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Productivity of C Holder 870 F tractor with double drum winch Igland 4002 in thinning beech stands

Željko Zečić, Ante P. B. Krpan, Stjepan Vukušić

Abstract – Nacrtak

Research of productivity of C Holder 870 F tractor in thinning beech stands was performed in the area of Forest Administration Bjelovar, Forest Office Velika Pisanica in the compartment 87a of the management unit Bilo Jezero. Timber was skidded uphill. Time study of a cycle was carried out by using collected data and by mathematical–statistical analysis, and it was shown that effective time accounted for 72.98 % and additional time accounted for 27.02 %. Additional time coefficient is 1.37. Time standard for skidding distance from 25 to 250 m ranges between 22.23 and 34.29 min/m^3, and daily output, at mean load volume of 0.76 m^3, is 21.59 m^3/day for skidding distance of 25 m, i.e. 14.00 m^3/day for skidding distance of 250 m. Based on official calculation of Hrvatske šume d.o.o. Zagreb for the year 2000 and daily output, the daily unit cost of C Holder 870 F tractor was established and it ranges from 69.16 kn/m^3 for skidding distance of 25 m to 106.66 kn/m^3 for skidding distance of 250 m.

Key words: *thinning beech stands, C Holder 870 F, skidding, productivity, costs*

1. Introduction and Scope of Research – *Uvod i cilj istraživanja*

Until the late 20th century forest exploitation relied mainly on man, because felling and processing were made by axes and hand saws, and wood was transported by animals or by water, i.e. gravitation. Only in the late 20th century, the use of chainsaws for felling became more intensive, as well as the use of tractors for skidding and trucks for transport to greater distances. Utilization of mechanization resulted in higher efficiency and more human approach to work and improvement of life conditions of forestry workers in general.

Mechanization started with the introduction of farm tractors modified by installation of additional equipment, which enabled easier and safer work in the forest. Modified farm tractors play an important role in forest exploitation, even after the development of specialized forest articulated tractors. Articulated tractors have a better maneuvering efficiency, they can operate on steeper slopes, they have all four-wheel drive and better performance compared to modified farm tractors. Further technological development resulted in multi-purpose forest machineries able to perform several operations simultaneously (processor, harvester).

The aim of this paper is to research some exploitation characteristics of articulated tractor C Holder 870 F equipped with double-drum winch Igland 4002 in skidding in hilly broadleaf stands. The structure of total consumed times is established as well as the structure of daily times, tractor speeds, speeds of pulling the choker and winching, time standards and daily output standards for specified skidding distances.

Tractor C Holder 870 F is designed for work in thinning operations. It is equipped with elements for the connection of various optional attachments (trailers, atomizers, hoes etc.). The cab is well laid out, noise level is minimal, and seats are ergonometrically designed. Driving safety has been improved owing to spring stabilizer, which provides changing the center of gravity and pressing the wheel against the ground at steeper slopes, and thus prevents overturning. This tractor is more environmentally friendly due to the use of oil having no det-

rimental effect to the environment. During testing, some faults of the tractor were noticed such as: inadequate motor protection from the bottom side, too narrow tires, laterally slipping at steeper transversal slopes etc.

Figure 1 Tractor C Holder 870 F at landing

Slika 1. *Traktor C Holder 870 F na pomoćnom stovarištu*

The main technical characteristics of the tractor are shown in Table 1. The tested tractor is equipped with duble-drum winch Igland 4002 manually controlled from the cab. The pulling force is 40 kN per each drum with braking force of 56 kN. Winch roles of 345 m in length and 8 mm in diameter (ISO 6687) were used. The manufacturer recommends the winch to be installed to a tractor with the power of 48 kW (65 kW).

