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Productivity of Vimek 404 T5 harvester and Vimek 610 forwarder in early thinning

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Abstract. The scope of the study was to evaluate productivity of small size forest machines in early thinning, as well as to identify opportunities to use this technology to Latvia. The study was implemented in Sweden using Vimek 404 T5 harvester and Vimek 610 forwarder. The machines were driven by experienced operators; harvesting and forwarding methods were adopted to the operators' experience. Time studies were done by team of researchers from Latvian State forest Research Institute 'Silava'. The study demonstrated that Vimek 404 T5 harvester has considerable advantages in compare to conventional forest machinery to produce limited number of assortments like biofuel or mixture of pulpwood and biofuel in early thinning. Annual capacity of a single harvester working in one shift is 800 ha or 25,000 m^3; however, application of the machine is limited – it might not work efficiently in commercial thinning in Latvia due to large number of assortments required by customers, and it has limited possibilities of utilization during seasonal restrictions of forest operations. Productivity of Vimek 610 forwarder is comparable with conventional middle size forwarders; however, it becomes less beneficial with increase of forwarding distance. Prime cost of biomass, including harvesting, forwarding and road transport to a 50 km distance is 14.3 EUR m^{-3}. Hourly cost of Vimek 404 T5 and 610 is similar – 26–28 EUR h^{-1}.

Key words: Vimek 404 T5, Vimek 610, early thinning, productivity.

INTRODUCTION

Demand for woody biomass as renewable material, including small dimension logs, as well as biomass is expected to rise in future. It can be supplied both by increasing planted areas of fast-growing trees and their hybrids (Jansons et al., 2014; 2013) and by more efficient extraction of wood in forest thinning operations (Lazdiņš & Thor, 2009). To increase the output of biomass from small size tree harvesting operations, specialized forest machinery including small harvesters and forwarders is of crucial importance (Spinelli et al., 2010; Spinelli & Magagnotti, 2010).

Vimek 404 T5 harvester is one of the smallest serially produced forest harvesters having at least twice smaller price than conventional 'small-size' harvesters like John Deere 1070 or Ponsse Beaver, which are currently the most common machines in forest thinning in Latvia (Būmanis & Lazdiņš, 2012). Another benefit of the Vimek harvester is low fuel consumption and maintenance costs (Lundberg, 2013a; Vimek 2013).

Vimek 404 T5 harvester is equipped Keto Forst felling head (newer models are equipped with Keto Forst Silver felling head), which is suitable for processing of small trees using accumulating function. A weight of the felling head is 300 kg and it can process trees with diameter of up to 30 cm. Control system (produced by Motomit) of the felling head is automated and it is compatible with the StanForD-standard and can be used in Joint stock company 'Latvia state forests'. It is possible to equip the felling head with stump treatment spreader. The harvester can be also equipped with other small size felling heads or guillotine heads to adopt the machine for specific operations. Ellipsoidal cutting bar improves performance of the machine in early thinning and cleaning of undergrowth (Lundberg, 2013a).

A drawback of the small felling head is ability to delimb trees in one direction only; respectively, if the operation should be repeated, an operator has to put the tree down, turn the felling head by 180 °, grip the tree again and repeat delimbing or to move tree back through feed rollers with open delimbing knifes to repeat delimbing. Both options require additional time (Lazdiņš et al., 2015).

Harvester is equipped with CAT C2.2T engine (44 kW, Kubota V2003T in earlier versions). Width of the machine is 1.8 m or 2.15 (with wider tires suitable for low baring soils), length – 3.35 m, clearance – 40 cm. Reach lenght of the MOWI 2046 crane is 4.6 m. Weight of the machine is 4400 kg. Fuel consumption is only 4 L per hour. A serial production of the machine was started nearly 15 years ago, in 2001 (Vimek 2013).

There are few offers of Vimek harvesters in the second hand market, price of the second hand machines varies from 110,000 to 145,000 EUR, which is close to a price of new machines. There are no Vimek harvesters operating in forest in Baltic states (Demonstrē 'Vimek 610 BioCombi').

The Vimek 610 forwarder is not unique in it's class, however, it's one of the few machines of this kind produced serially. The forwarder is equipped with the same engine as harvester, front tires of the forwarder are slightly bigger and rear tires are smaller than of the harvester. Clearance of the machine is 40 cm; length 6.8 m; loading area 1.65 m^2; height – 1.97 m; load capacity – 5,000 kg, own weight – 4,700 kg; a reach length of MOWI P25 crane is 5.2 m at maximum capacity of 330 kg (Lundberg, 2013b).

