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The chipping cost of wood raw material for fuel in Estonian conditions

Marek Irdla*, Allar Padari, Vahur Kurvits and Peeter Muiste

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Abstract. In Estonia up to now the producers of wood fuels have not yet adequately analysed the production and transport costs although it is known that the share of these costs form up to half of the final price of wood chips or hog fuel. With this in mind the goal of the case study was defined – to analyse the price formation of comminuted wood fuels in Estonian conditions. Within one year of the survey the initial data was collected from the company SLG Energy. Different types of machines (7 in total) were observed – wood chippers Jenz HEM 561, Jenz HEM 582, Heinola 910ES, and Doppstadt DH 608. All machines were equipped with a GPS tracking device which recorded the route and the fuel consumption and during the observation period all costs and revenues related to the concerned machines were accounted. It was determined that due to frequent repairs the maintenance costs of older machines were higher and productivity lower compared with new machines. The biggest item of expenditure turned out to be the fuel consumption. The second was the cost of repairs in the case of older machines and price in the case of new machines. Also the type of chipper had an impact on the production cost. Under the cumulative effect of various factors the production cost turned out to vary widely from 1.03 to 2.38 €/m_i^3.

Key words: wood chippers, productivity, production cost.

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Introduction

Year by year, the demand for wood chips has been growing globally and also in Estonia where, in the last years the number boiler plants working on wood has grown by new installations and reconstruction of existing boilers. In addition, several wood pellet and briquette plants have started operating, which has contributed to the growth in wood chip production. In 2010−2014 agricultural enterprises had the opportunity to apply for support from the Estonian Agricultural Registers and Information Board to purchase wood chippers as part of rural diversification. The purchases were funded by the agency to a maximum of 50%. As the demand for wood chips and the support programme coincided, a large number of wood chippers were purchased in Estonia. However, different problems are faced by prospective operators who are equipping to get into the chipping business and need as much information as possible on the performance of their equipment (Spinelli & Magagnotti, 2014). Many enterprises that purchased a wood chipper had no previous experience with chippers and therefore, they lacked any knowledge of the wood chipping process and related costs.

Chipper productivity has been explored with many studies, but not yet in Estonia, documenting the performance of a wide

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range of wood chipping equipment under a variety of work conditions (Asikainen & Pulkkinen, 1998; Talbot & Suadicani, 2005; Mitchell & Gallagher, 2007; Marchi *et al*., 2011; Spinelli & Magagnotti, 2014).

The goal of this study was to produce reliable estimates for the long-term productivity, fuel consumption, repair cost, manpower cost, depreciation cost and incidental expenses of industrial chippers under typical conditions in Estonia.

For a cost analysis of wood chip production the initial data was collected from SLG Energy OÜ, one of the largest producers and transporters of wood chips in Estonia since 2004. Outside Estonia, the company is also operating in Latvia, Lithuania, Finland, Sweden and Russia. The company's annual output of wood chips in 2013 was 1,114,460 m_l^3 produced by drum chippers and 214,279 m_l^3 produced by hammer mills (Irdla *et al*., 2016). The company's turnover was 7.8 million euros a year and the average number of employees was 81. The average monthly labour cost per employee in forestry sector in year 2013 was 1,121 euros before taxes (Statistikaamet, 2017).

The annual output of the wood chippers observed in this study remained between 43,446 and 112,290 m_l^3 of wood chips. The total output of seven wood chippers amounted to 579,116 m_l^3, which equals 82,730 m_l^3 of mean annual production per wood chipper.

Material and Methods

Since the majority of the production of SLG Energy OÜ (Estonia) in 2013 was manufactured by drum chippers, seven chippers among them were randomly selected for analysing costs related to the chippers. All observed chippers were drum chippers which are the most widely used across Europe (Spinelli & Magagnotti, 2014) and dominating in Estonia.