Table 1 Main technical characteristics of the tractor C Holder 870 F

Tablica 1. Osnovne tehničke značajke traktora C Holder 870 F

Tractor dimensions – *Dimenzije traktora*	
Length – *Dužina*	4950 mm
Width – *Širina*	1594–1820* mm
Height – *Visina*	2110–2360* mm
Wheel base – *Razmak mostova*	1827 mm
Clearance height – *Prohodnost traktora*	360 mm
Tractor weight – *Težina traktora*	3860–3960 kg
Max. speed – *Najveća brzina*	30.4 km/h
Motor characteristics – *Značajke motora*	
Maximum power – *Najveća snaga*	51.5 kW (70 KS)
Rotation speed at maximum power – *Br. okretaja pri najvećoj snazi*	2500 min^{-1}
Rotation speed at maximum moment – *Br. okretaja pri najvećem momentu*	222 Nm / 1800 min^{-1}
Motor volume – *Obujam motora*	2732 cm^3
Fuel tank volume – *Obujam spremnika za gorivo*	40 l

2. Location and Methods of Research – *Mjesto i metode istraživanja*

Field research was performed in the area of Forest Administration Bjelovar, Forest Office Velika Pisanica, in the compartment 87a of the management unit Bilo Jezero (Figure 2). The research involved thinning operations in beech felling site, the stand age was 69.

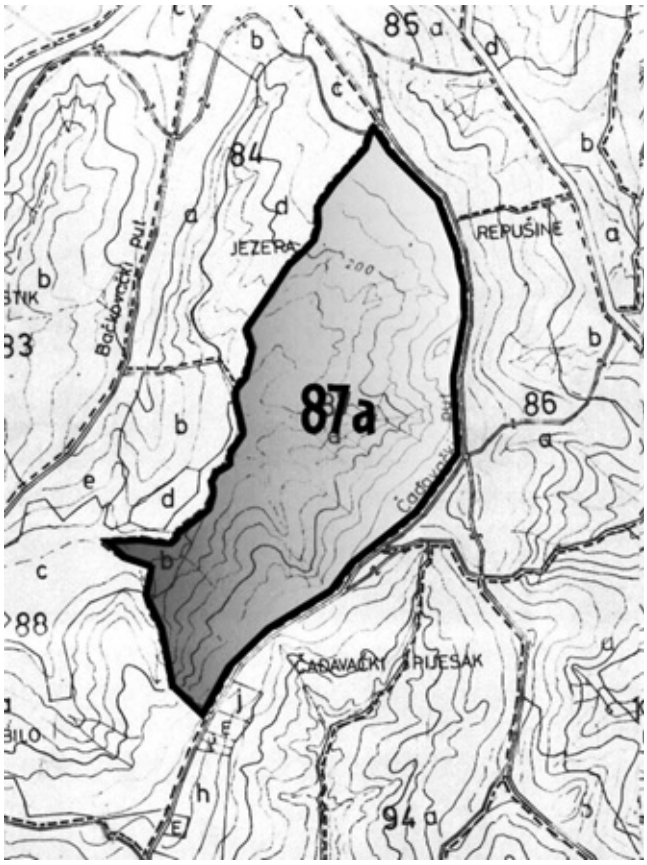

Figure 2 Compartment 87a in management unit Bilo Jezero

Slika 2. *Odjel 87a u gospodarskoj jedinici Bilo jezero*

In the section of an area of 60.37 ha, beech is dominating and accounts for 66.2 % of growing stock, followed by sessile oak (14.7 %) and hornbeam (13.1 %), and other species account for 10.9 % in the wood volume. In beech stands there are stronger sessile oak trees randomly distributed and hornbeam at lower level mainly. The west slope is criss-crossed in fan-

-shaped manner with channels and with hornbeam dominating at their ends. Total wood stock of the section is 21,549 m^3, i.e. 356 m^3/ha.

Four tractor trails were scheduled for travel of the tractor from the felling site to landing. In longitudinal profile from the landing to felling site, tractor trails go uphill, while at felling site they go along contour lines, sloping more gently. Along skid trails, soil was covered with leaves wetted with drizzle and snow, which hindered the tractor's ability to move. The forest road was used as the landing site as wood assortments were stocked along the road on both sides. The soil bearing capacity i.e. the landing site road kept changing during research depending on the amount of precipitation and number of tractor passes. The tractor was moving with difficulties when the soil was heavily soaked and partly frozen while muddy conditions caused no difficulties.

Weather conditions during research were quite unsettled. During the first few days it was raining, while during the second half of research work, the tractor was strongly hindered by snow (even up to 40 cm of snow on the ground). The ground was permanently soaked resulting in slippage of the tractor, even at lower slopes. The temperature ranged from –5 °C to 6 °C but sometimes it was as low as –10 °C in the morning.