The forwarder grip is supplied with 'tilt' function, which is necessary to transport trees by crane in vertical position securing significantly smaller damages to the remaining trees. Rear axle has mechanically driven drum between tires securing better performance on slopes and low bearing capacity soils (Lundberg, 2013b).

There is only one operating Vimek 606 forwarder in Latvia, availability of the machines in the second hand market is limited. Price of the second hand machines is 75,000 to 91,000 EUR depending from conditions. Price of new machines is about 110,000 EUR.

The regulations in Latvia formally do not permit use of small machinery like Vimek 404 harvester and Vimek 610 forwarder in thinning due to limitations of area of strip-roads. According to the Latvian legislation it may not exceed 20% of the stand area. The small-size machinery makes up to 2.5 m wide strip-roads (technological corridor) every 10 meters (using the maximum extension of the crane). In practice operators do not use the maximum extension of the crane and the distance between the corridors is even smaller. In Sweden, the strip-roads made by small-size harvesters and forwarders are not considered as corridors because no trees of the dominant species should be extracted to make these reads, i.e. the limitation of 20% of the stand area is not applied on small machines. According to Swedish regulations the part of a stand under the narrow strip-roads is considered as properly tended and not as a corridor.

The scope of the study was to obtain information on productivity of the Vimek harvester and forwarder in a conventional conditions, where the operators can apply the work methods they are used to, and to identify the potential issues and their solutions if the machines are utilized in Latvia; particularly, in relation to bucking orders and limitations of area of the strip-roads.

MATERIALS AND METHODS

Researchers from the LSFRI Silava took part in time studies of Vimek 404T6 harvester and Vimek 610 forwarder in Sweden in the beginning of 2015 (the last week of February). The trial was organized by the Vimek company with support of Urban Lundström, sales manager of the company, who consulted Latvian researchers during the trials and shared experience about the use of the small-size machinery in Sweden. The issues relating to forestry and quality requirements in Sweden were explained by the manager of the logging company providing machines for the trials.

The operators participating in the trials were experienced with the type of operation (early thinning), but less experienced with the machines – they used to work before with John Deere 1070 harvester and John Deere 810 forwarder.

The work time was accounted using shock- and humidity-resistant field computer Allegro CX with time tracking software SDI. During hauling the driving speed of the forwarder was determined using GPS measurements within the SDI software.

The time studies did not include accounting of fuel consumption, and the average figures provided by the manufacturer's were used. The work time of the harvester was matched with accounting of the engine hours, i.e. the time study was stopped when the engine was switched off and resumed when the engine was started again.

The time study of thinning was done during one shift per day. The duration of a shift was 8–12 hours. The consumption of work time was determined per every crane cycle recording at the same time the average diameter of the gripped trees (at the cutting height visually) and quantity of trees processed per crane cycle. The work time elements are shown in Table 1). Volume of every load forwarded to roadside were estimated by the operator.

Produced biomass was calculated using biomass expansion factors specified for Sweden and validated by the harvester accounting system (Marklund, 1988).

The air temperature during the tests was 3–8 °C during daytime and -2–0 °C during night-time. On 23 February there were small precipitations (10 mm per day). During other days the weather conditions were optimal and did not affect the productivity.

The study was implemented in 2 spruce stands typical for delayed pre-commercial thinning in Sweden according to the machine operators. The stands were surveyed before and after the operations, including assessment of thinning quality and the stand parameters (diameter and height of trees in circular sample plots). Circular sample plots of 50 m^2 area were equally distributed across the thinned area and at least 100 trees per ha were measured (species, diameter and height of about 10% of trees) in the sample plots. Damages of remaining trees were accounted across the whole stands after harvesting and forwarding to separate impact of both machines.

