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Management of chipping operations in Polish forests †

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Abstract: The aim of the research was to verify the impact of selected parameters on the efficiency and organization of chippers' operation. The paper analyzes chipping operations in Polish forests with a focus on work site location, overnight chipper location, chipper workload per site, fuel consumption, and work shift duration, as all of these factors may affect operating efficiency. The mean chipper travel distance between sites during a shift ranged from 4.74 km to 9.5 km (chippers moved on average every other day). The mean work shift duration was 12.4 h. At the end of a shift, the chippers traveled on average from 4.2 km to 6.3 km to an overnight location. At the beginning of a work day, the chippers were dispatched to sites at a distance of 2.5 km to 4.0 km. The average fuel consumption of the forwarder-mounted chippers was 16 L/h, and that of the truck-mounted chipper was 7.7 L/h. It was found that the following actions have a decisive influence on the effectiveness of the operation of the chippers: determination of the size of individual tasks and the deplyment of successive forest areas, indication of the proper location of the machine base and the method of accessing the forest area.

Keywords: wood, chipper, organization, productivity

1. Introduction

To ensure efficient chipper operations, it is necessary to consider a number of crucial determinants, such as: workload per site (the amount of forest residues to be chipped at a given site), the distribution of forest sites where chipping operations take place, and overnight chipper locations. However, the efficiency of the chipper operation also depends on the type of raw material, its purity or size. Also, the number of stages in the technology of chip production makes the process more complex [1]. A characteristic feature of Polish forests is that harvest and thinning areas are often small and scattered, that results from the principles of silviculture applied in Poland, which means that chippers may need to travel multiple times during a work shift, which decreases their efficiency [2]. In many cases, the unit tasks related to the removal of logging residues (residues chipping and chip removal) are relatively small and do not take one working day, which requires appropriate long-term organization of operation. In this case, in order to maintain the proper course of operation, it is necessary to take into account the achievement of the required quality and efficiency of operation and the lowest possible costs of its implementation. Under the circumstances, cutting-edge IT tools

and systems can be used to improve economic results by monitoring and optimizing forestry operations [3]. The objective of the study was to determine the basic parameters characterizing wood chipper operations and efficiency in Polish forests.

2. Materials and Methods

The machines involved in the study were five Brucks 805 CT chippers including four units with 18 m3 containers (designated as CH#1–CH#4) mounted on forwarders (figure 1), and one unit without a container (CH#5) mounted on a truck. The chippers were used six days a week in varying terrain conditions. They were part of a fleet owned by one company and managed by the same team.

(**a**) (**b**)

Figure 1. The BRUKS 805 CT chipper: (a) chipping of logging residues, (b) unloading.

Data were obtained from the fleet management application ComboClient3. Each chipper was equipped with a GPS device connected to a computer that read data from sensors and transferred them to the server. The examined period of operations was five to seven months, from August–October of one year to February of the following year, depending on the chipper; the operations were conducted in north-eastern Poland [4].

In the process of removing logging residues, forwarders collect them from the forest floor and stack them at the roadside. A wood chipper is fed the residues from the stack, with the resulting chips being stored in its container. Then, the chipper travels to a chip truck (a tractor unit with a semi-trailer), unloads the chips onto the semi-trailer, and returns to the stack to continue chipping operations. The parameters analyzed in this study included: the distance between the stack and chip truck, the distance between the forest site and the overnight chipper location, work shift duration, fuel consumption per shift, the distance traveled by chippers between forest sites during a shift, and the number of site changes per shift (work day). The accuracy of the data obtained from the fleet management system was 1 min, 10 m, and 1 L for time, distance, and fuel consumption measurements, respectively.

3. Results and Discussions

The obtained results concerning chipping operations and their efficiency are given in Table 1.

The mean distance from the stack to the chip truck ranged from 0.28 km to 0.53 km, with the minimum and maximum values being 0.02 km and 5–6 km, respectively (the largest distances were recorded for CH#3 and CH#4 in November, when the weather and terrain conditions may have prevented trucks from approaching the forest sites.

The average distances between forest sites were large, ranging from 6.0 to 9.5 km, and also highly variable, with minimum and maximum values being 0.02 km and 73.62 km, respectively. In the case of CH#5 the minimum distance was sometimes 0.0 km, meaning that it did not move between forest sites during one day as its workload exceeded one shift, which is the most efficient arrangement. The dispersion of individual task sites makes it necessary to move the machine to tasks that are often located in a much distant working area. This means a loss of operating time, which leads to a decrease

in the daily machine performance and an increase in the cost of the entire process, as confirmed by previous analyses carried out by Nurek and Gendek [2].

At the end of the shift, the chipper was either left overnight at the forest site where it was used, moved to the next forest site in preparation of the next day's work, or taken to a location outside the site (usually a forester's lodge or other forestry facilities). The mean distances traveled by chippers at the end of the shift were shorter than those traveled during a shift, ranging from 4.2 km do 6.3 km. The minimum distances of 200 m indicate that in many instances the chippers were left directly at the forest site. The maximum distances were 25–39 km; in those cases the chippers probably traveled to sites where they were supposed to start work the following day. In Poland, due to concerns about the safety of the machine, contractors very rarely decide to leave it overnight in the forest.

