 DOI:10.22616/rrd.23.2017.016

COMPARISON OF PRODUCTIVITY OF VIMEK HARVESTER IN BIRCH PLANTATION AND YOUNG CONIFEROUS STANDS

Agris Zimelis, Andis Lazdiņš, Gints Spalva
Latvian State Forest Research Institute 'Silava'
agris.zimelis@silava.lv

Abstract
The aim of the study was to compare the productivity and logging costs using the small class harvester Vimek 404 T5 in thinning of birch plantations and young coniferous stands. It was found in the study that due to a lower fuel consumption, maintenance costs and initial investment, the cost of a working hour of the harvester Vimek 404 T5 is significantly smaller than the cost of a working hour of the middle class harvester. The study confirmed that Vimek 404 T5 is a suitable harvester for thinning in a birch plantation; the study also confirmed the previous conclusions about the main advantages of Vimek harvester compared to a middle class harvester in the first thinning – low fuel consumption and costs of maintenance, high productivity and equipment compactness, which allow to reduce the strip road area. The average productivity for Vimek 404 T5 in birch plantation was 6.2 m^3 per productive hour, but in young conifer stand the productivity was 4.9 m^3 per productive hour. The average stem volume in the birch plantation was 0.06 m^3, but in conifer stand 0.05 m^3. Productivity for the same dimension trees in the birch plantation is not significantly different from the data obtained in the thinning of the coniferous stands.
Key words: productivity, Vimek 404 T5 harvester, thinning.

Introduction

Vimek 404 T5 is one of the smallest serially produced harvesters which is available in the market (Lazdiņš *et al*., 2016). This forest machinery is at least two times lighter than a middle class harvester (4.4 tons versus 10…12 tons). To work for JSC 'Latvia state forests' (LVM) as a service provider, the harvester measuring system must comply with StanForD-standard (Räsänen *et al*., 2010).

Only few studies on small forest machinery are implemented in the Nordic and Baltic region. A study in Sweden compared a conventional forest machinery with the smallest class forest machinery. The aim of the research was to determine economic gain in the first and second thinning, and also the impact on the remaining trees – how they react to wind and how the health condition changes in the stand. Leaving more trees on the strip roads in the first thinning when working with Vimek results in a bigger economic gain in the second thinning, which can be carried out with a middle class harvester (Jonsson, 2014). No differences were found in this study regarding forest health and wind damages in further years.

Using small machinery in the forest operations leads to a lesser number of damaged trees, which is approved by research carried out in Sweden. The study analyzed productivity, but it also addressed damages to the remaining trees and the possibilities of increasing the quality of the operation. The main advantages of small harvester are improved maneuverability and operator's location closer to the processed trees, which allows a better control of the felling and bucking while preserving the remaining trees.

In the studies of Latvian researchers in Sweden, it was found that forwarder Vimek 610 is more suitable in the early thinning than middle class forwarder. The forwarder used in the study was equipped with a tilt grapple which allows you to move logs in a vertical position, as it can be done with harvesters (Zimelis *et al*., 2016). The tilt crane allows loading of logs into forwarder following to the trajectory of the harvester crane.

In thinning the felling can be done in two ways, either with a chainsaw or harvester (Mederski, 2006). Working with Vimek 404 harvester secures a significantly better productivity than mechanized logging with chainsaw and, at the same time, without a significantly higher impact on the remaining stand (Zimelis *et al*., 2016).

An alternative for small class forest machinery is middle class forest machinery, equipped with a special grapple, which only allows production of biomass for energy. In theory, the advantages of these machines are higher productivity, but they require specialized strip road schemes and it results in a considerably smaller net income, because biofuel is still considerably less valuable in comparison to roundwood assortments (Bergström *et al*., 2010; Bergström *et al*., 2007).

The aim of the study was to compare the productivity and logging costs using small class harvester Vimek 404 T5 in the thinning of birch plantations.