Table 1. Work time elements in harvesting and forwarding

Harvesting		Forwarding	
Category	Explanation	Category	Explanation
Informative fields	work cycle number	Informative fields	various notes
	average diameter of gripped trees d1.3, mm	Productive work time	driving to stand
	qty. of gripped trees		reaching logs when loading
	felled half-trunks		gripping logs when loading
	various notes		loading logs in the bunk
Productive work time	reaching tree		arranging logs in bunk
	time for gripping tree		driving during loading
	cutting tree		putting logs and slash into strip-road
	drawing the trunk and placing in the assortment stack		driving out of stand
	clearing the undergrowth		reaching log when unloading
	bucking the tree		
	time consumed to enter the stand		unloading logs – from gripping till releasing in the yard
	time consumed to exit the stand		gripping logs when unloading
	other non-standard operations		moving when unloading
	activities not related to work		other work-related operations
Non-productive time		Non-productive time	activities not related to work

RESULTS AND DISCUSSION

The average tree diameter in Stand 1 increased from 9.7 cm to 10.3 and in Stand 2 – from 10.9 cm to12.1 cm due to thinning (Tables 2, 3), the remaining basal area decreased to 17 and 23 m^2 ha^{-1}, respectively. According to the measurement data the felled volume in Stand 1 was 73m^3 ha^{-1} and in Stand 2–89 m^3 ha^{-1} (Table 4).

Table 2. Stand characteristics before thinning

Stand	Number of trees per ha^{-1}	Diameter, cm	Height, m	Growing stock, m^3 ha^{-1}	Basal area, m^2 ha^{-1}
1	3,625	9.7	10.6	188	27
2	3,500	10.9	13.6	295	33

Table 3. Characterisation of the stands after thinning

Stand	Number of trees ha^{-1}	Average tree diameter, cm	Average tree height, m	Trunk volume, m^3 ha^{-1}	Basal area, m^2 ha^{-1}
1	2,025	10.3	10.9	115	17
2	2,000	12.1	14.3	206	23

Table 4. Parameters of extracted trees

Stand	Number of trees ha^{-1}	Trunk volume, m^3 ha^{-1}	Basal area, m^2 ha^{-1}
1	1,600	73	10
2	1,500	89	10

The number of trees remaining in the stands after thinning is comparatively high (both, according the Swedish and Latvian standards). Recommended thinning intensity in the experimental stands would be to extract 500 trees ha^{-1} more so that remaining number of trees is 1,500 trees ha^{-1} in both stands.

Most of the trees in the stands after the thinning are 9–12 cm thick; the proportion of the trees with diameter below 8.1 cm after the thinning does not exceed 10% (Fig. 1). The largest reduction during thinning took place in diameter group 5–8 cm.

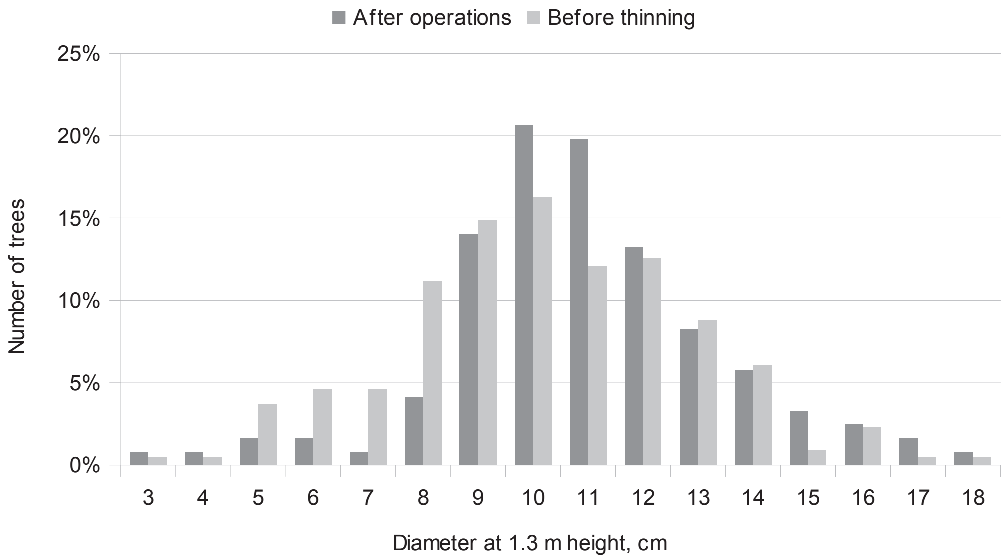

Figure 1. Distribution of the numbers of trees by diameter classes.