This study was carried out in 2013. Out of the 15 wood chippers that were operated in the enterprise during the study period, seven were observed: Jenz HEM 561 DQ (JENZ GmbH Maschinen- und Fahrzeugbau, Germany) was represented by three machines, Jenz HEM 582 DQ (JENZ GmbH Maschinen- und Fahrzeugbau, Germany) by two machines and Doppstadt DH 608 (Werner Doppstadt Umwelttechnik GmbH & Co., Germany), and Heinola 910 ES (Heinola Sawmill Machinery Inc., Finland), both by one machine (Figure 1).

During the observation period all costs and revenues related to the concerned machines were accounted. All costs and revenue related to the chipper have put in the Directo accounting program. Personal account created for each chipper and its operator reflects all expenses per calendar month, as well as all earned income. Monthly data was constantly analysed to improve the efficiency. All the operators, whose machines were the subject of a study had at least two years of work experience with chippers, and all had the prior work experience either as a forwarder and harvester operator or forest truck driver. During the study period, the operators did not work overtime and all taxes related to labour costs were calculated in accordance with Estonian legislation. All wood chippers were operated by one person per chipper and hence, work was done in one shift with a maximum duration of ten hours. Instead of estimating transportation costs by calculating costs per kilometre, this study made use of bulk cubic metres.

The fuel consumption of the wood chippers also includes the fuel used by the chippers for moving between various operating sites in Estonia and North-Latvia. The average annual transport distance between sites was 16,500 km. Its share of the total fuel consumption was less than 10% and it was similar to all types of chippers, excluding Doppstadt DH 608. Due to that this cost was considered as a production cost and no separate account was taken. Each chipper had its personal fuel cards which could be used only to refuel

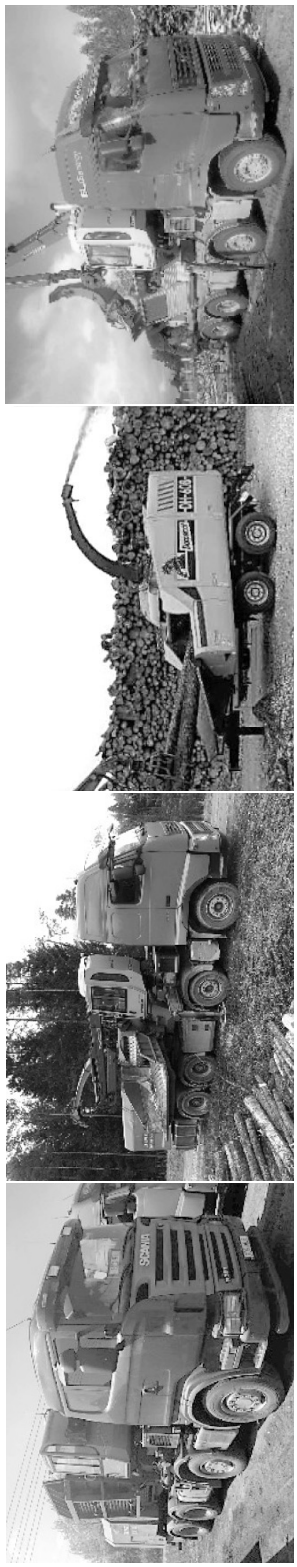

Figure 1. Observed wood chippers Jenz HEM 561, Jenz HEM 582, Doppstadt DH 608 and Heinola 910ES.
Joonis 1. Uuringus osalenud hakkurid JenzHEM 561, Jenz Hem 582, Doppstadt DH 608 ja Heinola 910ES.

that particular chipper. Monthly analysis of consumed fuel and output of produced wood chips was carried out. A monitoring system was used to observe the fuel consumption, mileage and to determine the location of the chipper. During the observation period the average price of diesel in Estonia was 1.020 + 20% (VAT) EUR.

The tracking system used was Navirec. Navirec system makes it possible to monitor objects supplied with special devices. These devices use GPS or GLONASS to position the vehicle and send this data, including speed, status of special equipment etc., via a mobile network (GPRS) to Navirec servers. This information can then be viewed in real-time on a map and can also be analysed using playback view or by generating statistical tables (Navirec, 2017).

