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BASIC PARAMETERS OF TIMBER HARVESTING PROCESSES IN MOUNTAIN BEECH STANDS IN KOMAŃCZA FOREST INSPECTORATE

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Abstract. The basic purpose of this study was to determine a working-day structure and work productivity rate during the process of timber harvesting in mountain conditions. The parameters were determined on the ground of data collected during field studies. The aforesaid working-day structure was defined on the ground of time study observations. The areas included in the survey were typically mountain stands, in which cutting was applied by means of a cutting method IVd. Work teams assigned approximately 50-70% of their work-shift time to technological operations, whose greatest part was taken by delimbing and slashing. A significant portion of the day was taken by preparation of a workstand (approx. 10%), as well as cutting and felling. This was caused primarily by the necessity of snow coat removal. Technological work productivity rates amounted to some 3 to 14 m^3 per day per one worker. During the skidding process, a significant percentage of trees remaining along the skidding path was being injured. On the ground of the obtained results and their analyses, an attempt was made to evaluate and suggest possible changes in timber harvesting organization, in order to improve work productivity rates.

Key words: mountain stand, cutting method IVd, work productivity rate, working-day structure

INTRODUCTION

Forest management in mountains forests is considerably different from that in lowland areas. Strongly diversified terrain, often with steep slopes, makes it difficult to design a regular spatial forest division network and engineer infrastructure providing access to the stands (transportation roads, slashing paths, timber stacking places). Diversified terrain and specific climate, as well as composition of tree species, directly affect the individual elements of the employed timber harvesting processes. Snow coat, steep slopes, these factors obstruct cutting and cross-cutting activities and transportation of

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timber. Technological processes and the level of mechanization in timber harvesting and slashing activities have continually changed over the years. In the recent years, multi-function harvesters have more often been used for cutting and cross-cutting. Unfortunately, they have limited application in mountain conditions. Grand changes have also taken place in the field of skidding and timber transportation (removal) from the forest. Initially, it was done by means of horse-drawn carts, later, by means of farm tractors. Recently, this type of work has often been done using specialist forwarders, equipped with cranes and hydraulic grabbers, and timber has been transported from the forest by means of heavy-duty machinery [Moskalik 2002, Kapral 2004]. In poorly accessible areas, cable cars are being employed increasingly more often.

Solutions employed in technological timber harvesting processes are not fully adapted for the requirements of today's forestry. Furthermore, technical means, utilised in our forests, show significant level of wear and tear. This makes it necessary to seek new solutions that would be more suitable for the requirements of sustainable forest management. That is because we need to aim for deep harmony in compromising the ecological, ergonomic, and work safety requirements, as well as appropriate effectiveness of performed work [Moskalik 2004, Suwała 2006].

The purpose of this study is to analyse the basic parameters of technological timber harvesting and skidding processes with the use of different sets of machinery and equipment in mountain forests, managed with cutting method IVd.

MATERIAL AND METHODS

The scope of the study includes presentation of work productivity rates and working-day structure during timber harvesting and skidding, achieved by different work teams. The level of damage to the remaining trees has also been taken into consideration. The survey was performed in three areas utilized with a cutting method IVd, located in Komańcza Forest Inspectorate. These areas had been selected so that the terrain and stand conditions were similar to each other, which would allow to compare the obtained results. All of them were accessible via a skidding path network, created during the stage of thinning operations. The studied plots contained beech stands in a mountain forest community. The ages of the stands remained within 60-120 years, where stands above 100 years were predominant. An average breast-height diameter oscillated from 20 cm in stands 60 years of age, to 50-60 cm in the oldest age classes. Wood volume in 1 ha amounted to approximately 400 m^3. In the studied areas, cutting and cross-cutting of wood assortment were performed with chainsaws. In the first area, skidding was performed using a specially adapted set ZIŁ 131B, with a truck trailer adapted for transportation of stack timber. Skidding distance equalled to 1.2 km. Processed wood assortment was S2a. In other plots, large-sized wood assortment were being harvested, skidded by means of a skidder Kocums 822, within a distance of approx. 3 km.

Working-day structure was determined with the use of time study. Working day division was adopted as presented by Laurow [1999]. Times of the individual operations and intervals were measured chronologically during the entire work shift. The measurements were being made with the use of a timer from the moment of workers' arrival at the site. The following working time division was adopted for a team of chainsaw operators: main time (T_g), comprising workstand preparation (T_{g1}), cutting and felling (T_{g2}), delimbing (T_{g3}), slashing (T_{g4}), timber stacking (T_{g5}); intermediate time (T_p), comprising preparation and completion time (T_{p1}), workstand operation (T_{p2}), ancillary time (T_{p3}), breaks and fixed resting time (T_{p4}); time losses (T_s) including time losses caused by a worker's fault (T_{s1}) and time losses caused by the organiser's fault (T_{s2}).