The tractor cycle started with the drive of the unloaded tractor along the skid trails to the load forming site. After a worker fastened the logs, the tractor driver started winching and driving the loaded tractor to the landing site. Wood was winched and skidded uphill. Due to heavy rain and snow and bad soil conditions along the skid trail, quite a lot of winching was required during the drive of the loaded tractor. The work at the landing site included the following operations: unhooking the load, pulling and arranging the chokers and chains, load sorting and piling up and reversing the tractor.

Time consumption per each operation was measured by snap-back chronometry method. Distances of the tractor drives were recorded by pre-measured and posted marks along the route (pickets, marks on trees). All values were recorder in special forms. The obtained pieces of information were entered into computer and the data base was formed.

3. Results of Research – *Rezultati istraživanja*

Table 2 shows information about the volume of skidded timber. A total of 67.06 m^3 or 181 pieces of round wood was skidded in 88 cycles. Mean piece diameter was 21.7 cm, mean piece length was 8.4 m and mean piece volume was 0.34 m^3. The average number of pieces in a load was 2.1 and mean load volume was 0.762 m^3

In total time consumed during thinning operations of the tractor C Holder 870 F, effective time accounts for 47.08 %, and the remaining 59.92 % are the actual delay times. Effective time per unit of skidded timber volume is 19.12 min/m^3 and total time consumed per unit is 40.62 min/m^3. Figure 2 shows the structure of effective time consumed, and Figure 3 shows the structure of delay time.

52.57 % of effective time accounts for tractor drive, out of which 16.50 % refers to unloaded tractor drive and 36.07 % refers to loaded tractor drive. Work at the felling site accounts for 21.23 % of effective time and work at the landing accounts for 26.20 %.

In the structure of delay times, 28.62 % refers to breaks for having meals, 4.86 % is consumed for rests and pauses, while 5.09 %, i.e. 15.81 % of daily time refers to excused and unexcused breaks. Breaks due to technical reasons account for 9.52 % from daily times, while occasional works account for 9.20 %. Preparatory and final operations account for 26.71 %

Table 2 Characteristics of timber skidded by tractor C Holder 870 F

Tablica 2. *Struktura privučenoga drvnog obujma traktorom C Holder 870 F*

Characteristic – *Sastavnice*	Minimum – *Najmanje*	Average – *Prosječno*	Maximum – *Najviše*
Total skidded timber volume, m^3 – *Ukupno privučeni drvni obujam, m^3*		67.06	
Total number of pieces – *Ukupan broj komada, kom.*		181	
Total number of cycles – *Ukupan broj turnusa*		88	
Mean load volume, m^3 – *Srednji obujam tovara, m^3*	0.206	0.762	2.283
Average number of pieces in a load – *Prosječan broj komada u tovaru*	1	2.1	4
Mean piece length, m – *Srednja duljina komada, m*	3.4	8.4	20.0
Mean piece volume, m^3 – *Srednji obujam komada, m^3*	0.020	0.340	1.552
Mean piece diameter, cm – *Srednji promjer komada, cm*	8.0	21.7	56.0

of daily times. Additional time coefficient was calculated by the analysis of the structure of delay times, and it is 1.37 and 37 % of effective time, respectively.