Doppstadt DH 608 was used in port terminals and on storage sites of sawmills and of enterprises producing wood pellets. This type of a chipper was used to chip round timber and sawmill industry waste. All other types of chippers were operated in very different conditions and used for chipping mainly harvesting residues, tree stems, sawmill industry residues and, to a lesser extent, round timber.

The main difference between Jenz HEM 561 DQ and Jenz HEM 582 DQ lies in the size of the intake opening, which is larger in Jenz HEM 582 DQ, and in the number of knives in the drum. Correspondingly, this results in a different volume of output per hour.

Results

The observation period extended from 01.01.2013 to 31.12.2013. During the period, the actual production of all wood chippers was recorded and resulting from this, also the fuel consumption was registered. In addition to fuel consumption, production, costs on manpower, depreciation, repair costs and incidental expenses were

Table 1. Data from chippers who participated in the study.
Tabel 1. Uuringus osalenud hakkurite andmed.

Chipper *Hakkur*	Doppstadt DH 608	Jenz HEM 582 DQ	Jenz HEM 561 DQ	Heinola 910ES
Truck *Veoauto*		Volvo	Scania	Volvo
Model *Mudel*		FH 540	R380	FH 540
Truck power (kW/hp) *Auto mootori võimsus (kW/hj)*		405/550	280/375	405/550
Chipper engine *Hakkuri mootor*	DaimlerChrysler	Mercedes-Benz	Mercedes-Benz	powered by truck
Year *Väljalaskeaasta*	2009	2011	2008	2010
Power (kW/hp) *Mootori võimsus (kW/hj)*	360/490	205/280	206/280	407/550
Drum diameter (mm) *Trumli läbimõõt (mm)*	1000	820	820	900
Knives (number) *Nugade arv*	4	24	20	2
Output (m_l^3/h) *Tootlikkus (m_l^3/h)*	100 –150	180	150	300
Main raw material *Peamine tooraine*	L; SR	L; HR; SR; WT	L; HR; SR; WT	L; HR; SR; WT

Main raw material: L – logs; HR – harvesting residues; SR – sawmill residues; WT – whole trees.
Peamine tooraine: L – notid; HR – raiejäätmed; SR – saetööstuse jäätmed; WT – kogupuu.

ascertained for each wood chipper. During the observation period 7 examined wood chippers produced a total of 579,116 m_l^3 of wood chips. The total fuel consumption for chipping was 343,244 litres, which constitutes the annual average fuel consumption of 0.593 l/m_l^3 per wood chipper.

Average output was 89.2 m_l^3/h: Doppstadt DH 608 – 99.3; Jenz HEM 582 DQ – 101.2; Jenz HEM 561 DQ – 78.2 m_l^3/h and Heinola 910 ES – 77.4 m_l^3/h. We can draw the conclusion that the output in production conditions is much less compared to the factory data (Table 1) – 79, 52, 56 and 26% correspondingly.

Doppstadt DH 608

During the observation period, the wood chipper produced a total of 107,267 m_l^3 of wood chips and their average fuel consumption was 0.450 l/m_l^3. While Doppstadt was working primarily on vast storage areas, other wood chippers were constantly moving between different objects. For this reason, the fuel consumption of these chippers was somewhat higher per bulk cubic metre than that of Doppstadt.

The distribution of costs is shown in Figure 2A. Based on the figure, it may be concluded that in the case of Doppstadt DH 608, the major item of expenditure was fuel, which made up 37% of total expenditure. Fuel consumption was followed by costs on manpower, which constituted 30% of total expenditure. Repair costs and incidentals both attributed to 9% and depreciation comprised 17% of total expenditure.