For more detailed characteristics of work-team performance, factor W_T was calculated, presenting the time of presence at the site in relation to the statutory work time:

$$W_T = T/480$$

To determine the amount of harvested timber, ROD (registration of wood) index was used, prepared during everyday timber collection. The stacks were measured as regards the lengths and diameters of timber collected in the individual pieces. The obtained data was then recorded in „Psion", and the volume of timber was being monitored. In the wood storage place, volume of skidded timber was being recorded, in compliance with the method adopted by State Forests, taking into consideration the size of a single load.

Stem damage, occurring during skidding and cross-cutting of wood assortment, was analyzed in direct neighbourhood of skidding paths and outside of them. In damage evaluation, criteria presented below, elaborated by Suwała [1998], were being applied.

The degrees of damage were qualified as follows:

1 – no damage,
2 – damage to bark and phloem max. 10 cm^2,
3 – damage to bark, phloem and wood from 11 to 100 cm^2,
4 – damage to bark, phloem and wood above 100 cm^2.

Finally, on the ground of the measured features, overall evaluation of respective timber harvesting processes was conducted, where each feature was assigned a specific value on a three-point scale.

RESULTS AND DISCUSSION

Working-day structure during cutting and cross-cutting with the use of chainsaws is presented in Table 1.

From the main time limit, a chainsaw operator devoted the greatest amount of time to delimbing that took him some 19% of a work shift. Not much less time was consumed by cutting combined with felling, which occupied some 12-16% of a day shift. The smallest amount of time was assigned to workstand preparation (approx. 10%). Amongst the times from group T_p (intermediate time) most time was occupied by breaks and fixed resting time. The shortest appeared to be preparation and completion time (5-6%), in majority assigned to making fires. In the first area, only stack wood was being processed, therefore it would be difficult to directly compare the parameters characteristic of the course of work, taken in other areas where large-sized wood was being processed, primarily in the form of long wood. Small amounts of cross-cut stack-wood remained on the surface because possible costs of transport would be higher than the actual value of this kind of wood. Moreover, in the first area, slightly thinner trees were being cut which made the labour much easier, thus cutting and felling time was shorter. A chainsaw operator assigned more time to slashing, which was understandable as cross-cutting of short wood required a greater number of slashes.

Table 1. Working-day structure and chainsaw work-productivity rates
Tabela 1. Struktura dnia roboczego i wydajność pracy pilarką spalinową

Subject of study and area Przedmiot badań i powierzchnia	Time – Czas												Daily work productivity rate Wydajność dzienna $m^3 \cdot 8\ h^{-1}$
	main główny T_g					ancillary pomocniczy T_p				loss strat T_s		total całkowity T	
	T_{g1}	T_{g2}	T_{g3}	T_{g4}	T_{g5}	T_{p1}	T_{p2}	T_{p3}	T_{p4}	T_{s1}	T_{s2}		
Work time, area 1 Czas pracy, pow. 1	33	57	86	70	57	22	23	27	43	18	10	446	3.20
			303				115				28		
Share, % Udział procentowy	7.4	12.8	19.3	15.6	12.7	4.9	5.2	5.1	9.7	4.1	2.2	100.0%	
			68.8%				24.9%				6.3%		
Work time, area 2 Czas pracy, pow. 2	45	70	84	57	0	27	54	31	45	12	10	435	11.80
			256				157				22		
Share, % Udział procentowy	10.3	16.1	19.2	13.1	0	6.2	12.5	7.1	10.3	2.8	2.4	100.0%	
			58.7%				36.1%				5.2%		
Work time, area 3 Czas pracy, pow. 3	39	70	75	41	0	25	40	38	51	26	18	423	14.00
Share, % Udział procentowy	9.3	16.4	17.8	9.7	0	5.9	9.4	8.9	12.1	6.2	4.3	100.0%	
			53.2%				36.3%				10.5%		

Noteworthy was a significant share of workstand operation time (up to 12%). This primarily resulted from the use of old and worn chainsaws that required frequent repairs on the site. Time losses amounted to from approximately 5 to 10%. These losses were mainly caused by workers' fault, but they were also generated by the production organisers – ZUL managers – who failed to provide oil and fuel in time. Regular supervision would certainly prevent such time losses.

