Arbetsrapport

Från Skogforsk nr. 830–2014

Proceedings of the Nordic Baltic Conference OSCAR14. Solutions for Sustainable Forestry Operations, June 25–27, 2014 NOVA Park Conference, Knivsta, Sweden.

Proceedings från den Nordiska Baltiska konferensen OSCAR14.
Solutions for Sustainable Forestry Operations, June 25–27, 2014,
NOVA Park Conference, Knivsta, Sverige.

Editor Rolf Björheden

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In the Arbetsrapporter series, Skogforsk presents results and conclusions from current projects. The reports contain background material, preliminary results, conclusions, and analyses from our research.

Titel:
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Bildtext:
Forest Operations are demanding. This calls for skilled operators and smooth co-operation between all tiers of the supply chain. OSCAR2 is dedicated to simplifying this complex process. Framsidesbild (Foto R. Björheden).

Ämnesord:
Forest Operations, Contractor Forestry, Transports, Logistics, Site Impact.

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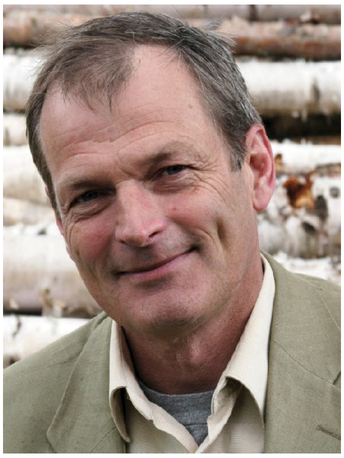

Professor Rolf Björheden is the co-ordinator of OSCAR and works at Skogforsk where he runs the R&D Programme Forest Operations and Products after a period as responsible for the Forest Fuels Programme. His research has mainly been dedicated to methods and systems development for logging and forest fuel harvesting.

Abstract

Arranged by Skogforsk, OSCAR14 was the 4th biennial conference of OSCAR, the Operating Systems Centre of Advanced Research. OSCAR is one of the Virtual Centres of Advanced Research (CAR) funded by SNS, the Nordic Forest Research Co-operation Committee.

The name of the conference, Solutions for Sustainable Forestry Operations, gives a fair picture of the joint focal interest of the current research on forest operations at the six national forestry research institutes that are the founders of OSCAR. The main objective is applied R&D, aimed at improving the efficiency of forest operations, with the secondary goals of improving economic conditions, reducing negative impact on soil fertility and ecosystems, and improving the attractiveness and status of forestry.

The proceedings contain abstracts of 60 scientific presentations made during the conference. The presentations were grouped into sessions focusing on:

- Site impact
- Organisation and training
- Silviculture and reforestation
- Wood value and logistics
- Transports
- Systems evaluation
- Bioenergy
- Research tools and methods

In the proceedings, the reader will find a good overview of current problems and solutions relating to research on applied forest operations in the Nordic Baltic countries.

Acknowledgements

OSCAR2 (2011–2015), is the second period of OSCAR – Operating Systems Centre of Advanced Research, a network for applied forest operations research funded by SNS.

The aim of OSCAR is to achieve synergies, to avoid duplication in R&D work and to use of the collective Nordic Baltic resources more efficiently, thereby increasing the return on R&D investments.

The founders of OSCAR are the research institutes Skov & Landskab at the Faculty of Life Sciences, University of Copenhagen (Denmark); Metla (Finland); Metsäteho (Finland); Silava (Latvia); Skog og Landskap (Norway) and Skogforsk (Sweden). OSCAR2 is open to any research organization with interest and activities in this field of research.

OSCAR14 Solutions for Sustainable Forestry Operations is the last of the joint biennial conferences when our ability to fulfil the aim of funders and founders is put to the test. These proceedings represent a wide variety of R&D activities, developed by OSCAR and the founding institutes over the years. I think that they also illustrate the power of joining forces around mutual problem areas.