The time studies of the harvester and forwarder continued 3 days; the forwarder started to operate with delay of 2 days. The most of the work time was used to delimbing and bucking operations (Fig. 2); driving in and out from the stand, as well as the work cycles that did not resulted in produced logs took 9% of the work time (the time when the engine was on). Bucking, delimbing and driving in stand altogether consumed 66% of the productive time.

Trees with diameter above 8 cm dominated in extracted stock (Fig. 3). Their proportion in the number of the felled trees was 79 % and their volume was 85 % of the produced roundwood and biofuel. Operator avoided to cut trees with diameter below 8 cm; however, considering the high initial density, it was impossible to fully avoid cutting of small trees.

The diameter distribution of the extracted trees significantly differs from similar tests in Latvia (Lazdiņš et al., 2013; Lazdiņš et al., 2014; Liepiņš et al., 2015), where the most of the trees extracted in early thinning have diameter below 8 cm. The reasons for the difference are influence of the undergrowth, which is extracted to improve visibility and accessibility, and considerably higher number of types of the assortments to be produced in thinning in Latvia. Swedish experience (reduction of the number of assortments) can provide solution for this problem, however productivity and economic consequences of the optimisation of the assortments' structure should be evaluated in further studies. Another Swedish experience to expand to Latvia is getting switching to variable length of logs (2.2–5.5 m for pulpwood or biofuel logs).

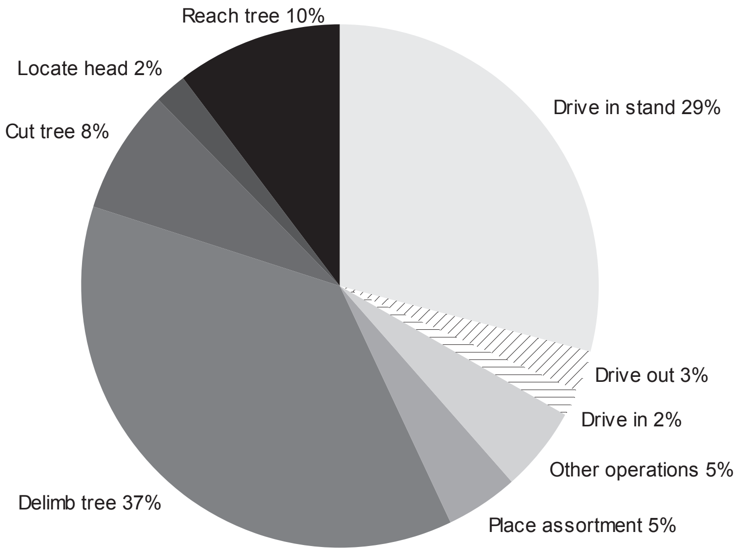

Figure 2. Distribution of work time elements in the total duration.

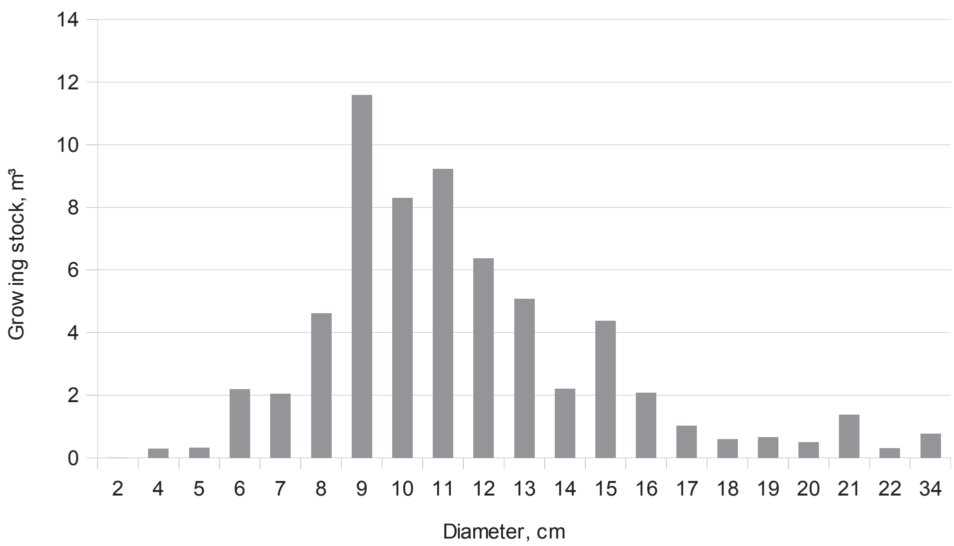

Figure 3. Distribution of the number of felled trees by diameter.