In the first area, some 3 m^3 of 1.3 m long stack-wood were harvested per day. In the second area, work productivity rate reached the value of 12 m^3. In the last area, cross-cutting productivity rate was the highest. Differences in work productivity rates in these areas resulted from insufficient professional qualifications of chainsaw operators working in the second plot, and from the use of old and worn chainsaws that would often fail to function, which, amongst other factors, was reflected in a large percentage share of workstand operation (12.5%).

The indices of presence on the site W_T amounted to 0.929, 0.906, 0.881 respectively. It was relatively high for all technologies. This proves good labour discipline, despite winter weather conditions (snow coat, sub-zero temperatures).

In technological timber harvesting process, skidding was of great importance. The stack-wood skidding machine set (ZIŁ 131 B) moved 16.80 m^3 of wood material S2 per day. During one work shift, a specialist articulated tractor Kocums 822 skidded 15.80 m^3 of long large-sized timber per day (17.20 m^3 and 14.4 m^3 respectively). It should be noted that in the first area, only short wood was skidded at a distance of 1200 m. Loading and unloading were done manually. In two other areas, long wood assortment was skidded with application of skidding method into distances exceeding 3 km. In this case, differences in work productivity rates resulted from the lengths of skidding paths, which in the third area were approximately 200m greater. In comparison with lowland conditions, this work productivity rate is definitely lower. One of the causes is the fact that in lowland forests, in the skidding process, timber is usually moved within shorter distances [Sadowski et al. 2011]. Important factors affecting skidding work productivity rates are qualifications of workers and technical condition and quality of equipment applied. Machinery monitored in this study were old-fashioned and significantly worn, and in spite of vast experience of the operators, they were incapable of providing high productivity rates.

Timber harvesting operations (cutting, cross-cutting, and skidding) cause damage to trees remaining in a stand. Bark becomes injured (torn), and phloem and wood get damaged. This may effect in changes in growth, fungal infections, and finally the quality of obtained wood material. Detailed information as regards the above is presented in Table 2.

Table 2. Damage to trees remaining in a stand
Tabela 2. Uszkodzenia pozostających drzew

Area Numer powierzchni	Alongside skidding path Wzdłuż szlaku					In a stand W drzewostanie				
	none brak	max. 10 cm^2	11-100 cm^2	> 100 cm^2	average area średnia powierzchnia cm^2	none brak	max. 10 cm^2	11-100 cm^2	> 100 cm^2	average area średnia powierzchnia cm^2
	%					%				
1	83	8	5	4	40.6	90	7	2	1	25.6
2	79	10	8	3	55.3	89	6	3	2	38.2
3	75	11	9	5	65.2	87	7	4	2	42.6

The greatest amounts of the largest injuries were observed in direct neighbourhood of the skidding path. Damage caused to the stand was significantly less serious and primarily included scratched and torn bark occurring during tree felling. The observed injuries were considerably more serious than described in literature [Stajniak and Suwała 1997, Stańczykiewicz et al. 2011]. The causes of such circumstances should mainly be sought in maladjustment of the widths of the existing skidding paths (2.5-3.5 m) to the parameters of skidding machinery. For this kind of equipment they should amount to approx. 3.5-4.0 m. Due to possible soil erosion on the slopes, this was impossible to accomplish in the local conditions. In the first area, changes were the smallest because stack wood was shifted and loaded manually, and along the paths some 1 m high stumps were left, which formed a certain kind of buffers. In the third area, this solution was also applied and the damage was visibly smaller than in the second area, even though similar (large-sized) wood assortment was being harvested and skidding was done with the same tractor. It is certain that employment of a modern specialist skidding machine, suitable for the local terrain and stand conditions, would make it possible to reduce negative effects of machine operation and increase work productivity rates.

Accordingly to the adopted assumptions, evaluation of the observed technologies was made (Table 3).

Table 3. Evaluation of timber harvesting processes
Tabela 3. Ocena procesów pozyskiwania drewna

Factor Czynnik	Pints given – Przyznane punkty		
	area 1 powierzchnia 1	area 2 powierzchnia 2	area 3 powierzchnia 3
Technological work productivity rate Wydajność prac technologicznych	1	2	3
Skidding productivity rate Wydajność zrywki	2	3	1
Tree damage along the skidding path Uszkodzenia drzew wzdłuż szlaku	3	2	1
Tree damage outside of the path Uszkodzenia drzew poza szlakiem	3	2	1
Sizes of injuries along the path Wielkość ran wzdłuż szlaku	3	2	1
Sizes of injuries outside of the path Wielkość ran poza szlakiem	3	2	1
Number of points Liczba punktów	15	13	8
Place Miejsce	1	2	3

With equal approach to the analysed features, the technology ranking shows that the best was the solution applied in the first area, despite the lowest technological work productivity rate. Employment of a skidding forwarder would improve work productivity and reduce the number of stem injuries. Increased thickness of skidding paths for all the variants would improve the obtained results and decrease the extent of stand damage.

