results of timber harvesting with the use of harvesters is greatly determined by appropriate organization of their operation. It is important to find the solutions that could maximally reduce the share of working day phases that are unconnected with production. The carried out simulation calculations enabled to determine the working time structure under most favourable conditions, without preparation of bases and making passages to them and under conditions similar to the real ones. The experiments were executed for various number of tasks; therefore, the effect of passages between bases on working day structure was investigated also. The obtained results showed a very strong effect of mentioned factors working day utilization. In most favourable conditions and 100 tasks, about 50% of total time is taken by operating time that is directly devoted to execution of tasks, while in less favourable conditions and 600 tasks only 5% of time is spent on timber harvesting with the machine; the remaining part of time can be regarded as the lost time.

*Key words*: timber harvesting, harvester productivity, organization of timber harvesting process, working day structure, working time utilization

## INTRODUCTION

A requisite for application of special forest machines for timber harvesting is achievement of satisfactory specific costs that are competitive in relation to traditional technologies of timber harvesting (internal combustion chain saws). However, the multifunctional machines are characterized by very high costs of amortization resulted from the price of these machines [Nurek 2005]. Such situation demands from production engineers or persons responsible for timber harvesting organization in forest inspectorates (or superior units) to pay special attention to harvesters' utilization degree. To reduce the specific costs one should utilize the machine in the best way, mostly decreasing its down-times. In references one can find a series of papers concerning working techniques on the felling sites [Dybcio et al. 2005a, 2005b], while less attention was paid to pointing out at importance of entire working day organization or timber harvesting on the large area (forest inspectorate, regional management of state forests). The area structure of Polish forests and the assumed principles of forest utilization do not favour the full utilization of multifunctional machines of large operating productivity. One of unfavourable elements is, for example, relatively high scattering of forest complexes and the harvesting tasks [Moskalik 2000]. Only wide approach that contains many tasks planned for realization on a relatively large area can give the basis for rational actions towards reduction of the timber harvesting specific costs.

## MATERIAL AND METHODS

The carried out simulation calculations aimed at determination of working day structure and at investigating the effect of selected factors on the harvester's operation time utilization. The calculations were based on a mathematical model that enabled to determine the balance indices for working day [Nurek 2013]. There were used two notions: the lower boundary (least favourable organization conditions) and the upper boundary (organization of work that was most favourable for full utilization of the harvester's potentials).

Let us remind that to assure execution of all tasks by the harvester in shortest time (upper boundary) with its highest operating productivity, the total time of harvester's operation will include only time of passages between tasks ($T_{61}$) and time of task identification ($T_{71}$) apart from operating time ($T_{02}$) and time of breaks ($T_{3-5}$). It was assumed that under such conditions no machine parking bases are present; this eliminates time of passages between tasks and bases, time of organization and taking bases and not utilized time of working day. Under such conditions, the coefficient values determined in the model amount to: $\eta_{61} = 1$, $\eta_{62} = 0$, $\eta_{72} = 0$, $\eta_{73} = 0$. The final equation that determine total time of task realization on the selected area takes the form:

$$T_{07}^{c} = \frac{\sum_{j=1}^{n_g} n_j \cdot t_{cj} + \frac{1}{10 \cdot v_1} \cdot \sqrt{S_o \cdot n_z} + t_{71} \cdot n_z}{1 - \alpha} \quad \text{[h]}$$

It was assumed for the lower boundary conditions, that apart from $T_{02}$ and $T_{3-5}$ there occur also: time of passages between all tasks, between tasks and bases, time of identification and taking bases and not utilized time. Under such conditions the coefficients amount to: $\eta_{61} = 1$, $\eta_{62} = 0{,}71$, $\eta_{72} = 1$, $\eta_{73} = 1$. Upon their substitution into equation for total time of working day there was obtained the following form [Nurek 2013]:

$$T_{07}^{c} = \frac{\sum_{j=1}^{n_g} n_j \cdot t_j + \frac{1}{10 \cdot v_1} \cdot \sqrt{S_o \cdot n_z} + t_{71} \cdot n_z + n_z \cdot t_{72}}{1 - \alpha - \frac{1}{T_{07}} \cdot \left[ \frac{\sqrt{S_o}}{10 \cdot v_2} \cdot \left( \frac{1{,}42}{\sqrt{n_b}} + \frac{1}{\sqrt{n_z}} \right) + t_{71} + 0.5 \right]}$$

Calculations were carried out assuming that in every analyzed case the total quantity of planned harvesting ($Q_c$) amounts to 35,000 m$^3$, while volume of a single tree ($q_j$) to 0.8 m$^3$. Since under Polish conditions the machine should not be left on a felling site without supervision, it was also assumed utilization of machine parking bases ($n_b$) equals 9 in the process of task realization. As mentioned previously, one of important factors that determine degree of working day utilization is the number of tasks (determined felling sites) and the total area for these tasks realization.