Materials and Methods

Small class harvester Vimek 404 T5 was used in the study, which was carried out in LVM and JSC 'Latvijas Finieris' (LF) forests. Characteristics of the forest stands in LVM are provided in Table 1. LF stands were birch plantations located in the southwestern part of Latvia. Plantations were established on agricultural land where soil had been prepared before planting.

Table 1

Stand characteristics

Stand	Stand number	Average tree diameter, cm	Species	Forest type	Regeneration	Stand age, years	Area, ha
601-186-12	1	11.2	Pine	Mr	Artificial	37	3.4
602-28-19	2	14	Spruce	Mr	Artificial	26	1.9
602-32-8	3	8.9	Spruce	Dms	Artificial	39	1.3
711-358-5	4	8.8	Spruce	Vr	Artificial	26	3.5
601-186-16	5	16.2	Pine	Mr	Artificial	67	3.3
602-46-29	6	11	Spruce	Dm	Artificial	32	0.7
602-74-7	7	9.7	Birch	Vr	Natural	18	2.7

The average diameter of a tree – 11 cm; the number of trees – 1700 per ha.

During working process, the working time accounting was carried out with a specialized field computer Allegro II. The computer was equipped with a time study program SDI. Working time was split into 10 work elements and other operations (Table 2). Breaks and other activities that do not comply with the table set-time elements are described in notes. Time studies do not include preparatory work, which takes about 1 hour a day, but the working time records include moving part lubrication that is normally carried out during the shift. Time tracks were recorded in centiminutes (1min = 100 centiminutes).

The same operators of forest machinery were employed in both – young coniferous stands and birch plantations. Operators worked in 8 hours shifts.

In the birch plantations, two types of logs were produced – pulp wood and biofuel, which was determined by dominant tree dimensions in the plantation. Roundwood assortments in LVM stands were produced according to the company internal rules for roundwood production (JSC 'Latvia state forests', 2017). Biofuel in LVM stands was produced as firewood and partly delimbed small wood from tree tops. No residues were extracted for biofuel production, consequently, operators could leave residues distributed across the stand as far as they

Table 2

Working elements for time studies in a field work

Working time category	Working element numeration	Explanation
Information fields	1	Work cycle number
	2	Diameter of processed tree, d1.3, cm
	3	Number of processed trees per operation
	4	Felled half trunks
	5	Various notes, including brakes, travel, strip-road change etc.
Productive working time	6	Reaching for tree with crane
	7	Positioning of felling head
	8	Cutting of tree
	9	Delimbing and bucking
	10	Delimbing times (how many times trunk was dragged through delimbing knives)
	11	Log moving and stacking
	12	Undergrowth cutting
	13	Time spent on driving into a stand
	14	Time spent on leaving a stand
	15	Other non-standard operations, including machine maintenance
Unproductive time	16	Time spent on activities not related to harvesting

Table 3

Produced roundwwood volume (above bark) and characteristics of processed trees

Stand	Number of processed trees	Average diameter of processed tree, cm	Volume of processed trees, m^3	Average volume of processed tree, m^3
Plantation	1101	10 (± 1.33)	69	0.063
Naturally regenerated stand	2012	8 (± 3.25)	92	0.045
Artificially regenerated stand	11981	11 (± 4.47)	2600	0.085

were not making obstacles for piling of roundwood assortments.

In the birch plantations and young forest stands, the undergrowth trees with a diameter of less than 6 cm were left growing or felled down if they interfered with the harvester productivity, or a space for loading of logs had to be cleaned. Strip roads were organized asymmetrically and winding (bypassing the remaining target trees).

Air temperature during the study in the birch plantations ranged from 16 to 18 °C. Logging in the birch plantations took place from 12.09.2016 till 16.09.2016. Air temperature during the study in the young forest stands ranged from 6.5 to 24.9 °C. Logging in the young forest stands took place from 3.06.2016 till 15.08.2016.