Uppsala 2014-07-02

Rolf Björheden

Professor of Forest Operations

OSCAR2 Co-ordinator

Nordic Forest Research Co-operation Committee (SNS)

Proceedings of the

Nordic Baltic Conference OSCAR14

Solutions for Sustainable Forestry Operations

June 25-27, NOVA Park Conference, Knivsta, Sweden

Editor Rolf Björheden

The participants of OSCAR14 posing on one of the Kings Mounds in Old Upsala.

The Eco Log ELGP low ground pressure concept machine getting ready to run the vibration standard test track at Jälla – a result of one of the first joint OSCAR projects.

norden
Nordic Forest Research
Co-operation Committee (SNS)

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Quick facts of SNS Research and OSCAR

SNS research

Forestry is a major business sector in the Nordic countries. Forests have a key role in the terrestrial ecosystems, and they are used by many people for recreation, hunting or earning their living. The central role of the forest is also reflected in the active research and development. The Nordic countries are taking a leading position in many fields of forest science.

SNS-funded research in the form of ongoing and closed networks, research projects and CARs has produced a wide range of results of interest to the forest research community at large, decision makers, forest owners and practitioners.

SNS research can be divided into the following types of research collaboration:

- Networks
- Research projects
- Virtual centres of Advanced Research (CAR)

Virtual Centres of Advanced Research (CAR), are networks, with a specified core of scientific subject. Research is carried out in a decentralized manner. The aim of CAR is to achieve synergies and avoid duplication in R&D work. The aim is also to use of the collective Nordic R&D resources efficiently, thereby increasing the return on R&D investments. A CAR integrates existing networks the Nordic and Baltic area and works for Nordic synergy in its activities. OSCAR is one of these CARs.

OSCAR2 (2011-2015)

Operating Systems for Centre of Advanced Research (2011-2015), second period
Coordinator: Professor Rolf Björheden, Skogforsk, Sweden

OSCAR Partners

The founders of OSCAR are the research Institutes Skov & Landskab at the Faculty of Life Sciences, University of Copenhagen (Denmark); Metla (Finland); Metsäteho (Finland); Silava (Latvia); Skog og Landskap (Norway) and Skogforsk (Sweden). OSCAR2 is open to any research organization with interest and activities in our field of research. The main target is applied R&D.

OSCAR strengthens networks in the Nordic -Baltic area to achieve synergies and avoid duplication

Host Mellanskog Forest Owners' Association greets welcome. Site impact avoidance, wood value recovery and improved contractor communication were on the agenda.

With correct use of current measurement systems, wood value recovery can be improved

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FOREWORD AND WELCOME ADDRESS

Rolf Björheden

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A timely conference

For us in the Nordic-Baltic area, the Midsummer Fest is probably the most deeply rooted festivity of the year, a celebration of nature's replenishment, a period of warmth, play, and reproduction. Ultimately it is an echo of pagan rites in honour of the returning sun, and its short annual of reign – the prerequisite for life on our latitudes.

Thus, I am deeply impressed that we have managed to muster such an impressive cohort of participants and contributors to this Biennial OSCAR Conference 2014 "*Solutions for Sustainable Forestry Operations* ". But in all aspects excluding the calendary placement close to the Midsummer Fest, OSCAR14 is a very timely conference. All over the world, people are searching for a new, sustainable perspective on utilization of natural resources, allowing us to turn round for a society based on sustainable bioeconomy. This will profoundly affect the perspective on our northern forests and how we manage and utilize them.

It is my belief that, although we can still make considerable improvements, forestry in the Nordic-Baltic area are in the vanguard for this process. For example in Sweden and Finland, the concept of sustainable forestry goes a long way back, to the formation of *Bergskollegium* in 1637. Originally it was preoccupied with the sustainability of forest products for the mining industry. But it also planted the concept of sustainability, which over the centuries has become now deeply rooted in our culture and way of thinking in such a way that the will to preserve resources and to leave a "better" forest to coming generations is part of our heritage. Although yet not perfected, we have come a long way in adapting Nordic-Baltic forestry to our societies and to the functions of our forest ecosystems.