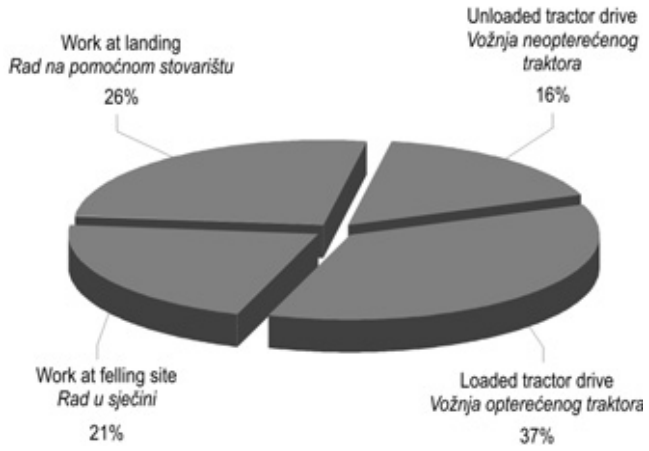

Figure 3 Structure of effective time

Slika 3. *Struktura utrošenih efektivnih vremena*

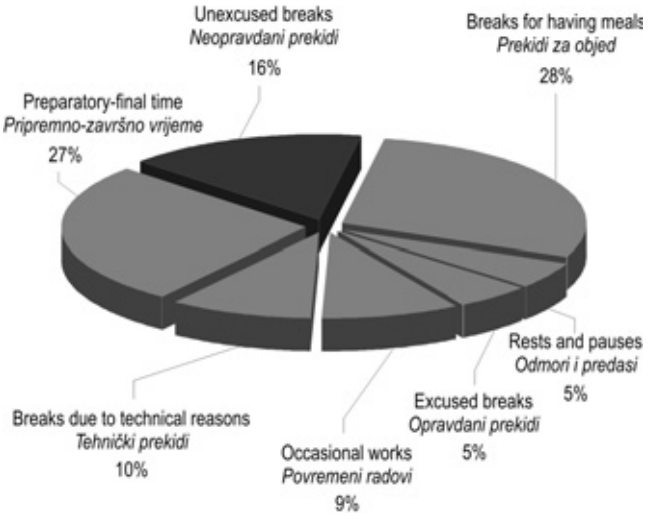

Figure 4 Structure of delay times

Slika 4. *Struktura utrošenih općih vremena*

Drive times of loaded and unloaded tractor along the tractor skidd trail and at landing are regressed, depending on drive distances by potential equations of ($y = a \cdot x^b$). Table 3 shows the obtained equations with pertaining correlation coefficients. Drive speeds of unloaded and loaded tractor along skid trails and landing are calculated by regressed time consumptions and are shown in Figure 5.

The average speed of unloaded tractor along the skid trail was 3.77 km/h and of the loaded one it was 1.33 km/h. Low speed of the loaded tractor reflects extremely bad work conditions because of which a lot of time was consumed on winching during skidding. Winching time during skidding was

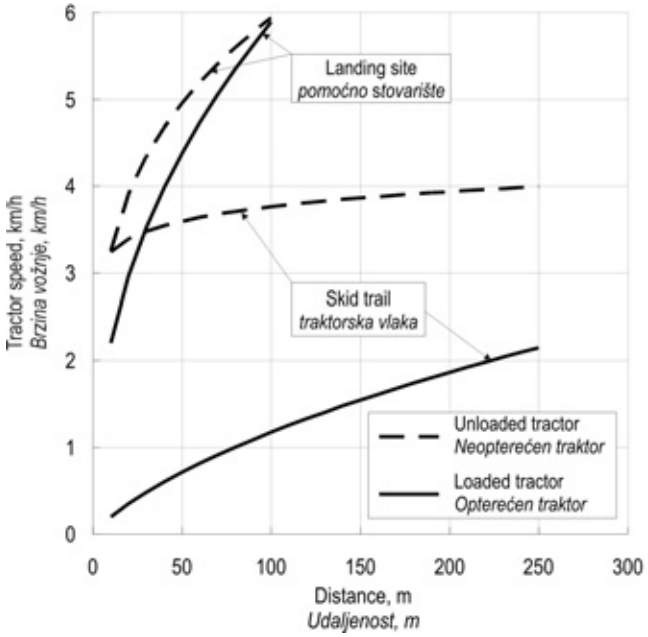

Figure 5 Drive speeds of unloaded and loaded tractor along skid trails and landing

Slika 5. *Brzine vožnji opterećenoga i neopterećenoga traktora po traktorskoj vlaci i po pomoćnome stovarištu*

Table 3 Regression equations of time consumption related to the distance of tractor drive along the tractor skidding trail and landing site

Tablica 3. *Jednadžbe izjednačenja utroška vremena s obzirom na udaljenost za vožnje traktora po traktorskoj vlaci i pomoćnome stovarištu*

Work operations *Radna aktivnost*	Regression equation *Jednadžba izjednačenja*	Correlation coefficient *Koeficijent korelacije*
Drive of unloaded tractor along skidding trail *Vožnja neopterećenoga traktora po traktorskoj vlaci*	$y = 0.0215\ x^{0.9351}$	$R = 0.7480$
Drive of loaded tractor along skidding trail *Vožnja opterećenoga traktora po traktorskoj vlaci*	$y = 0.2276\ x^{0.5496}$	$R = 0.7388$
Drive of loaded tractor at landing *Vožnja opterećenoga traktora po pomoćnom stovarištu*	$y = 0.0728\ x^{0.5729}$	$R = 0.6720$
Drive of unloaded tractor at landing *Vožnja neopterećenoga traktora po pomoćnom stovarištu*	$y = 0.0336\ x^{0.7391}$	$R = 0.7080$