The simulation experiments were carried out for two variants of total area: $S_o$ = 30,000 and $S_o$ = 90,000 ha. In order to prove the effect of number of tasks (distance between them) on working day structure, the calculations in every variant were carried out for their various number – $n_z$ = {100; 600}.

## RESULTS AND DISCUSSION

The boundary values of harvester's operating productivity were calculated with the use of mentioned earlier equations. In the case of lower boundary, an additional simulation experiment was performed for the prolonged working day equal to 10 and 16 hours. Results of these calculations are presented in Figure 1. They point out at substantial range of the harvester's operating productivity changes as a function of the assumed variables. scattered forest complexes, productivity decreased to about 45 m$^3$/h ($n_z$ = 100) and 30 m$^3$/h ($n_z$ = 600). When all phases of working day are considered (lower boundary), a decrease in productivity is even more significant – to about 12 m$^3$/h at $n_z$ = 100 and 5 m$^3$/h at $n_z$ = 600. The discussed diagram describes the effect

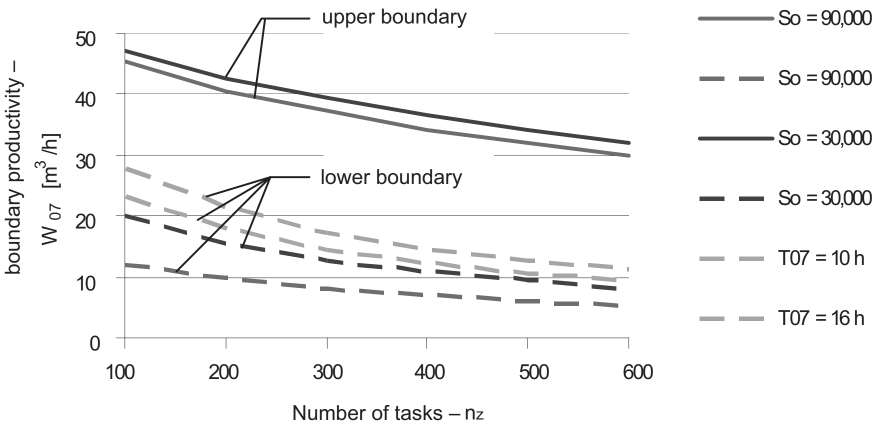


FIGURE 1. Change in harvester's boundary productivity depending on number of tasks distributed on area $S_o$ = 30,000 ha and $S_o$ = 90,000 ha at timber harvesting 35,000 m$^3$

On lower area ($S_o$ = 30,000 ha) the upper productivity is above twice higher (2.4 times) than the lower one. In the case of small number of tasks ($n_z$ = 100) it amounts to about 48 m$^3$/h under optimal working conditions and to about 20 m$^3$/h under conditions close to the real ones. Along with an increase in number of tasks (smaller distance between them and higher number of passages and total time of "auxiliary" phases' duration) the operating productivity decreases. Under conditions of upper boundary it amounts to about 32 m$^3$/h, while for lower boundary to 9 m$^3$/h only. In the case of higher area (in simulation experiments $S_o$ = = 90,000 ha was assumed) of more of two factors on timber harvester productivity. The lower area of timber harvesting and lower number of tasks, the higher productivity (at constant harvested volume). Such activities undoubtedly positively affect the multifunctional machines' effectiveness but call for increasing of timber volume harvested from the unit area, which not always corresponds to silviculture principles.

The above changes in harvester productivity in timber harvesting directly affect diversification of task realization time at particular calculation variants. In the case of upper boundary, the harvesting time of 35,000 m$^3$ varied from 742.95 to 1,096.15 h (93–137 working days), depending on number of tasks on the area 30,000 ha and from 772.79 to 1,169.23 h (97–146 days) on the area 90,000 ha. Under conditions of lower boundary the task realization times are considerably increased. On the smaller area they range from 1,744.17 to 4,243.40 h (218–530 days), on the bigger one from 2,904.66 to 6,464.25 h (363–808 days). It is evident from carried out calculations that distribution of tasks on bigger area (at similar harvesting volume) results in a decreased harvester's effectiveness, especially under conditions of the lower boundary.