Results and Discussion

Characteristics of the extracted trees and roundwood in the LVM and LF stands are given in Table 3. Stands are grouped by owners and regeneration type. In total, 46 stands were thinned in LF owned plantations. Detailed time studies were done in about 2 ha area.

Altogether, during the trials 16.8 ha were thinned by Vimek 404 T5 harvester. The proportion of felled trees divided by the diameter classes in each stand is provided in Fig. 1 and Fig. 2. Minimum diameter of the trees to be processed (delimbed and bucked) is set to 6 cm, based on the previous studies on impact of the tree diameter on the harvesting productivity (Lazdiņš *et al*., 2016). Smaller trees were felled mainly because they hindered productive work. Those small trees were felled and processed as biofuel or left intact. The dominant diameters in the group of extracted trees were from 8 to 14 cm.

The diameter distribution of extracted trees depending on the diameter of the average harvested tree in the birch plantation and coniferous forest stands is characterized by Weibull equation (parameters of the equation are provided in Table 4). This equation is used to model the prime cost of extraction depending on the average diameter of the extracted trees.

Productivity curve depending on the diameter of extracted trees can be characterized by polynomial equation (Error: Reference source not found). Comparing the results obtained in the birch plantation and forest stands, no statistically significant difference was found. In the birch plantations, the diameter of harvested trees did not exceed 20 cm, so, unlike to the young coniferous stands, no decrease of productivity was found while cutting trees with a diameter above 20 cm.

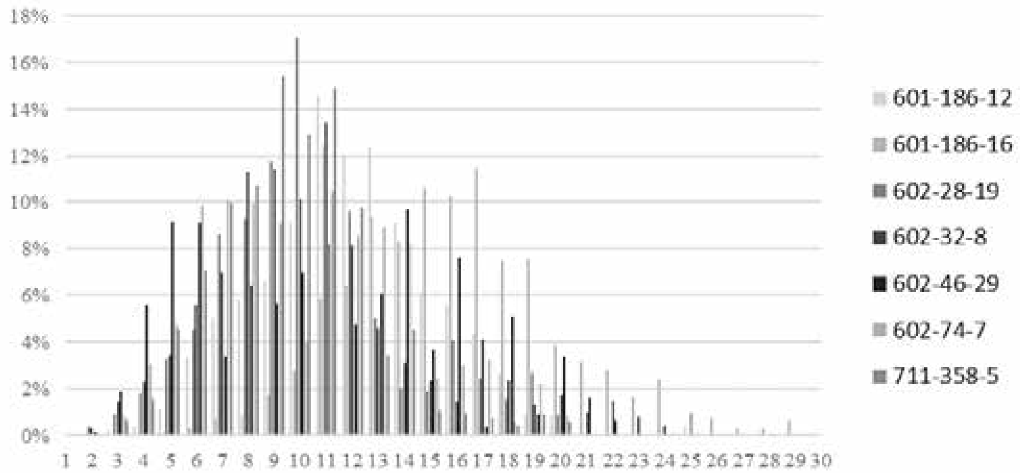

Figure 1. Diameter distribution of trees in thinned LVM stands.