Table 4 Regression equations of time consumption related to distances of pulling the choker and winching
Tablica 4. *Jednadžbe izjednačenja utroška vremena s obzirom na udaljenost za izvlačenje užadi i privitlavanje*

Work operations *Radna aktivnost*	Regression equations *Jednadžba izjednačenja*	Correlation coefficient *Koeficijent korelacije*
Pulling the left drum choker – *Izvlačenje užeta lijevog bubnja*	$y = 0.1473\ x^{0.5134}$	$R = 0.7210$
Pulling the right drum choker – *Izvlačenje užeta desnog bubnja*	$y = -0{,}0002x^2 + 0.0363x + 0.1434$	$R = 0.8190$
Left drum winching – *Privitlavanje lijevog bubnja*	$y = 0.1278\ x^{0.5363}$	$R = 0.7211$
Right drum winching – Privitlavanje desnog bubnja	$y = 0.1499\ x^{0.5193}$	$R = 0.7685$

taken as fixed time (2.25 min/cycle) and it was added to the time consumed for the drive of the loaded tractor along skidding trail obtained by regression analysis.

The average speed of loaded tractor at landing is 4.37 km/h and it is 4.90 km/h for the unloaded one.

Times consumed for pulling the left drum choker and for winching the left and right drum were equalized by potential equations, while the parabola equation (y=ax^2+bx+c) was more convenient for time consumed for pulling the right drum choker. Correlation coefficients range from 0.7210 to 0.8190. Table 4 shows regression equations and their pertaining correlation coefficients. Speeds of pulling the choker of the left and the right drum (Figure 6) and load winching speed for the left and right drum were calculated based on regressed time consumption (Figure 7).

Speeds of pulling the choker of the left drum ranges between 0.89 km/h for the distance of 5 m and 2.45 km/h for the distance of 40 m. The speed of pulling the choker of the right drum ranges between 0.94 km/h for the distance of 5 m and 1.88 km/h for the distance of 40 m. The average speed of pulling the left drum choker is 1.78 km/h and it is higher than the speed of pulling the right drum choker, which is 1.51 km/h.

The winching speed of the left drum is also higher, i.e. it ranges from 0.99 km/h for the winching distance of 5 m to 2.60 km/h for the winching distance of 40 m. The average speed of the left drum winching is 1.91 km/h, which is 0.19 km/h higher than the average speed of the right drum winching, which is 1.72 km/h. For the distance of 5m, the right drum winching speed is 0.87 km/h and for the winching distance of 40 m the speed is 2.36 km/h.

Table 5 shows the structure of activities during the cycle time of the tractor C Holder 870 F with double drum winch for the winching distance of 250 m along the skid trail and 100 m at landing. Total cycle

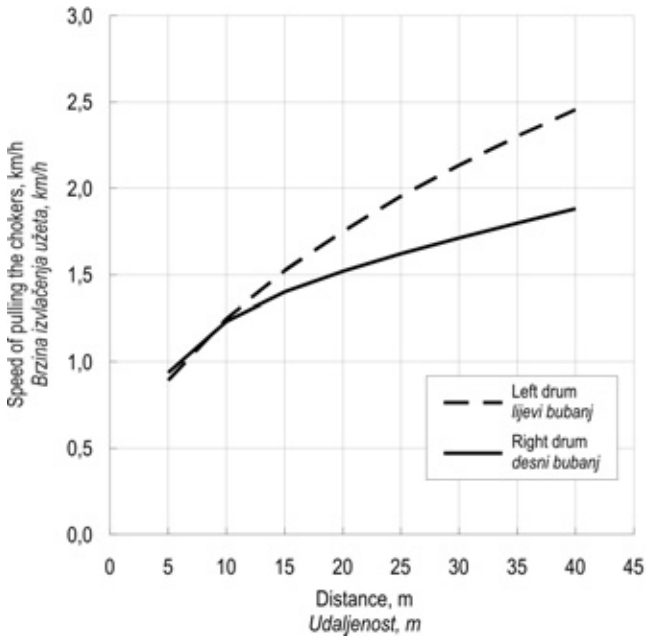

Figure 6 Speeds of pulling the choker of the left and right drum
Slika 6. *Brzine izvlačenja užeta lijevoga i desnoga bubnja*