The challenges

Nordic-Baltic forestry plays an important role in supplying renewable feedstock for materials in an increasingly bio-based economy in Europe and globally. For the forestry sector in the Nordic-Baltic region, this entails tremendous business opportunities. But at the same time, forestry is increasingly under critical scrutiny of the public, especially with reference to environmental impact of forestry. Also, in densely populated regions, the value of the forest landscape for recreation poses new demands on forest management. Declining volumes are projected for many products that have previously been in great demand, such as newsprint and other paper qualities. New products must be developed. Competition on the export markets is relentless. Thus, strengthening the status of Nordic-Baltic forestry as the "wood shed" of Europe must be built on commercial competitiveness as well as trust from end consumers. Such recognition requires:

- Forest products with high value at competitive costs
- Excellent environmental standards and sustainability
- Attractive, safe and profitable work opportunities

The solutions

In the Nordic Baltic area, forestry conditions and industrial traditions have many similarities, both concerning problems and opportunities. This provides a strong incentive for collaboration in R&D.

This collaboration manifests itself through the activities of OSCAR, with the biennial OSCAR conference as one of the most important for the development of practical forestry in our region. Relatively small R&D units reach critical mass and improve penetration through working together and through exchanging ideas and results. Working together, both to improve operations and to provide decision makers with reliable facts, is part of the solution.

The OSCAR14 Conference *Solutions for Sustainable Forestry Operations* is dedicated to solutions and possibilities offered by Forest Operations R&D in achieving the abovementioned long term goals. Some of the solutions, I think, are part of the record-breaking list of presentations for OSCAR14 and will be presented or outlined in the following three days.

At OSCAR14, I will learn many new things, meet new colleagues and strengthen my existing network.

I feel confident that we will make this conference a success and in three days, when we all return home, we will all bring back many new ideas and contacts.

Very welcome to OSCAR14!

Rolf Björheden

OSCAR Co-ordinator
Skogforsk, the Forestry Research Institute of Sweden

KNOWLEDGE EXCHANGE: A QUARTER CENTURY WITH THE INTERNATIONAL JOURNAL OF FOREST ENGINEERING

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Abstract

The 1980's were very active years for the world's forest harvesting industry. Many new machines and logging systems were being introduced, particularly in North America and Scandinavia. However, the forest engineering community had no dedicated scientific journal in which to report the results of their research, and to disseminate these findings back to the industry.

Thanks to the initiative of faculty and staff in the department of Forest Engineering, University of New Brunswick (UNB), Canada, and a dedicated international group of editorial board members, the first issue of the ***Journal of Forest Engineering*** was published in July 1989, under the editorship of Jeremy Rickards. Thus, this year is the 25th anniversary of the first peer-reviewed scientific journal dedicated entirely and solely to forest engineering.

The number of contributors and subscribers to the journal expanded rapidly and in year 2000 ***International*** was added to the title, recognizing subscribers and contributors on all continents.

Much has happened during the journal's first quarter of a decade, both in terms of how forest operations are conducted as well as of research focus and the conditions for the researcher's publishing in the journal. These developments unfolds quite clearly when following the happenings of and the publications in IJFE. Here we, all five of the editor-in-chiefs during the 25 years, summarize these developments, as well as provides behind-the-scene facts. Naturally we also provide our view on the future on forest engineering research in general and of IJFE's role in particular.

Keywords: Development, scientific journal, peer-review, research, publication, editor, history, future.

CONTRACTOR FORESTRY – FINDING NEW WAYS

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Forest contractors greatly influence how forestry practices are carried out and how the forests are formed. The forest industry is dependent on the predictability of harvesting capacity and deliverability, presupposing well-functioning, stable contractors, with good skills and under professional management.

In Norway, we currently have about 250 forest contractors with an average of 2 - 5 employees. These small businesses are often family enterprises. There are no formal requirements on competence for forest contractors or operators, but many have a certificate as a “skogsoperatør”; a forest operator. These firms are characterized by great practical and technical skills, but less so on the administrative and financial competence. This is a challenge, since such knowledge gives strength and power in competition and negotiation with a large and professional business partner.