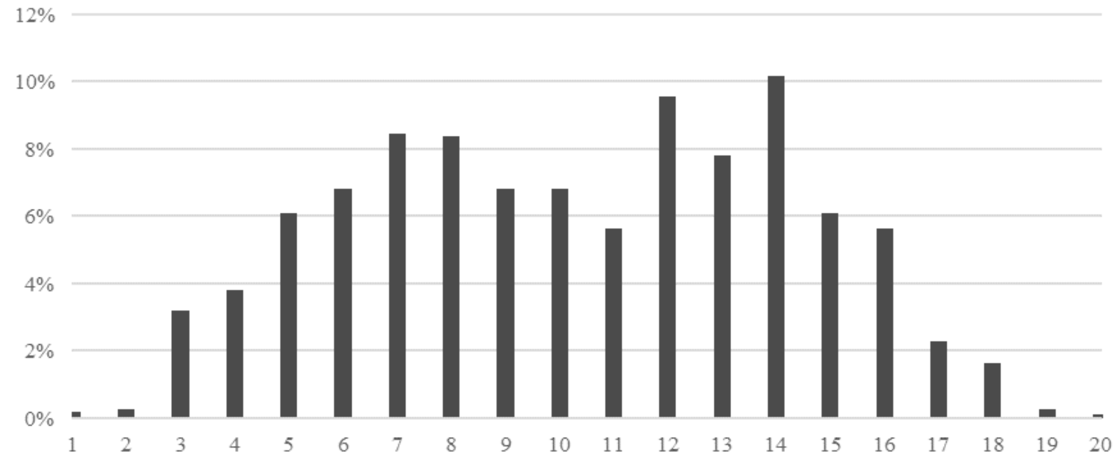

Figure 2. Diameter distribution of extracted trees in LF plantations.

Table 4

Parameters of Weibull

Equation parameters		Birch plantations	Conifer stands
Alfa	Inter	-1.93319	2.01004
	β	0.64682	0.14034
	β2	-0.02087	-0.00059
Beta	Inter	0.40971	0.19689
	D	1.08979	1.09419
Minimal diameter, cm		8	6
Maximal diameter, cm		20	18

While analyzing productivity data both in the young forest stands (Error: Reference source not found) and in the birch plantations (Fig. 5), it was observed that there is a significant increase in time consumption for a single tree processing, which is mainly determined by delimbing and bucking operations. On average, these processes take 51% of the productive time spent on a single tree processing. Delimbing and bucking of trunks in the diameter class till 5 cm consumes 36% from the whole tree processing time, in the diameter range from 6 to 9 cm it takes 45%, in diameter range from 10 to 13 cm it takes 48%, but if the tree diameter is above 14 cm delimbing and bucking time rapidly increases and reaches 64% of the total processing time. Time consumed to process a tree mainly depends on the feed roll speed and pulling force, which for small class harvester is not significantly changeable (Nilsoon, 1996).

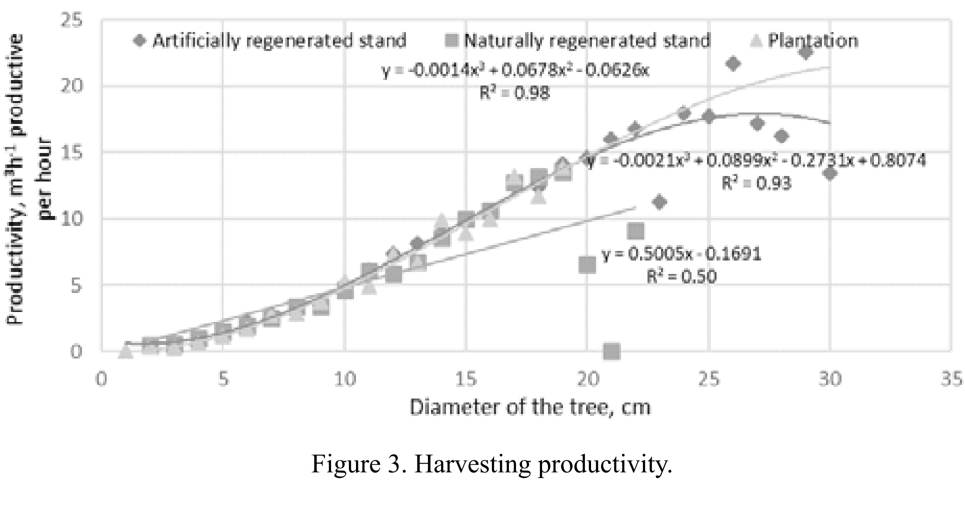

Figure 3. Harvesting productivity.