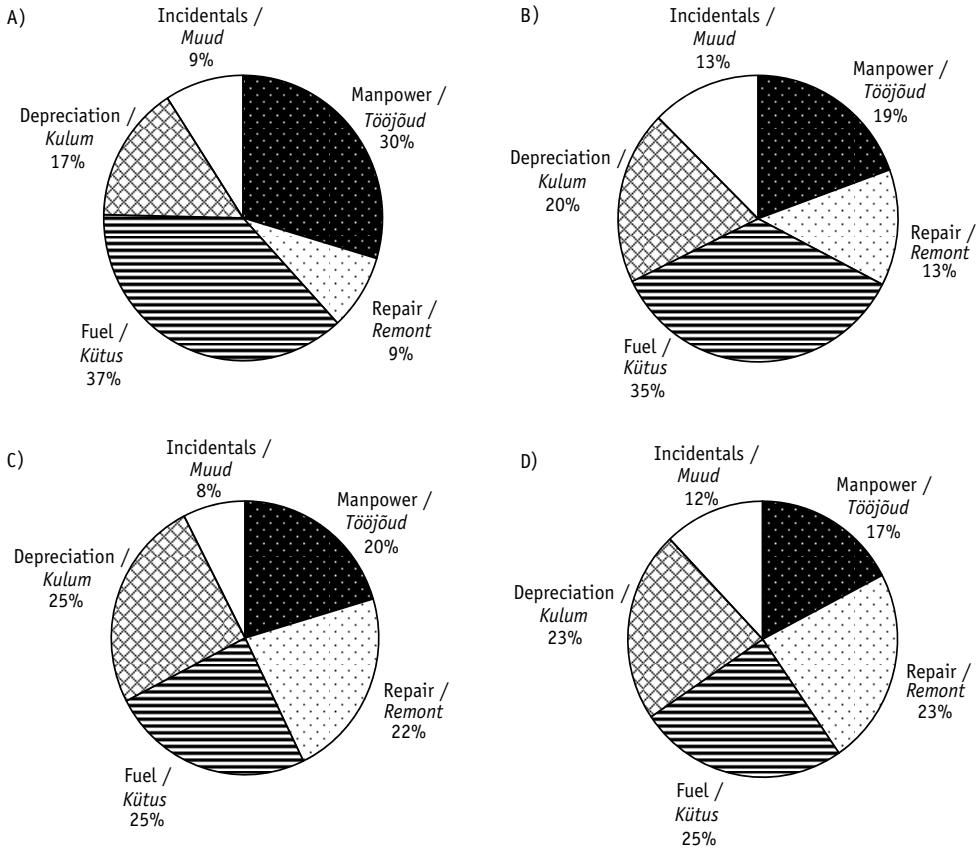

Figure 2. Distribution costs – A) Doppstadt DH 608, B) Jenz HEM 582 DQ, C) Jenz HEM 561 DQ and D) Heinola 910 ES.

Joonis 2. Kulude jaotus – A) Doppstadt DH 608, B) Jenz HEM 582 DQ, C) Jenz HEM 561 DQ and D) Heinola 910 ES.

Jenz HEM 582 DQ

During the observation period, these wood chippers produced a total of 217,590 m_l^3 of wood chips and their average fuel consumption was 0.616 l/m_l^3.

The distribution of costs is shown in Figure 2B. Based on the figure, it may be concluded that in the case of Jenz HEM 582 DQ, the major item of expenditure was fuel, which made up 35% of total expenditure. Fuel consumption was followed by costs on depreciation, which constituted 20% of total expenditure. Costs on manpower formed 19% and costs on repair and incidentals comprised 13% of total expenditure.

Jenz HEM 561 DQ

During the observation period, these wood chippers produced a total of 180,750 m_l^3 of wood chips and their average fuel consumption was 0.690 l/m_l^3.

The distribution of costs is shown in Figure 2C. Based on the figure, it may be concluded that in the case of Jenz HEM 561 DQ, the major item of expenditure was fuel and depreciation, both of which made up 25% of total expenditure. Fuel consumption and depreciation were followed by costs on repair, which constituted 22% of total expenditure. Costs on manpower formed 20% and costs on repair and incidentals comprised 8% of total expenditure.

