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Investigations on horse skidding productivity and costs under mountainous conditions

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Abstract: *Investigations on horse skidding productivity and costs under mountainous conditions.* The results of investigations on horse skidding productivity and costs are presented in the paper. The investigations were carried out in Forest Inspectorate Ujsoły. Horse skidding was the first phase of skidding that aimed at pulling up logs to wider skid roads. The horses of Polish Cold-blooded Horse breed were used in skidding; they were equipped with horse-collar harnesses. The investigations were carried out on three sites different in the skidding conditions.

Key words: horse skidding, skidding productivity, skidding costs

INTRODUCTION

Up to the forties of XX century, the skidding had been executed exclusively with the use of horses. In recent several dozen years a considerable development in mechanization of logging and skidding operations has occurred. The special skidding tractors and suitably adapted agricultural tractors were introduced to forests. The highly efficient machines (e.g. harvesters) are used more and more often [Nurek 2010]. In spite of this development, there are still some situations, where horses can be used in skidding. They are irreplaceable on the sites of substantial inclinations, boggy and littered with big amount of cutting residues or protruding stocks, and also in places with very dense tree stand (e.g. during skidding from early thinning sites) as well as at substantial snow cover. Considering the above, undertaking investigations and analyzes on productivity and costs of application of horses in skidding seems to be justified. The horses used in skidding should be characterized by the following features: easy and sedate temperament, patience, inclination towards cooperation with a man, big draught, good condition. The breeds and types of cold-blooded horses bred in Poland characterized by the above features are: Polish Cold-blooded Horse, Sztum Horse, Sokolsky Horse and Silesian horse. The horse designed for forest operations must be fully healthy and of proper constitution. In skidding there are used horses at least 5-year-old; their exploitation period ranges from 3 to 5 years. Besides, horses used in skidding should be previously properly trained for the work under difficult ground conditions. It should be noted that 100% utilization of draught occurs only in a one--horse harness, while in the case of two horses the draught utilization amounts to about 92%; it results in uneven pull and start as well as in improper selection of horses [Kaproń 1996].

The investigations aimed at determination of productivity and costs of

skidding executed with a horse harness on mountainous sites. The field measurements on dragging productivity were carried out on the three sites of different skidding difficulties. Basing on the obtained results the skidding costs were calculated.

MATERIAL AND METHODS

The investigations were carried out in Forest Inspectorate Ujsoły, within the precincts of Rycerka, forestry Bendoszka, forest compartments 208 and 219. Skidding was performed down the slope, on the site littered with cutting residues.

Two-phase skidding was performed on the investigated sites. Horse skidding was the first phase of skidding that aimed at pulling up logs to wider skid roads, where larger loads were extracted with the use of special tractor of cable skidder type or mini-tractor "iron horse". The investigated species was 70-year-old--spruce harvested with the use of internal combustion chain saws.

The site No 1 was situated in compartment 208 at altitude from 725 to 1,100 m; it was of I valuation class and small slope. The wood was extracted on average distance 60 m. The site was not much littered with cutting residues and the cut branches did not disturb skidding. The forest stand consisted of 70-year--old spruce-and-beech with additions of hoary alder, larch and sycamore. Stocking amounted to 0.9, average height of trees to 27 m, and their mean diameter breast high to 36 cm. The working conditions on this site were evaluated by the workers as good.

The ground of site No 2 was more inclined and contained more obstacles. It was very much littered with cutting residues. The carters had to pass round obstacles to prevent horses from wounds. The snowbreak residues on this site created also some difficulties. The small spruce sticks of average volume 0.2 m^3 was extracted on that site.

The ground of site No 3 was strongly inclined and skidding called for going up the steep slope to the top; besides, particular trees were substantially spaced and the time of load forming was considerably increased.

The grounds 2 and 3 were situated in compartment 219 of slope up to 60° and I valuation class. The forest stand consisted of fir-and-spruce with addition of 55-year-old beech. The stocking amounted to 1.1, average height of trees to 20 m, and their mean diameter breast high to 22 cm.

The workers on ground No 1 did not exceed 30 years of age and they were younger than that on grounds 2 and 3, where the carters were over 40 years old.

On working sites there were measured: wood length, wood diameter, duration of working cycles and duration of operational breaks. The skidding distance was measured also. The length was measured with the use of a measuring tape of accuracy 1 cm, diameter breast high with a tree caliper of accuracy 0.5 cm, and times with a stop watch of accuracy 1 s. All measurement results were recorded on the previously prepared sheets. The photographs were made also.

Upon completion of measurements there were calculated: the wood volume, skidding productivity and costs, using the MS Excel program.

In calculations on wood volume the well-known Huber equation was used [Czuraj 1972]:

$$V = \frac{\pi \cdot d_{1/2}^2}{4} \cdot l \quad (1)$$

where:
V – volume of bolt or bolt part [m^3];
$d_{1/2}$ – bolt diameter at half of its length [m];
l – length of bolt or bolt part [m].