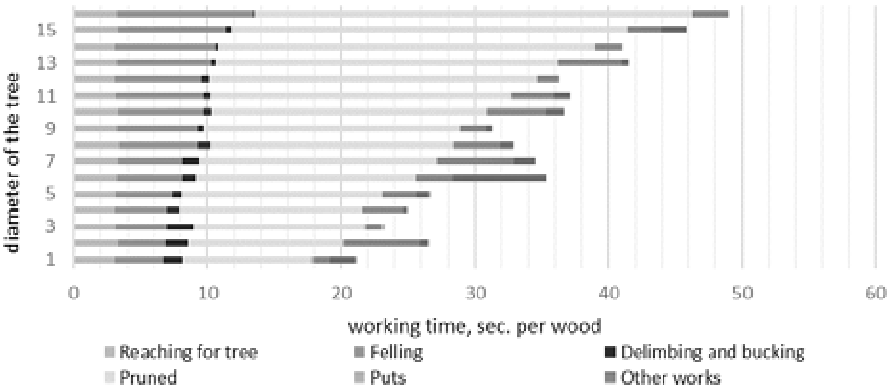

Figure 4. Distribution of work time consumed (sec. per processing of a single trunk) in different diameter classes in young coniferous stands.

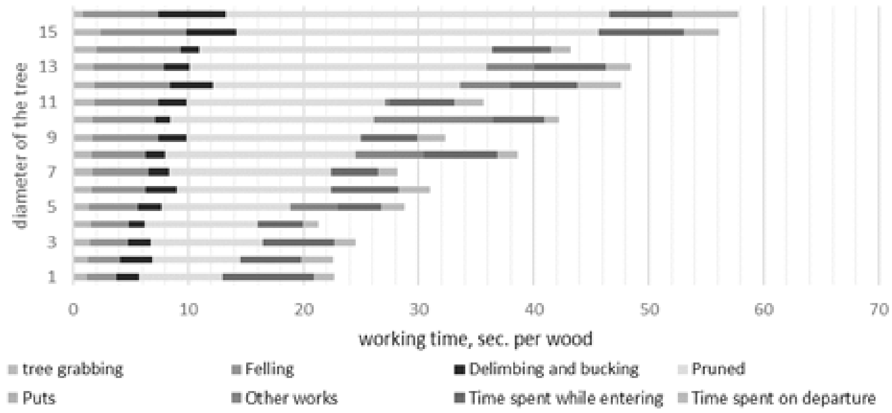

Figure 5. Distribution of work time consumed (sec. per processing of a single trunk) in different diameter classes in birch plantations.

Table 5

Average productivity and its distribution by diameter class

Stand type (regeneration type or plantation)	Diameter class, cm	A percentage of the total number of trees	Number of processed trees in productive working hour	Productive working time of total working time	Productivity, m³ in productive hour
Naturally regenerated	≥5	19%	151	93%	1.39
	6-9	54%	108	82%	3.15
	10-13	19%	81	61%	6.26
	14≤	8%	37	76%	5.90
	Average		94	78%	4.18
Plantation	≥5	14%	159	99%	0.88
	6-9	30%	132	99%	3.07
	10-13	30%	99	99%	6.66
	14≤	26%	65	99%	8.69
	Average		114	99%	4.82
Artificially regenerated	≥5	11%	114	77%	0.91
	6-9	32%	97	77%	3.10
	10-13	32%	83	77%	6.37
	14≤	25%	58	77%	10.65
	Average		88	77%	5.26

Summaries of productivity figures depending on the stand types and the diameter of extracted trees are provided in Table 5. In an artificially regenerated forest, the average productivity is 5.26 m^3 h^{-1} (min = 0.91, max = 10.56), in birch plantations 4.82 m^3 h^{-1} (min = 0.88, max = 8.69), in naturally regenerated stands – 4.18 m^3 h^{-1} (min = 1.39, max = 6.24). Increase in productivity can be observed in all types of the stands in the same diameter classes until the tree diameter reaches 15 cm. Productivity decrease can be observed in naturally regenerated stands, when cutting trees with a diameter above 14 cm.