On average, in 5.3 m^3 of roundwood and biofuel was produced during 1 productive work hour (Table 5). The efficient work time (work cycles resulting with logs) was 94 % of the planned work time. Productivity increase with growth of diameter of extracted trees (Fig. 4); but number of threes processed per productive hour decreases with increase of the diameter, reaching 124 trees per productive hour at 8 cm diameter (Fig. 5).

Table 5. Summary of productivity figures of harvesting

Stand	Productivity, m^3 per productive work hour	Productivity, m^3 per planned work hour
1	5.494	5.287
2	4.783	4.638
On average	5.312	5.122

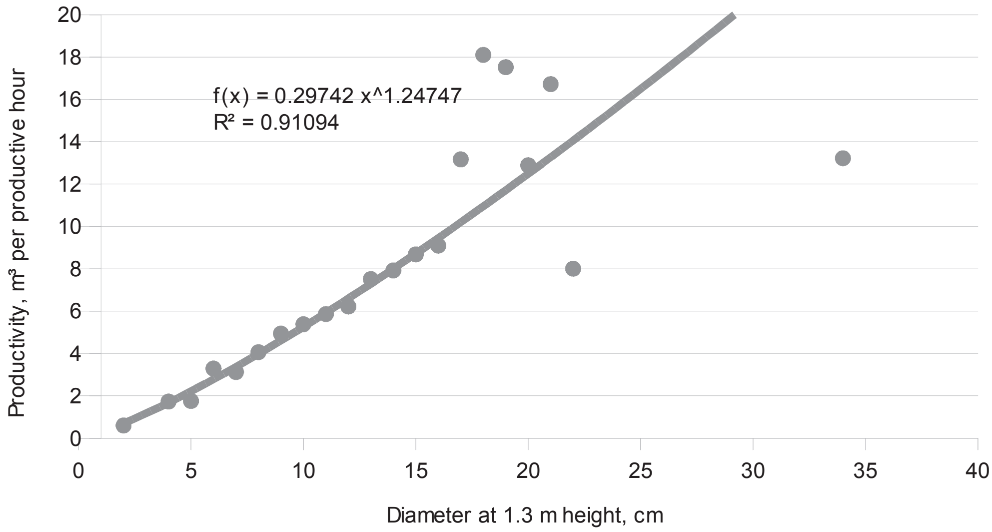

Figure 4. Harvesting productivity (m^3 per direct work hour) depending from diameter of tree.

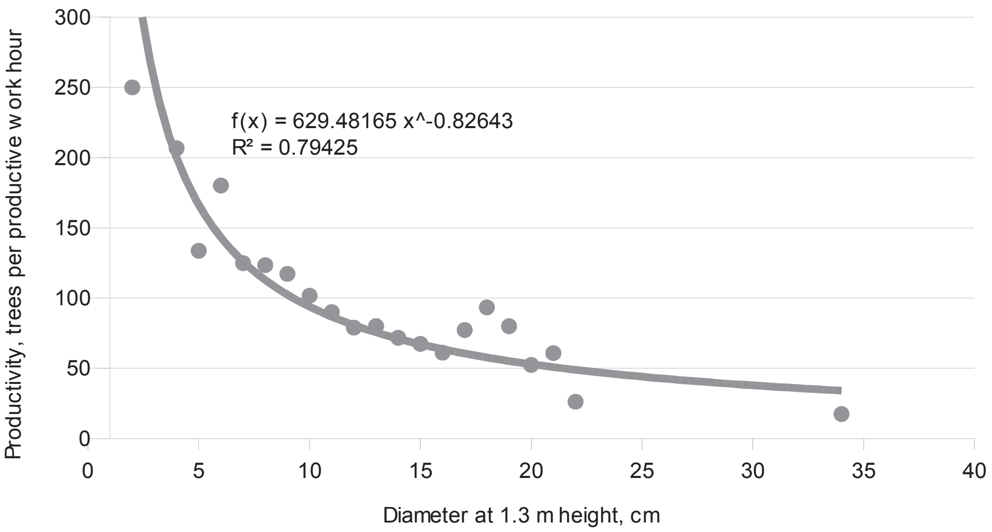

Figure 5. Harvesting productivity (trees per direct work hour) depending from diameter of tree.