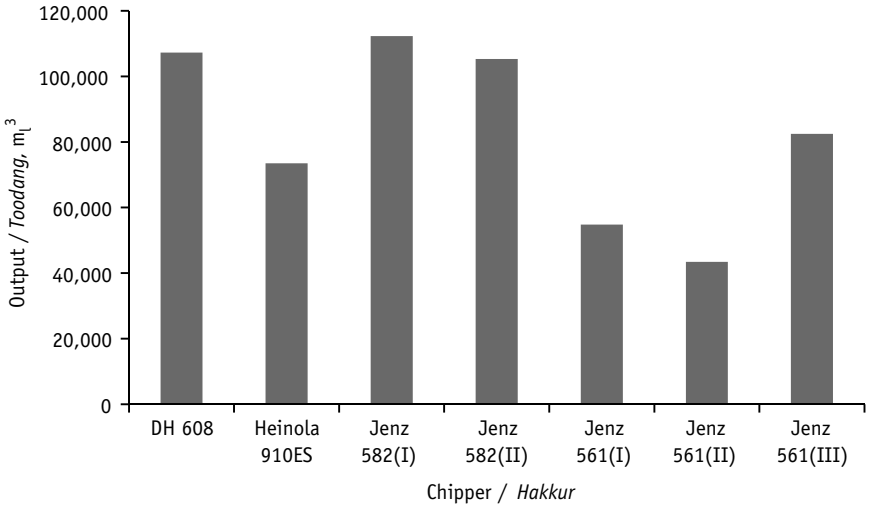

Figure 3. Wood chip production in 2013.
Joonis 3. Puiduhakke toodang 2013.

Heinola 910 ES

During the observation period, the wood chipper produced a total of 73,509 m_l^3 of wood chips and their average fuel consumption was 0.495 l/m_l^3.

The distribution of costs is shown in Figure 2D. Based on the figure, it may be concluded that in the case of Heinola 910 ES, the major item of expenditure was fuel, which made up 25% of total expenditure. Fuel consumption was followed by costs on depreciation and repair, which both constituted 23% of total expenditure. Costs on manpower formed 17% and incidentals comprised 12% of total expenditure.

This study observed 7 wood chippers with very different annual output rates. In order to illustrate the differences in annual output rates (in bulk cubic metres) of the same type of machines, the following Figure 3 was drawn. Major differences in the production of machinery is caused by age, because older machines require more repair. It is well seen in the production of Jenz HEM 561 DQ.

Similarly to the figure showing wood chip production, we were able to draw a figure showing the fuel consumption of each observed wood chipper separately by using existing data. When we compare the data on Figure 3 and Figure 4, it may be concluded that the fuel consumption of low-productivity wood chippers may be even higher than in large-capacity wood chippers. This naturally depends on the distances between objects as well as on the size of the objects. When two analogous machines chip wood of up to 10,000 m_l^3 per month and one of them covers 500 kilometres to achieve this but the other needs to cover 2,000 kilometres for the same purpose, this results in a considerable difference between the fuel consumption per one bulk cubic metre.

The following Figure 5 shows, the effect of age of the chipper on the production cost. As the age rises, the share of repairs increases most and the share of fuel remains virtually unchanged.

The effect of the age of the chipper on the production cost can be described by a linear the formula:

$$C = a + b \times A,$$

where C – expenditure, EUR/m_l^3;
A – age of the chipper, year;
a, b – formula coefficients (Table 2).