The following phases of skidding cycle were distinguished: t_1 – time of travel to load; t_2 – time of load forming; t_3 – time of travel with load and t_4 – time of load release. The time of planned and unexpected breaks was considered also.

Basing on the recorded results the effective productivity was calculated with equation:

$$W_1 = \frac{q_a}{t_c} \quad (2)$$

where:
W_1 – effective productivity [m^3/h];
q_a – average volume of wood raw material within working cycle of skidding [m^3];
t_c – mean time of cycle [h].

As the time of effective operation T_1 there was taken the sum of all cycle times during the working shift.

The practical productivity was calculated with the following equation [Botwin 1993]:

$$W_{07} = \frac{Q}{T_{07}} \quad (3)$$

where:
W_{07} – practical productivity [m^3/h];
Q – average volume of wood raw material during working shift of skidding [m^3];
T_{07} – total time of working shift [h].

The speed of travel with load for particular grounds was calculated by dividing the average distance of skidding by the mean time of travel with load. The speed of travel to load was calculated analogically.

The costs were calculated and analyzed with the use of method proposed by Zychowicz [2004]. It was adapted to the costs of horse work by substitution the costs of fuel and lubricants with the cost of annual feed, recalculated per one hour of horse work. The total annual time of horse work was estimated basing on data obtained during interview with the carters. The amount of feed was calculated according to valid horse feeding standards [Normy żywienia 1997]. Basing on the standards, the amount and type of feed was selected to provide the animals with all essential micro- and macroelements and calories.

The time of carter's work was assumed according to Polish code of work (kodeks pracy art. 129 § 1 Dz.U. 1974 no 24, item 141 with later alterations). The costs of repairs and technical maintenance in this case are equal to the costs of veterinary care.

The Polish 5 to 9 years old, cold--blooded, gelded horses of weight about 700 kg were used in skidding. A single horse worked on particular site. The horses were trained for work under difficult conditions and equipped with special shoes with calcs. In skidding there were used collar harnesses, a metal equalizer and a chain with hook. An advantage of the collar harness is loading of a rela-

tively large area of horse body [Nowicka 2002].

The exploitation period of horses in skidding was assumed as 5 years.

RESULTS

During investigations the skidding distance varied from 34 to 128 m, while the assortment volume from 0.09 to 1.52 m^3 per one working cycle. Average results obtained during measurements on particular grounds are presented in Table 1.

TABLE 1. Results of measurements

Specification	Site No 1	Site No 2	Site No 3
Average distance of skidding [m]	60	40	100
Average volume of assortment per one cycle (q_a) [m^3]	0.5	0.4	0.6
Average time of travel to load (t_1) [s]	74	47	172
Average time of load forming (t_2) [s]	35	44	135
Average time of travel with load (t_3) [s]	83	42	388
Average time of load release (t_4) [s]	18	15	38
Average time of skidding cycle (t_c) [s]	210	148	733
Average speed of travel with load [m/s]	0.73	0.95	0.26
Average speed of travel without load [m/s]	0.81	0.85	0.58
Average effective productivity (W_1) [m^3/h]	8.57	9.7	2.95
Average practical productivity (W_{07}) [m^3/h]	3.75	2	1.6

The time of cycle depended mainly on skidding distance and conditions on the skidding site; it varied from 2.5 min – on the site of level and cleaned up terrain and at small skidding distance, to 12.5 min – on the site with steep slope, substantial dispersion of logs and with many cutting residues.

The main reasons for substantial diversification of productivity on the investigated sites were the terrain shape and littering, as well as skidding distance. Site No 1 of the highest productivity was characterized by small inclination and low littering with cutting residues. The workers assessed working conditions as good ones. The ground of site No 2 was more inclined and contained more obstacles. The ground of site No 3 was strongly inclined and skidding called for going up the steep slope to the top; besides, particular trees were substantially spaced and the time of load forming was considerably increased. Relatively big differences in productivity may result from different conditions on particular skidding sites, and may be connected with previously described age diversification of workers on particular sites. Productivity on particular sites varied from 1.6 to 3.75 m^3/h. Figure 1 presents average percent share of particular times in working cycle on all investigated sites. The highest share is taken by the travel with load; it amounts to 46% of the en-

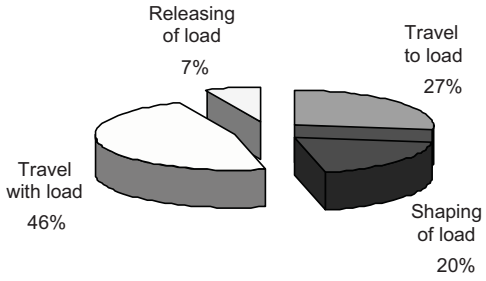

FIGURE 1. Average percent share of particular times in working cycle

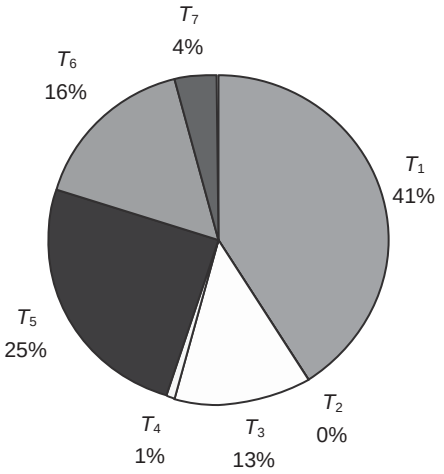

FIGURE 2. Average percent share of particular times in working day: T_1 – time of effective work, T_2 – time of technological standstills, T_3 – time of daily horse care, T_4 – time of technological fault correction, T_5 – time of rest and evacuation, T_6 – time of transport travels, T_7 – time of technical maintenance