Opportunities

1. **Common web-based system for communication**
   Well organized and effective communication, documentation and quality assurance is required to succeed in a country with high cost levels, as Norway. This is a challenge that requires joint effort. I think that forestry will serve to develop a common seamless system of data flow through the entire supply chain, from forest owner to industry, and maybe this could be done across national borders?

2. **Training, instruction, guidance and tools**
   Beyond this, the supply of updated training and instruction measures, guidance and tools is important for business performance and cost efficiency. It is also reasonable to think that greater expertise in one part of the value chain will also affect other players in the chain. Competent logging contractors demand more from their employer and business partners, who must "sharpen" up and broaden their skills.

   In Norway, we have had a great success by introducing the Swedish Forest Research Institute’s (Skogforsk) concept of RECO (Rational Effective Cost Efficiency) in recent years. RECO is one of several answers to how we can be more efficient while simultaneously increasing job satisfaction and improving the work environment. These courses have shown a significant effect on productivity and reduction in fuel consumption. Another important consideration is increased focus on pre-planning of forest operations. It is possible to reduce costs through better organization, routines and practices which can help to reduce standing time, and at the same time increase the precision of information and ensure compliance with environmental certification schemes such as PEFC.

3. **Professionalizing**
   - In the future, it is possible that we will see a move to professionalism forcing increased merging of small businesses into larger units. This, in turn, means increased demands for expertise in business management and business administration.

- Appropriate agreements are important to develop a professional industry. Like in ABSE09 – “Agreed documents” in Sweden, and “General conditions of agreements for forestry” in Norway. Dialogue and cooperation between entrepreneurs, their customers, research and education institutions and industry in general are important to be prepared to meet future demands and challenges.
- Certification is on the agenda for many industries, including for forest contractors. Sweden has established a standard for contractors in PEFC certification. Norway and several other countries consider to do the same. I think this can achieve increased professionalization of the contractors witch may help to strengthen their position. The disadvantage is that all systems have expenses, and then applies that the rewards exceeds this.

The goal is to get larger economic returns from the forest in a sustainable manner. Changed climate combined with forestry operations throughout the year provides great challenges. It will also be important to optimize the workflow and utilization of each tree in terms of quality and features, which are essential to increase the value of the raw material.

For all the Nordic countries, the situation is relatively similar, although with variations.
I think working together is the most efficient way to build future skills and competence for a strong and robust contractor forestry. I believe that future competence must be based on three types of knowledge:

- Research-based knowledge - in science, technology, engineering, methodology, and innovation.
- Commercial knowledge - knowledge about markets and business models - is to "run a business ".
- Experiential Learning - practical knowledge. "Best practice".

Through a combination of these, instruments, tools and training measures that are targeted and customized can be developed.

All with one common goal: To find new ways for the attractive, profitable and efficient contractor forestry of the future.

Keywords*: professionalization, contractor forestry, harvesting operations, logging, operations management, Contractor, education, entrepreneur*

MITIGATING EFFECTS ON RUN-OFF WATER QUALITY AFTER FINAL FELLING USING FOREST BUFFERS

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Forest operations like final felling have potential to strongly affect water quality, in head-water streams in particular. In order to reduce the potential effects tree buffers left along the streams could be an efficient countermeasure.

The riparian zone forms the link between up-land soil and the water environment, and is a key factor for forming run-off water quality. Quite often the riparian zone acts as a discharge area for ground water and provides suitable conditions for processes important for the greenhouse gas balance like denitrification. A main driver for the aquatic ecosystem is the input of nutrients and energy from riparian forest. Further, the riparian forest is also of importance for water temperature, stream bank stability, the production of coarse woody debris and stream flow velocity. Leaving a forest buffer also prevent driving with logging machines close to water thus reducing the risk for sediment transport. As rule of thumb, small headwaters are more sensitive to disturbance then larger waters, partly due to the lower water volumes.