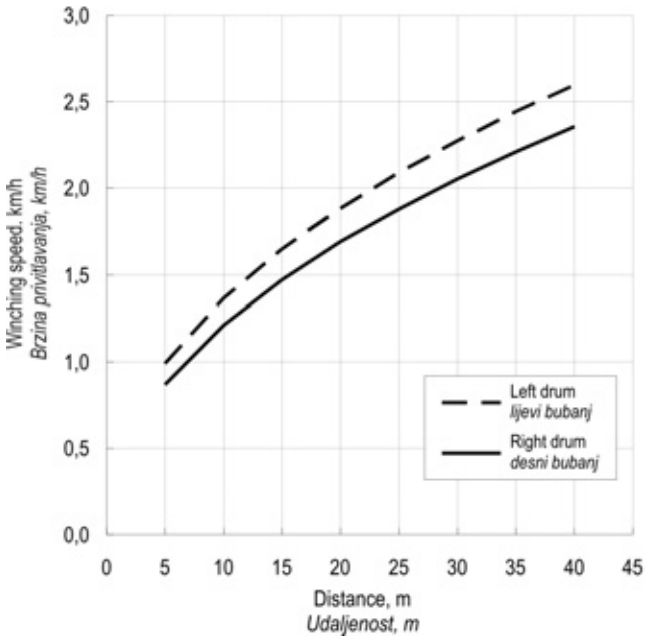

Figure 7 Winching speeds of the left and right drum
Slika 7. *Brzine privitlavanja lijevoga i desnoga bubnja*

Table 5 Structure of the cycle time of the tractor C Holder 870 F with double-drum winch for the winching distance of 250 m along the skid trail and 100 m at landing

Tablica 5. *Oblikovana struktura vremena turnusa traktora C Holder 870 F s dvobubanjskim vitlom za udaljenost privlačenja po vlaci i sječini 250 m i po pomoćnom stovarištu 100 m*

Work operations *Vrsta aktivnosti*	Time consumption *Utrošak vremena*		
	Total time *Ukupno vrijeme*	Percentage in *Postotni udio prema*	
		Total time *ukupnom vremenu*	Effective time *efektivnom vremenu*
	min	%	
1. Unloaded tractor drive *1. Vožnja neopterećenoga traktora*	3.74	14.32	19.61
2. Loaded tractor drive *2. Vožnja opterećenoga traktora*	6.98	26.72	36.60
3. Work at felling site *3. Rad u sječini*	4.74	18.14	24.86
4. Work at landing *4. Rad na pomoćnom stovarištu*	3.61	13.82	18.93
5. Effective time *5. Efektivno vrijeme*	19.07	72.99	100.00
6. Additional time (37 %) *6. Dodatno vrijeme (37 %)*	7.06	27.01	
7. Total time *7. Ukupno vrijeme*	26.13	100.00	
8. Average load volume, m^3 *8. Prosječni obujam tovara, m^3*	0,762		
9. Time standard, min/m^3 *9. Norma vremena, min/m^3*	34.29		
10. Daily output, m^3/dan *10. Dnevni učinak, m^3/dan*	14.00		

time is 26.13 min. The effective time accounts for 72.99 % of total cycle time, i.e. 19.07 min. Based on the additional time coefficient (37 % of effective time), additional time is calculated and it amounts to 7.06 min and it accounts for 27.01 % in the total cycle time.

Based on average consumed fixed and regressed variable times, additional time coefficient and average load volume are determined, as well as time standard (min/m^3) and daily output (m^3/day) of the tractor C Holder 870 F with double-drum winch Igland 4002 for the skidding distances from 25 to 250 m. Figure 8 shows time standards and daily output depending on the skidding distance.

Time standard ranges between 22.23 min/m^3 for the skidding distance of 25 m and 34.29 min/m^3 for the distance of 250 m. Daily output of the tractor C Holder 870 F in thinning beech stands decreases from 21.59 m^3/day for the skidding distance of 25 m to 14.00 m^3/day for the skidding distance of 250 m.