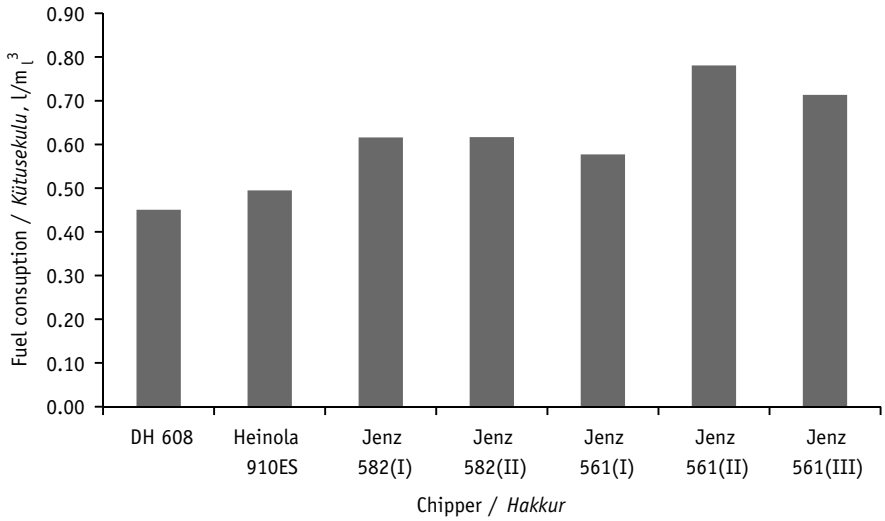

Figure 4. Fuel consumption of chippers.
Joonis 4. Hakkurite kütusekulu.

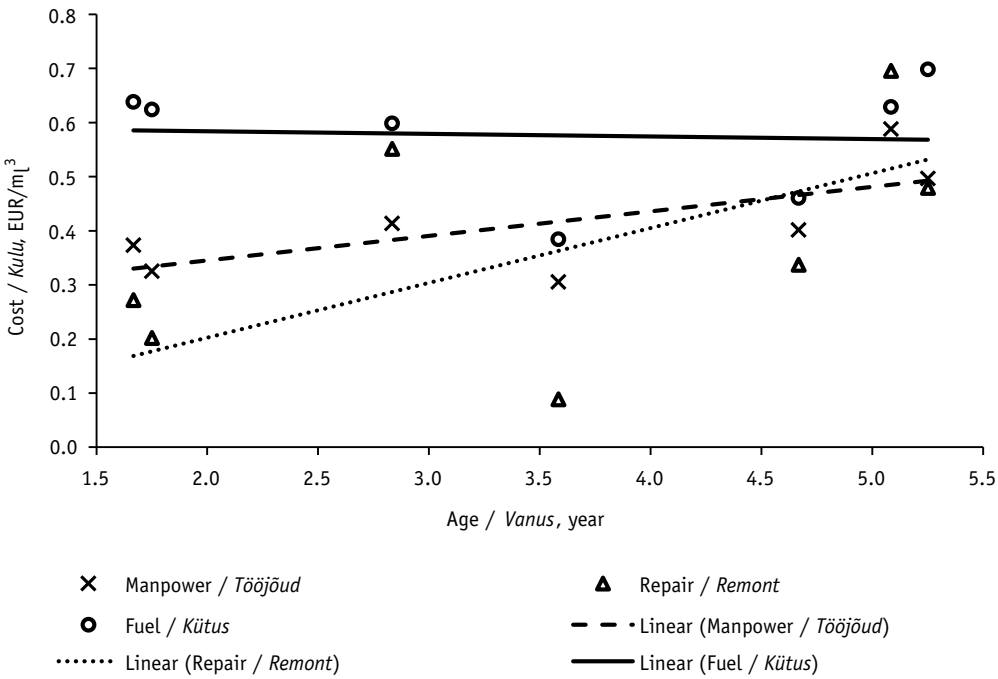

Figure 5. The effect of age of the chipper on the production cost, EUR/m³.
Joonis 5. Vanuse mõju hakkuri toodangu maksumusele.

Table 2. Parameters of formula 1.
Tabel 2. Valem 1 parameetrid.