Productivity of forwarding is shown in Table 6, structure of work elements – in Fig. 6. Loading and unloading time is comparable results obtained in Latvia in trials in similar conditions with heavier machines like John Deere 810D. Driving speed of the Vimek forwarder is considerably smaller (Lupiķis et al., 2014).

Table 6. Summary of forwarding productivity

Productivity of loading in, m^3 per productive work hour	Productivity of loading out, m^3 per productive work hour	Productive time from total time	Average driving speed, m min^{-1}
17.9	56.1	99%	22.7

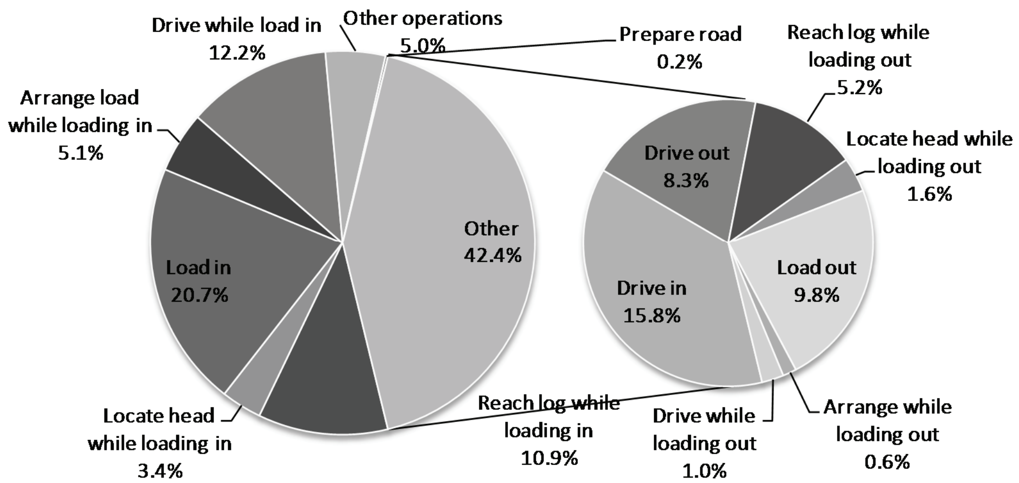

Figure 6. Structure of work elements in forwarding.

Productive time consumption per load, excluding driving, in trials was 23 min. including 17 min. for loading and 5 min. for unloading, average load was 5 m^3.

CONCLUSIONS

1. The productivity figures of harvesting obtained in early thinning in Sweden are at least twice better than the results of similar trials in Latvia. High productivity is result of better work methods (time spent to cut undergrowth trees is negligible); simple structure of roundwood and biofuel assortments in Sweden (not more than 3 types of logs are produced in early thinning, variable length of logs is accepted, all the types of logs are piled in one stack in a stand); optimal choice of work method that makes it possible to make a free network of strip-roads adjusting the pathway of harvester to the actual structure of stand.
2. Damages to the remaining trees and soil in the trials in Sweden were far below the thresholds according to Latvian regulations. The forwarder operator had no problems hauling even 5 m long logs following the path of the harvester. It is important to use this combination of machines in early thinning and not the Vimek harvester and a larger

forwarder or vice versa, as the benefits come from the use of the combination of particular harvester and forwarder.

3. The revenues from the sale of timber from thinning using Vimek machine set cover the production costs if the diameter of average cut tree is at least 6 cm if biofuel is delivered as partially delimbed small logs and at least 5 cm if wood chips are delivered to customer. The work conditions are optimal in stands where the diameter average cut tree is 8-10 cm. In stands with larger trees, in particular in fertile forest types, the productivity is hindered by the increasing time consumption for delimbing.

4. The harvester's measurement system makes it possible to account the timber according to the requirements of Joint stock company 'Latvia state forests'; consequently, there are no organisational obstacles to using this set of machines in thinning and other logging works in the state forests.

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REFERENCES

Būmanis, K. & Lazdiņš, A. 2012. *Pārskats par tehnoloģiju un tehnikas pieejamību enerģētiskās koksnes sagatavošanai un piegādei no galvenās cirtes, kopšanas cirtēm un meža infrastruktūras apauguma* (Report No. 2012/26-IP on availability of technologies for biomass production and deliveries from regenerative felling, thinning and ditch cleaning operations). LSFRI Silava, Salaspils, 65 pp. (in Latvian).