The cost of a productive working hour of the Vimek harvester during the trials was 54 €, and average fuel consumption in trails was 4.5 L $hour^{-1}$. Logging costs, according to the average productivity figures in the artificially regenerated stands were 8.0 € m^{-3}, in naturally regenerated stands – 11.9 € m^3 and in birch plantations – 8.7 € m^{-3}.

Conclusions and Recommendations

1. The highest average productivity rate was achieved in the artificially regenerated stands – 5.26 m^3 h^{-1}. However, no statistically significant difference was found in the productivity of processing trees in the same diameter group. Therefore, the main factor affecting productivity and cost of harvesting is the diameter of extracted trees.
2. It is important to avoid processing of trees with a diameter below 6 cm to retain high productivity in thinning. Processing of small trees reduces the average productivity, however, further analysis is necessary to compare theoretical and practical possibilities to avoid processing of small trees.
3. The number of trees processed per working hour, which is a significant indicator of the harvester performance in thinning, ranged on average from 88 to 114. The highest number of trees processed per hour was in birch plantations – 114 trees. h^{-1} (min = 65, max = 159).

Acknowledgements

The study was implemented within the scope of the JSC funded research project ‘Research program on forest biofuel and mechanization of forest operations’ (agreement No 5-5.9_003v_101_16_47).

References

1. Bergström, D., Bergsten, U., & Nordfjell, T. (2010). Comparison of Boom-Corridor Thinning and Thinning From Below Harvesting Methods in Young Dense Scots Pine Stands. *Silva Fennica*, *44*(4). Retrieved January 21, 2017, from: http://www.metla.fi/silvafennica/full/sf44/sf444669.pdf.
2. Bergström, D., Bergsten, U., Nordfjell, T., & Lundmark, T. (2007). Simulation of Geometric Thinning Systems and Their Time Requirements for Young Forests. *Silva Fennica*, *41*(1). Retrieved January 21, 2017, from: http://www.metla.fi/silvafennica/full/sf41/sf411137.pdf.
3. Jonsson, M. (2014). En jämförelse avseende beståndsgående-och stickvägsgående gallringsmaskiner (A comparison regarding stand-thinning and strip road-going thnning machines), 27. Retrieved February1, 2017, from: http://stud.epsilon.slu.se/7547/7/jonsson_m_141229.pdf.
4. JSC ‘Latvia state forests’, J. ‘Latvia state forest’. (2017). *Apaļo kokmateriālu kvalitātes prasības (Round timber quality requirements)*. Rīga: AS ‘Latvijas valsts meži’. Retrieved January 21, 2017, from: http://www.lvm.lv/images/lvm/koksnes_produkti/ligumu_pielikumi/2017.gada_I_pusg/AKKP_2017.01_uz_2017_I.pdf. (in Latvian).
5. Lazdiņš, A., Prindulis, U., Kalēja, S., Daugaviete, M., & Zimelis, A. (2016). Productivity of Vimek 404 T5 harvester and Vimek 610 forwarder in early thinning. *Agronomy Research*, *14*(2), 475 – 484. Retrieved February 10, 2017, from: http://agronomy.emu.ee/wp-content/uploads/2016/05/Vol14-_nr2_Lazdins.pdf.
6. Mederski, P.S. (2006). A comparison of harvesting productivity and costs in thinning operations with and without midfield. *Forest Ecology and Management*, *224*(3), 286 – 296. DOI: 10.1016/j.foreco.2005.12.042.
7. Nilsoon. (1996). A feed roller. Swiden: World intellectual property organization. Retrieved January 25, 2017, from: https://patentscope.wipo.int/search/docservicepdf_pct/id00000000654240/PAMPH/WO1996000141.pdf.
8. Räsänen, T., Sorsa, J.-A., & Oy, M. (2010). *StanForD 2010 – Naming and design rules*. Vantaa.
9. Zimelis, A., Spalva, G., Saule, G., Daugaviete, M., & Lazdiņš, A. (2016). Productivity and cost of biofuel in ditch cleaning operations using tracked excavator based harvester. *Agronomy Research*, *14*(2).