Cost type / *Kululiik*	*a*	*b*	Standard error *Prognoosiviga*	R^2	*p*-value *p-väärtus*
Fuel / *Kütus*	0.593	-0.0048	0.122	0.065	0.889
Repair / *Remont*	0	0.1013	0.187	0.912	0.003
Manpower / *Tööjõud*	0.254	0.0454	0.078	0.696	0.082

Table 3. Average expenditure and production.
Tabel 3. Keskmised kulud ja toodang.

	Doppstadt DH608	Jenz HEM 561DQ	Jenz HEM 582DQ	Heinola 910ES
Produced wood chips, m_l^3 *Toodetud hakkpuitu, m_l^3*	107,267	60,250	108,795	73,509
Fuel, €/m_l^3 *Kütus, €/m_l^3*	0.384	0.573	0.631	0.599
Repair costs, €/m_l^3 *Remont, €/m_l^3*	0.089	0.523	0.236	0.552
Depreciation, €/m_l^3 *Kulum, €/m_l^3*	0.160	0.585	0.352	0.536
Manpower, €/m_l^3 *Tööjõud, €/m_l^3*	0.306	0.476	0.349	0.414
Incidentals, €/m_l^3 *Muud, €/m_l^3*	0.094	0.176	0.226	0.288
Total cost, €/ m_l^3 ***Kogukulu, €/m_l^3***	**1.033**	**2.332**	**1.794**	**2.388**

The available data indicates that the increasing age of chipper has little impact on consumption of fuel ($p > 0.05$), moderate impact on increase of labour cost ($p > 0.05$) and significantly rise the repair costs ($p < 0.05$). The parameters of the formula are given in Table 2.

Based on all data collected, Table 3 was compiled which shows the amount of wood chips produced by the chippers and all costs incurred in the production process. Since there was more than one chipper of the same type, the arithmetic mean values were calculated for the costs and production of Jenz HEM 561 DQ and Jenz HEM 582 DQ.

Discussion and Conclusions

Based on the data collected on the wood chippers, it may be suggested that the main item of expenditure in the case of all the chippers was fuel consumption, followed by depreciation and repair costs.

The results of our research can be compared with the data from a similar study in 2014 (Spinelli & Magagnotti, 2014), where the working hours of the observed chippers were 1203 h y^{-1}, mileage 12,925 km y^{-1}, fuel consumption 47,578 l y^{-1} and output volume of 85,697 m_l^3. The observed chipper in our study was characterized by data: the working hours of the observed chipper were 927 h y^{-1}, mileage 16,571 km y^{-1}, fuel

Table 4. Average expenditure excluding Doppstadt DH 608.
Tabel 4. Keskmised kulud ilma Doppstadt DH 608.

	Jenz HEM 561DQ	Jenz HEM 582DQ	Heinola 910ES	**Average** ***Keskmine***
Produced wood chips, m_l^3 *Toodetud hakkpuitu, m_l^3*	60,250	108,795	73,509	**78,642**
Fuel, €/m_l^3 *Kütus, €/m_l^3*	0.573	0.631	0.599	**0.604**
Repair costs, €/m_l^3 *Remont, €/m_l^3*	0.523	0.236	0.552	**0.395**
Depreciation, €/m_l^3 *Kulum, €/m_l^3*	0.585	0.352	0.536	**0.470**
Manpower, €/m_l^3 *Tööjõud, €/m_l^3*	0.476	0.349	0.414	**0.408**
Incidentals, €/m_l^3 *Muud, €/m_l^3*	0.176	0.226	0.288	**0.216**
Total cost, €/ m_l^3 ***Kogukulu, €/m_l^3***	**2.332**	**1.794**	**2.388**	**2.171**

consumption 49,035 l y^{-1} and output volume of 82,730 m_l^3. We can draw the conclusion, that though the working conditions and processed raw material were different, the results were very similar.