As it is evident from dependences presented in paragraph about material and methods, the results of harvester operation obtained under conditions of lower boundary depend also on the assumed time of working day ($T_{07}$). Prolongation of this time may enable to complete the task on a given day and to avoid subsequent passages on the next day. Figure 1 presents harvester productivity for two additional times of working day: ($T_{07}$ = 10 and $T_{07}$ = 16 h, at harvesting volume 35,000 $m^3$ from the area 30,000 ha.

In the case of prolonged working day ($T_{07}$ = 10 h), harvester's operating productivity increases by 15.0% for 100 tasks and by 16.6% for 600 tasks. In the case of two-shift work ($T_{07}$ = 16 h), productivity is increased by 42.5 and 44.4%, respectively.

The carried out simulation calculations enabled to learn the working day structure under conditions of lower and upper boundaries, and the effect of task number on the share of particular phases in total time of working day. The results of calculations are presented in Figures 2 and 3. Under conditions of upper boundary, on both analyzed area the similar structure of operating time utilization can be found. There should be noted only that the time of passages between tasks is increased; this results from the assumptions for both calculation variants. Realization of the same number of tasks scattered on considerably bigger area must result in the prolonged time

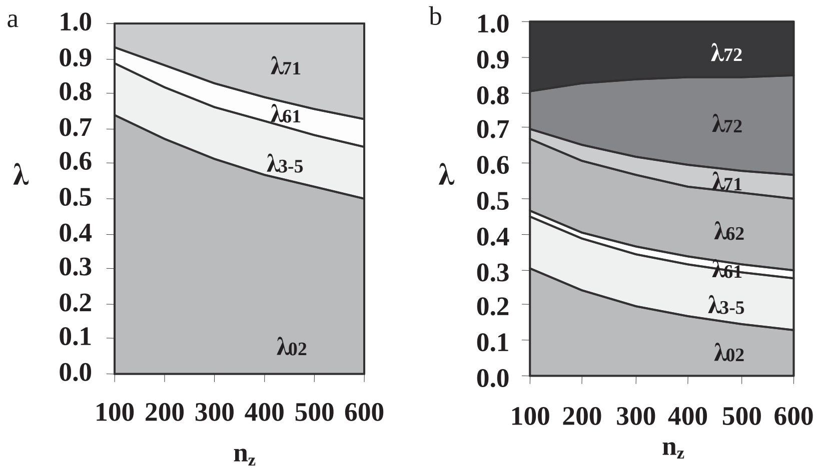


FIGURE 2. Change in duration time indices for distinguished harvester operation phases for tasks distributed on area $S_o$ = 30,000 ha under conditions of: a – upper boundary, b – lower boundary

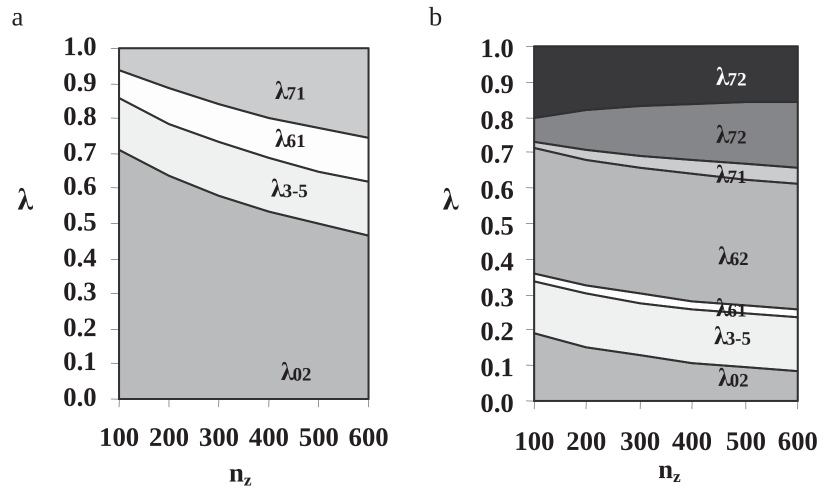


FIGURE 3. Change in duration time indices for distinguished harvester operation phases for tasks distributed on area $S_o$= 90,000 ha under conditions of: a – upper boundary, b – lower boundary

of passages between tasks. A very distinct deterioration of the time utilization structure is evident. The share of operating time ($T_{02}$) drops drastically, while there occurs a very significant share of time of passages to bases and their taking and also the not utilized time. In the case of area 90,000 ha, the total sum of these times depends on number of realized tasks and varies from about 60% (100 tasks) to about 70% (600 tasks).