Mežaks R. 2015. Demonstrē 'Vimek 610 BioCombi' (Demonstration of 'Vimek 610 BioCombi'). *Meža avīze* **235**, p. 11. (in Latvian).

Jansons, A., Sisenis, L., Neimane, U. & Rieksts-Riekstins, J. 2013. Biomass production of young lodgepole pine (*Pinus contorta* var. latifolia) stands in Latvia. *iForest – Biogeosciences and Forestry* **6**, 10–14.

Jansons, A., Zurkova, S., Lazdina, D. & Zeps, M. 2014. Productivity of poplar hybrid (*Populus balsamifera* x *P. laurifolia*) in Latvia. *Agronomy Research* **12**, 469–478.

Lazdiņš, A., Kalēja, S., Gruduls, K. & Bārdulis, A. 2013. Theoretical evaluation of wood for bioenergy resources in pre-commercial thinning in Latvia. In: *Annual 19th International Scientific Conference Research for Rural Development Proceedings* **2**, Jelgava, Latvia, pp. 42–49.

Lazdiņš, A., Kalēja, S. & Zimelis, A. 2014. Results of evaluation of Bracke C16.b working methods in coniferous and mixed stands. In: *Proceedings of the Nordic Baltic Conference OSCAR14. Presented at the Nordic Baltic Conference OSCAR14 Solutions for Sustainable Forestry Operations*, Skogforsk, Knivsta, Sweden, pp. 106–109.

Lazdiņš, A. & Thor, M. 2009. Bioenergy from pre-commercial thinning, forest infrastructure and undergrowth – resources, productivity and costs, in: *Annual 15th International Scientific Conference Research for Rural Development Proceedings*. Jelgava, Latvia, pp. 147–154.

Lazdiņš, A., Zimelis, A., Prindulis, U. & Kalēja, S. 2015. *Vimek harvestera 404 T5 un pievedējtraktora 610 ražīgums jaunaudžu kopšanā Zviedrijā* (Report No. 2015/09, Productivity of Vimek 404 T5 harvester and Vimek 610 forwarder in early thinning in Sweden). LSFRI Silava, Salaspils, 37 pp. (in Latvian).

Liepiņš, K., Lazdiņš, A., Liepiņš, J. & Prindulis, U. 2015. Productivity and Cost-Effectiveness of Mechanized and Motor-Manual Harvesting of Grey Alder (*Alnus incana* (L.) Moench): A Case Study in Latvia. *Small-scale Forestry* **14**, 493–506.

Lundberg, F. 2013a. 404T5 – upgraded member of the dream team. *Vimek magasin 7*. Available at: https://www.yumpu.com/en/document/view/48542151/vimek-404t5-baltic-fcs. Accessed at: 11.05.2015.

Lundberg, F. 2013b. Vimek 610 enters pro class. *Vimek magasin 6*. Available at: https://www.yumpu.com/en/document/view/47254072/vimek-610. Accessed at: 11.05.2015.

Lupiķis, A., Sarkanābols, T. & Lazdiņš, A. 2014. Comparison of soil compaction using tracked and wheeled machines in early thinning. In: *Proceedings of the Nordic Baltic Conference OSCAR14. Presented at the Nordic Baltic Conference OSCAR14 Solutions for Sustainable Forestry Operations*, Skogforsk, Knivsta, Sweden, pp. 11–13.

Marklund, L.G. 1988. *Biomassafunktioner för tall, gran och björk i Sverige*. Sveriges lantbruksuniversitet, Institutionen för skogstaxering, 73 pp. (in Swedish).

Spinelli, R. & Magagnotti, N., 2010. Performance and cost of a new mini-forwarder for use in thinning operations. *Journal of Forest Research* **15**, 358–364.

Spinelli, R., Magagnotti, N. & Nati, C. 2010. Benchmarking the impact of traditional small-scale logging systems used in Mediterranean forestry. Forest *Ecology and Management* **260**, 1997–2001.

Vimek. 2013. VIMEK 404 T. Available at: http://www.forsttechnik-koch.de/papers/404-eng.pdf. Accessed at: 11.05.2015.