By using existing data, the average expenditure of all wood chippers could be calculated. We separated the data for Doppstadt DH 608 from the general data because this wood chipper was operated primarily on large storage sites and wood terminals, which kept its costs lower, but would have influenced the average expenditure. Data gathered on the remaining 6 wood chippers that worked in different conditions and chipped different material are described in Table 4.

Jenz HEM 582 DQ chippers produced the highest annual output with twice as low expenditure on repairs and spare parts than in the case of other chippers. Thus, it may be concluded that using Jenz HEM 582 DQ wood chippers is the most cost-efficient, because their expenditure on chipping one bulk cubic metre constituted EUR 1.794. However, the costs on repairs and spare parts are likely to increase as the wood chippers age and depreciate.

References

Asikainen, A., Pulkkinen, P. 1998. Comminution of logging residues with evolution 910R chipper, MOHA chipper truck, and Morbark 1200 tub grinder. – Journal of Forest Engineering, 9(1), 47–53.

Irdla, M., Padari, A., Muiste, P. 2016. The alternatives of transport of wood chips in Estonian conditions – a case study. – Baltic Forestry, 22(2), 163−168.

Marchi, E., Magagnotti, N., Berretti, L., Neri, F., Spinelli, R. 2011. Comparing terrain and roadside chipping in Mediterranean pine salvage cuts. – Croatian Journal of Forest Engineering, 32(2), 587–598.

Mitchell, D., Gallagher, T. 2007. Chipping whole trees for fuel chips: a production study. – Southern Journal of Applied Forestry, 31(4), 176–280.

Navirec. 2017. Solutions. Navirec OÜ. [WWW document]. – URL https://www.navirec.com/solutions/ [Accessed 04 May 2017].

Spinelli, R., Magagnotti, N. 2014. Determining long-term chipper usage, productivity and fuel consumption. – Biomass and Bioenergy, 66, 442–449.

Statistikaamet. 2017. Average monthly gross and net wages (salaries) by Year. 2017. [WWW document]. – URL https://www.stat.ee/wages-and-salaries-and-labour-costs [Accessed 08 Aug 2017].

Talbot, B., Suadicani, K. 2005. Analysis of two simulated in-field chipping and extraction systems in spruce thinnings. – Biosystems Engineering, 91(3), 283–292.

Puidu hakkimiskulude analüüs Eesti tingimustes

Marek Irdla, Allar Padari, Vahur Kurvits ja Peeter Muiste

Kokkuvõte

Eestis ei ole veel väga põhjalikult analüüsitud hakkpuidu tootmis- ja transpordikulusid, mis võivad moodustada isegi kuni poole toodangu lõpphinnast. Käesoleva uuringu eesmärgiks oli välja selgitada hakkpuidu tootmiskulude kujunemist Eestis.

Ühe aasta jooksul (01.01.–31.12.2013) koguti ettevõtte SLG Energy OÜ erinevate puiduhakkuritega seotud kuluandmed ja toodangumahud. Valimis olid erinevate tootjate masinad (kokku 7 hakkurit) – puiduhakkurid Jenz HEM 561, Jenz HEM 582, Heinola 910ES, Doppstadt DH608. Kõik masinad olid varustatud GPS jälgimisseadmetega, mille kaudu sai teada masinate kütusekulu ja liikumisteekonna. Vaatlusperioodi jooksul fikseeriti kõigi uuritud masinate kulutused ja hakketoodangu mahud.

Vaatlusandmete põhjal tehti kindlaks, et vanemate masinate hoolduskulud olid enamate remontide tõttu, suuremad ja toodangu mahud madalamad võrreldes uuemate masinatega. Kõige suuremaks kuluartikliks osutus kütus. Suuruselt teiseks kuluartikliks oli vanematel masinatel kulu remondile ning uuematel tööjõukulu.

Lisaks mõjutas tootmiskulusid puiduhakkuri tüüp. Kõikide kuluartiklite koosmõjul jäid puiduhakke tootmiskulud erinevate puiduhakkurite puhul vahemikku 1,03–2,38 EUR/puiste m^3.

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