Comparison has been made between the daily output of the tested tractor with the results of similar researches based on the daily output for the skidding distances of 50 and 250 m, which are 19.96 m^3/day and 14.00 m^3/day for C Holder 870 F. According to Zečić (1998) the daily output of the tractor Torpedo in Kutjevo ranges from 20.05 m^3/day for the winching distance of 50 m to 15.77 m^3/day for the skidding distance of 250 m. The same tractor in Pleternica has the daily output from 15.32 m^3/day for 50 m and 11.48 m^3/day for 250 m. Within the same research, the tractor Ecotrac V-11-1033F has the following ranges of daily output: from 18.93 m^3/day at 50 m to 15.18 m^3/day at 250 m at the work site Kutjevo, and from 14.60 m^3/day at the skidding distance of 50 m to 11.07 m^3/day at the distance of 250 m at the work site Pleternica. At the work site B, the same tractor has the output of 24.35 m^3/day at the skidding distance of 50 m to 19.80 m^3/day at the skidding distance of 250 m.

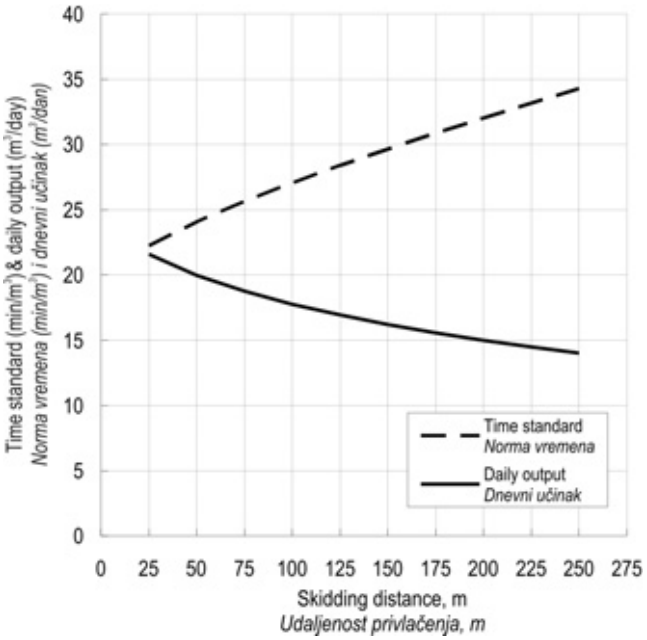

Figure 8 Standard time and daily output of the tractor C Holder 870 F

Slika 8. *Brzine vožnji opterećenoga i neopterećenoga traktora po traktorskoj vlaci i po pomoćnom stovarištu*

The unit cost of the tractor C Holder 870 F during skidding operations at different distances in thinning beech stands is shown in Table 6. Calculation of daily cost is based on cost estimate of *Hrvatske šume d.o.o. Zagreb*.

Table 6 Unit cost of timber skidding in thinning beech stands by the tractor C Holder 870 F

Tablica 6. *Jedinični trošak privlačenja oblovine iz prorednih bukovih sječina traktorom C Holder 870 F*

Skidding distance *Udaljenost privlačenja*	Daily cost *Dnevni trošak*	Daily output *Dnevni učinak*	Unit cost *Jedinični trošak*
m *m*	kn/day *kn/dan*	m^3/day m^3/dan	kn/m^3 kn/m^3
25	1493.19	21.59	69.16
50	1493.19	19.96	74.81
75	1493.19	18.74	79.68
100	1493.19	17.75	84.12
125	1493.19	16.92	88.25
150	1493.19	16.20	92.17
175	1493.19	15.56	95.96
200	1493.19	14.98	99.68
225	1493.19	14.47	103.19
250	1493.19	14.00	106.66

4. Conclusions – *Zaključci*

The research of productivity of the tractor C Holder 870 F in thinning beech stands was performed in the area of Forest Administration Bjelovar, Forest Office Velika Pisanica in the compartment 87a of the management unit Bilo Jezero.

In total time consumption, effective time accounts for 47.08 %, and delay time for 52.92 %. The total volume of the skidded timber is 67.06 m^3. The average daily output is 7.45 m^3/day.