It was also found that in the case of upper boundary the area size (at the same number of tasks) caused a substantial diversification of the share of time of passages between tasks; in the considered case $\lambda_{61}$ = 0.047–0.077 on the area 30,000 ha and 0.078–0.126 on the area 90,000 ha, while in the case of lower boundary a decisive factor was the time of passages between tasks and bases – $\lambda_{62}$ = 0.205 on the area 30,000 ha and $\lambda_{62}$ = 0.355 on the area 90,000 ha.

It should be underlined that under conditions of lower boundary and big number of tasks, the share of duration time in the phases: down-times ($T_{73}$), identification and taking bases ($T_{72}$), passages between tasks and bases and breaks ($T_{3–5}$) is bigger than the share of operating time ($T_{02}$). It undoubtedly proves that conditions of lower boundary at high scatter of tasks result in very low indices of multifunctional machine utilization effectiveness (harvesters). Unfortunately, such conditions are common in Polish forests. On the one hand it results from fragmentation of tree stands and small average area of forest complexes, on the other hand from obligatory principles of silviculture that prefer small felling sites, often not exceeding 0.5 ha (group felling).

Under conditions of lower boundary (close to real ones) and for both analyzed areas, among the phases "unconnected with production", the highest share is taken by passages between tasks and bases. It point out at the need to perform a very penetrating analysis during planning of harvesting operations and to search for the solutions that can minimize time lost for this kind of passages.

## CONCLUSIONS

Achievement of high operating productivity and reduction of specific costs of timber harvesting with the machines of high operating productivity is strongly affected by organization factors. The carried out simulation calculations proved that in the most favourable case, the share of operating time in the total time of working day ranged from 70 to almost 50%, depending on number of tasks realized in analyzed site. In the case of bigger number of tasks, the highest share in time unconnected with production is taken for identification of tasks. When the tasks are relatively small and their number amounts to 600, it equals to about 25%. These results were obtained under most favourable conditions: the machine was left on forest site and there was no need for organization of machine parking bases. In reality, upon daily task completion the machines travel to the night parking base. Under such circumstances, the share of operating time at small number of tasks (100) amounts to about 20% only, while at 600 tasks it amounts to 5% only. The highest share (independent of number of tasks) takes the time of machine passages between bases and the working sites. The carried out experiments proved the importance of organization aspects in order to obtain satisfactory economic effects of multifunctional machines' operation. Unfortunately, organization of harvesters' operation close to "upper boundary" conditions is practically impossible under conditions of Polish forests. Therefore, comparison between costs of timber harvesting with the use of harvesters and traditional internal combustion chain saws still shows advantage of the later method.

However, the results of carried out calculations can be taken as a guide for the persons responsible for timber harvesting planning in forest inspectorates and for organization of machine operation. Implementation of two ways can improve effectiveness of multifunctional machines' application to the greatest degree: concentration of timber harvesting on possibly smallest area and the assignment of lower number of large tasks.

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**Streszczenie:** *Struktura wykorzystania czasu pracy harwestera w warunkach lasów polskich*. Osiągnięcie korzystnych wyników ekonomicznych pozyskania drewna harwesterami uwarunkowane jest w znacznym stopniu odpowiednią organizacją ich pracy. Istotne jest znalezienie takich rozwiązań aby w maksymalnie zmniejszyć udział nieproduktywnych faz dnia roboczego. Przeprowadzone obliczenia symulacyjne pozwoliły ustalić strukturę czasu pracy w najkorzystniejszych warunkach bez przygotowywania baz i przejazdów do nich oraz w warunkach zbliżonych do rzeczywistych. Eksperymenty przeprowadzono dla różnej liczby zadań dzięki czemu zbadano także wpływ przejazdów pomiędzy nimi na strukturę dnia roboczego. Uzyskane wyniki pokazują bardzo silny wpływ wymienionych czynników na wykorzystanie dnia roboczego. Dla najkorzystniejszych warunków i 100 zadań około 50% całkowitego czasu to czas operacyjny – bezpośrednio poświęcony na wykonanie zadań, w najmniej korzystnym dla 600 zadań jedynie 5% czasu maszyna pozyskuje drewno – pozostałą część należy uznać za czas stracony.

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