The above deliberations did not however include any economic aspect. This is a very important matter which in the era of market economy must not be neglected. According to general tendencies, increased costs of production and timber harvesting should be expected, with simultaneous stoppage of increase of wood material prices. Such a situation requires increased work productivity which in the case of chainsaw operations may be hard to achieve. Increased profitability of timber harvesting and skidding activities may be achieved through mechanisation. However, one should remember that introduction of high-performance machinery into a forest would require suitable preparation of the working site, along with appropriate work planning. Cost calculation for the employed machinery and equipment would allow to reject unprofitable variants [Glazar and Wojtkowiak 2009]. In mountain conditions, applied technological timber harvesting processes must take into consideration the features and requirements of local stands [Sowa 2000]. Not in all places, however high-performance machinery may be employed. Furthermore, it should be remembered that the applied solutions should cause the least possible damage to forest areas.

SUMMARY AND CONCLUSIONS

In stable and sustainable forest management, timber harvesting processes in mountain areas, being considerably less accessible and more diversified, with the application of complex cutting methods, employed technologies should take into consideration the specificity of terrain, appropriate economic and technological parameters, and ensure sufficient protection of forest environment.

Conducted study and analysis of selected literature items allow to formulate the following conclusions:

1. Work teams assigned some 50-70% of a single work shift to technological operations, where the greatest time share was occupied by delimbing and slashing. A considerable portion of the day was occupied by workstand preparation (approx. 10%), and tree cutting and felling. This was primarily caused by the necessity of snow coat removal in order to expose the roots.

2. Work productivity rates, skidding in particular, were unsatisfactory. This was mainly the result of bad work organisation, bad technical condition of worn equipment, and bad engineering infrastructure. It seems purposeful to conduct an analysis of communication access to the stands and introduce modern skidding equipment adapted to the local conditions.

3. Considerable tree injuries, occurring during timber cutting and skidding, indicate the need to verify the widths of operation paths, in order that they are suitable for the employed machinery. Possibly, it is also worth considering the purposefulness of introducing a more environment-friendly manner of skidding (e.g. gravity extraction, cable cars).

4. Conducted deliberations indicate that in mountain conditions, in combined cutting systems, a good solution would be to introduce cross-cutting of wood assortment of limited lengths at the trunk, and skidding along separated operation paths, ideally in a forwarding manner.

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PODSTAWOWE PARAMETRY PROCESÓW POZYSKIWANIA DREWNA W GÓRACH BUKOWYCH W NADLEŚNICTWIE KOMAŃCZA

Streszczenie. Podstawowym celem pracy było ustalenie struktury dnia roboczego oraz wydajności pracy przy pozyskiwaniu drewna w warunkach górskich. Parametry określono z wykorzystaniem danych zebranych podczas badań terenowych. Strukturę dnia roboczego ustalono na podstawie chronometrażu i obserwacji migawkowych. Powierzchnie objęte pomiarami to drzewostany typowo górskie, w których wykonywano użytkowanie rębne rębnią IVd. Zespoły robocze przeznaczały na operacje technologiczne około 50-70% czasu zmiany roboczej, przy czym najwięcej na okrzesywanie i przerzynkę. Znaczną część dnia zajmowało przygotowanie stanowiska roboczego (ok. 10%) oraz ścinka i obalanie drzew. W głównej mierze wynikało to z konieczności odgarnięcia pokrywy śnieżnej. Wydajność prac technologicznych wynosiła dziennie od 3 do 14 m^3 na 1 robotnika. W czasie zrywki uszkadzany był znaczny procent drzew pozostających wzdłuż szlaku zrywkowego. Na podstawie otrzymanych wyników oraz ich analizy podjęto próbę oceny oraz wskazania możliwości wprowadzenia zmian w organizacji pozyskiwania drewna mających na celu zwiększenie efektywności pracy.

Słowa kluczowe: drzewostan górski, rębnia IVd wydajność, struktura dnia roboczego

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