The average speed of the unloaded tractor along tractor trail is 3.77 km/h and of the loaded tractor it is 1.33 km/h. The speed of the loaded tractor is influenced by bad soil conditions on the tractor trail caused by rain and snow, which made the movement of the tractor more difficult with the effect of increased time consumption due to frequent winching during the drive.

The average speed of the left drum choker pulling is 1.78 km/h and it is higher than the average speed of the right drum choker pulling, which is 1.51 km/h. The average winching speed of the left drum is 1.91 km/h, which is 0.19 km/higher than average winching speed of the right drum, which is 1.72 km/h.

The average drive speed of the loaded tractor at the landing is 4.37 km/h and of the unloaded one 4.90 km/h.

Time standard for the skidding distance from 25 to 250 m ranges between 22.23 and 34.29 min/m^3 and the daily output for the average load volume of 0.762 m^3 is 21.59 m^3/day for the skidding distance of 25 m and 14.00 m^3/day for the skidding distance of 250 m. Based on daily performance, it is possible to increase the tractor productivity by 2.9 (15 m) to 1.9 (250 m) times related to the average actual daily output of 7.45 m^3/day.

Based on calculations and daily output, unit cost of C Holder 870 F tractor was established and it ranges from 69.16 kn/m^3 for skidding distance of 25 m to 106.66 kn/m^3 for skidding distance of 250 m.

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Sažetak

Proizvodnost traktora C Holder 870 F s dvobubanjskim vitlom Igland 4002 u prorednim bukovim sastojinama

Istraživanje proizvodnosti traktora C Holder 870 F prorednim bukovim sječinama obavljeno je na području UŠP Bjelovar, Šumarija Velika Pisanica u 87a odsjeku gospodarske jedinice Bilo jezero. Privlačenje drva traktorom odvijalo se uzbrdo.

U strukturi ukupno utrošenoga vremena efektivno vrijeme čini 47,08 %, a opća vremena 52,92 %. Ukupno je privučeno 67,06 m³ drvnoga obujma. Ostvaren je prosječni dnevni učinak od 7,45 m³/dan. Temeljem prikupljenih podataka i matematičko-statističkih analiza oblikovana je struktura vremena turnusa. U strukturi vremena turnusa efektivno vrijeme čini 72,98 %, a dodatno vrijeme 27,02 %. Koeficijent dodatnoga vremena je 1,37. Prosječna brzina kretanja neopterećenoga traktora po traktorskoj vlaci iznosi 3,77 km/h, a opterećenoga 1,33 km/h. Na brzinu kretanja opterećenoga traktora utjecalo je loše stanje tla traktorske vlake zbog kišnih i snježnih vremenskih uvjeta, što je za posljedicu imalo otežano kretanje traktora i povećani utrošak vremena zbog učestaloga privitlavanja tijekom vožnje. Prosječna brzina izvlačenja užeta lijevoga bubnja iznosi 1,78 km/h i veća je od prosječne brzine izvlačenja užeta desnoga bubnja koja iznosi 1,51 km/h. Prosječna brzina privitlavanja lijevoga bubnja iznosi 1,91 km/h što je za 0,19 km/h veće od prosječne brzine privitlavanja desnoga bubnja koja iznosi 1,72 km/h. Prosječna brzina vožnje opterećenoga traktora po pomoćnom stovarištu iznosi 4,37 km/h, a neopterećenoga 4,90 km/h.

Norma vremena za udaljenost privlačenja od 25 do 250 m kreće se od 22,23 do 34,29 min/m³, a dnevni učinak uz prosječni obujam tovara od 0,762 m³ iznosi 21,59 m³/dan za udaljenost privlačenja 25 m odnosno 14,00 m³/dan za privlačenje na udaljenosti od 250 m. Temeljem kalkulacija tvrtke »Hrvatske šume« d.o.o. Zagreb za 2000. godinu i dnevnoga učinka izračunat je i jedinični dnevni trošak traktora C Holder 870 F koji se kreće od 69,16 kn/m³ za udaljenost od 25 m do 106,66 kn/m³ za udaljenost privlačenja od 250 m.

***Ključne riječi**: proredne bukove sastojine, C Holder 870 F, privlačenje uzbrdo, proizvodnost*

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