tire cycle, while travel to load amounts to 27%, and load release 7%.

Average practical productivity calculated for all sites amounted to 2.65 m^3/h, while daily productivity ranged from 15 to 30 m^3, depending on the site.

Figure 2 presents percent shares of particular times in working day. One can find that time of effective operation (T_1) takes only 41% of working shift, while the lowest share is taken by the time of technological fault correction – in our case it is the time for removing branches off the skidding roads. A high share of the rest break time was found; it amounted to even 25% of total working time. It results from the fact that every few cycles the horse must rest to recover its strength; besides, around noon the horse must get its meal. However, the horse should not eat directly after big effort, not before its breath is equalized. After feeding, the horse must not directly get to work; a break of about 0.5 h is essential. As a result, average time of meal break amounted to 60 min. It affected significantly the time for rest breaks in total time of work. The share of transport travel time amounted to 16%; it was the sum of times for travel from a stable to forest parking place, approaching horse to the site, leaving the site and return to a stable. Share of time for daily horse care (cleaning, harness fixing and removing) amounted to 13%. Share of remaining times for: technological fault correction (removing branches off skidding roads) and technical service of harness amounted in total to 5%.

Particular cost components and calculated total exploitation costs are presented in Table 2. One can find that the highest share of the costs is taken by wedges of workers, while the lowest share by the costs of storage (stable maintenance). As a result of calculations it was found, that annual cost of feed for a heavy working horse amounted to almost 2,500 PLN, while the cost of horse work amounted to 19.77 PLN/h. Considering skidding productivity obtained during investigations, it gives the specific cost range from 5.27 to 12.35 PLN/m^3, on the average

TABLE 2. List of exploitation costs

Specification	PLN/year	PLN/h
Fixed costs		
Depreciation	2,197.44	1.09
Insurance	1,108.80	0.55
Storage	221.76	0.11
Credit	887.04	0.44
Animal care	1,900.00	0.95
Total	6,315.04	3.14
Variable costs		
Feed	2,475.00	1.23
Wedges	29,836.80	14.80
Costs of veterinary care	1,209.60	0.60
Total	33,521.40	16.63
Total fixed and variable costs	39,836.44	19.77

7.46 PLN/m^3. Dudek [2012] reported, that skidding cost with the use of tractor MTZ 82 under mountainous conditions amounted to 52.06 PLN/h. Długosiewicz and Grzebieniowski found [2009] specific cost of skidding with tractor Ursus C 385M equipped with a hoisting winch, amounted under lowland-conditions to 15.34 PLN/m^3. Therefore one can find, that horse skidding is chipper than skidding with agricultural tractor even under lowland-conditions.

CONCLUSIONS

The following conclusions can be drawn from presented analyses and dependences:

1. Effective productivity of horse skidding during described investigations ranged 2.95–9.7 m^3/h, while practical productivity – 1.6–3.75 m^3/h. Its high diversification might be influenced by different shape of terrain on particular investigated sites.
2. Average hourly cost of horse work amounts to 19.77 PLN, while average specific cost to 7.46 PLN/m^3; it is lower than the costs calculated by other researchers for skidding with an agricultural tractor under lowland--conditions.
3. A big share in overall time of shift during horse skidding is taken by the time for horse rest and evacuation breaks.

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Streszczenie: *Wydajność i koszty zrywki konnej w warunkach górskich.* W artykule przedstawiono wyniki badań wydajności i kosztów zrywki konnej w warunkach górskich. Badania przeprowadzono w Nadleśnictwie Ujsoły. Zrywka konna była pierwszym etapem zrywki i jej zadaniem było dociągnięcie drewna do szerszych szlaków zrywkowych. Do zrywki wykorzystywano konie rasy Polski Koń Zimnokrwisty wyposażone w uprząż chomątową. Średnia odległość zrywki wynosiła od 40 do 100 m. Badania przeprowadzono na trzech powierzchniach o różnym stopniu trudności zrywki. W wyniku przeprowadzonych pomiarów i analiz okazało się, że wydajność eksploatacyjna zrywki konnej w trudnych górskich warunkach wynosi od 1,6 do 3,75 m^3/h. Średni jednostkowy koszt zrywki wynosi 7,46 zł/m^3, jest on niższy od kosztów wyliczonych przez innych badaczy dla zrywki ciągnikiem rolniczym

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