Table 1. Parameters characterizing chipping operations and efficiency

Chipper	Mean	Min	Max	Chipper	Mean	Min	Max
Stack to chip truck distance (km)				Number of forest site changes per shift			
CH#1	0.47	0.02	2.72	CH#1	0.61	0.00	6.00
CH#2	0.28	0.02	2.87	CH#2	0.66	0.00	6.00
CH#3	0.33	0.02	5.06	CH#3	0.61	0.00	7.00
CH#4	0.53	0.02	6.06	CH#4	0.51	0.00	3.00
CH#5	-	-	-	CH#5	0.39	0.00	3.00
Distance per forest site change during a shift (km)				Shift duration (h)			
CH#1	6.02	0.07	29.28	CH#1	12.75	0.00	20.75
CH#2	6.53	0.06	36.30	CH#2	12.35	0.98	20.55
CH#3	4.74	0.02	34.30	CH#3	11.84	0.00	21.53
CH#4	7.61	0.06	73.62	CH#4	13.09	0.37	23.67
CH#5	9.48	0.00	60.52	CH#5	11.87	0.40	18.53
Forest site to overnight location distance (km)				Fuel consumption (L/h)			
CH#1	5.46	0.00	31.73	CH#1	17.41	1.57	38.61
CH#2	4.20	0.02	25.57	CH#2	16.91	0.66	36.96
CH#3	5.65	0.02	33.83	CH#3	16,25	0.00	36.05
CH#4	6.30	0.05	39.36	CH#4	16,12	0.00	44,43
CH#5	6.01	0.06	31.52	CH#5	7,77	0,31	26,44
Overnight location to forest site distance (km)							
CH#1	2.52	0.00	11.62				
CH#2	3.30	0.02	20.43				
CH#3	3.45	0.02	31.50				
CH#4	4.00	0.02	33.33				
CH#5	3.43	0.02	18.08				

The mean distances from overnight locations to forest sites ranged from 2.52 km to 4.0 km, which is less than the end-of-shift values. Similarly as in the previous case, minimum values were below 0.02 km for chippers that continued operations at the same site the following day. Maximum distances from overnight locations to forest sites were 11.6–33.3 km, which is again less as compared to the end of the shift. This indicates that the chippers tended to start work at sites that were closer to their overnight locations, which also reduced chipper travel time.

The chippers moved between forest sites on average 0.39 to 0.66 times a day (more or less once every two days). Minimum and maximum values indicate that while during some work shifts the chippers stayed on the same sites, on other days they made up to six or seven trips, depending on the assigned workload at a given site. Maximum trip numbers were found in the winter months (December, January, and February), which may be attributable to adverse weather conditions and

snow cover. It is often the case that in wintertime some logging residues are left under the snow, and when it melts away the chipper must return to remove them, which decreases chipper efficiency due to additional trips.

The mean measured shift durations ranged from 11.84 h to 13.09 h, which roughly reflects the work schedule adopted by the company whose machines were analyzed (12 h, from 6.00 a.m. to 6.00 p.m.). Minimum shift durations of less than 1 h were caused by chipper breakdowns soon after starting work. Some records also showed 0.00 h shifts; according to the operators they were attributable to instances when chippers were briefly turned on and off while being serviced, thus generating shift start and finish signals. On the other hand, maximum shift durations reached approx. 20 h and more because of organizational failures (e.g., delayed arrivals of chip trucks preventing further chipping operations) or chipper downtime in situations when the assigned workload had to be completed on a given day with the chipper moving to a distant location the following day.

The mean fuel consumption ranged between 7.77 L/h and 17.41 L/h, with the lowest value found for CH#5 (the other chippers used twice as much fuel, at approx. 16 L/h). Minimum fuel consumption for individual chippers was less than 1 L/h. Similarly as in the case of shift duration, it was observed in a situation when a chipper did not perform work, but was briefly turned on for servicing purposes. Maximum fuel consumption for chippers working under a heavy load was approx. 44 L/h, which is consistent with literature data [5–7].

4. Conclusions

The efficiency of chipper use depends on the organization of chipping operations, and in particular workload per site (the number of site changes per shift), the distribution of work sites and overnight chipper locations (which translates into travel distances during a shift and between shifts), as well as forest site availability to road transport (the distance from the stack of processed forest residues to the chip truck).

The mean distance between the stack and the chip truck ranged from 0.28 km to 0.53 km. While the manager responsible for operations aimed to minimize that distance, it was not always possible due to terrain conditions, with the distance exceeding 2 km in some extreme cases.

Other major aspects of chipping operations included workload per site, the distance between chipping sites, and the number of site changes per shift. The results show that the managers tried to organize operations in such a way as to maximize chipper work time at one site and minimize the number of site changes per shift. It was found that the forwarder-mounted chippers moved between sites on average once every two days, and the truck-mounted chipper once every 2.5 days.

Of importance is also the distance between forest sites and overnight chipper locations as well as between those locations and the sites scheduled for the following day. It was found that chippers which were not supposed to move to another forest site were usually left overnight at their current sites. At the same time, the manager aimed to plan overnight chipper locations with a view to minimizing the distance to the next forest site the following day. As a result, while mean distances from forest sites to overnight locations were 4.20–6.30 km, those from overnight locations to forest sites were shorter by approx. 50% (2.52–4.0 km). The recorded shift duration of 12.41 h was slightly longer than the scheduled operator shift time of 12 h.

Last but not least, analysis of chipper fuel consumption enables the operators to optimize refueling times and the managers to plan fuel supplies for individual chippers.

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