In order to study the effect of forest buffers along a small headwater stream we established a paired-catchment study in Northern Sweden. The study was initiated in 2004 and included in total six catchments; two catchments to be felled with or without a forest buffer, two unfelled control catchments and two larger catchments where the logging effects on a larger scale could be studied. Water flow has been measured continuously, and run off water chemistry (about 20 constituents) on a fortnight schedule for the last eight years. After two years of reference measurements two of the catchments where felled with or without a forest buffer.

In the stream surrounded by a forest buffer the concentration of nitrate and ammonium in the run-off was substantially reduced, while constituents like potassium, chloride and total phosphorus increased regardless of the presence of a forest buffer.

By an active management, like increase the standing volume of broadleaf trees there is a possibility to improve the function of the riparian forest. By retaining the riparian forest following logging the functionality and the resilience could be maintained. Further, by being a transition zone the riparian forest is important for maintaining biodiversity both on land and in water.

COMPARISON OF SOIL COMPACTION USING TRACKED AND WHEELED MACHINES IN EARLY THINNING

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Early thinning has significant impact on forest growth. The use of machinery in early thinning is determined by necessity to increase productivity of forest operations and to secure deliveries of solid biofuel, although the forest machinery can impact growth conditions adversely. Compaction of soil (expressed as penetration resistance) can be 3-4 times higher in the corridors in compare to untouched parts of a stand; ruts may speed up distribution of root rot dramatically. The aim of the study is to evaluate impact of different combinations of wheeled and tracked machines on soil penetration resistance and rut formation during harvesting and forwarding operations.

The study were done in 7 deciduous stands in a fertile *Aegopodiosa* and *Dryopteriosa* site types. Soil penetration resistance were measured with Eijkelkamp penetrologger down to 80 cm depth or 3.5 MPa level. The harvesting trials was done in August and September, 2013. Measurements of the penetration resistance was done in November, 2013.

Wheeled harvesters John Deere 1070E (equipped with Bracke C16.b felling head, no residues in corridors) and Rottne H8 (accumulating felling head, residues in corridors) and tracked harvester Timbear (accumulating felling head, residues in corridors) where used in harvesting trials. Wheeled forwarders Rottne F10B and John Deere 810E and tracked forwarder Timbear were used in forwarding trials. Wheeled machines operated without tracks in all stands. The machines were combined into 4 different work methods: (1) John Deere 1070E (no residues in corridors) and Timbear as forwarder (JD-T); (2) Timbear as harvester (residues in corridors) and forwarder (T-T); (3) Rottne H8 (residues in corridors) and Rottne F10B forwarder (R-R); (4) John Deere 1070E (no residues in corridors) and John Deere 810E forwarder (JD-JD).

In T-T method soil penetration resistance in corridors significantly increased ($p > 0.05$) in upper soil layers (down to 25 cm depth). In deeper soil layers no differences was found. In JD-T method significant difference in soil penetration resistance between corridors and remaining stand was found at 0-35 cm deep soil layer. Critical for development of plant roots value of penetration resistance (> 2 MPa) in JD-T method was reached at smaller depth in corridors rather than in untouched part of the stand. In R-R and JD-JD methods significant difference was found in the whole soil layer down to 80 cm depth. Critical value of 2 MPa in corridors was reached at a considerably smaller depth, if R-R or JD-JD method where applied.

Relatively weak compaction of upper soil layers in R-R method can be explained by moist conditions during forwarding and specific issues with Rottne H8; R-R was the only method, where 4 wheel harvester was used, and instead of compaction of soil this machine rapidly made ruts, which might be related to considerably higher pressure to the ground in compare to 6 wheel machines. Significant difference ($p > 0.05$) in soil penetration resistance was found between R-R and T-T methods, R-R and JD-T methods, JD-JD and T-T methods, JD-JD and JD-T methods, R-R and JD-JD methods. Application of R-R and JD-JD methods resulted in significant soil damages – ruts were found in 46 % of total length of the corridors. Application of T-T and JD-T methods at the same time resulted in 2 % of corridors with ruts.

The biggest difference in soil penetration resistance between corridors and untouched areas was found for JD-JD method. The most significant difference is observed in upper soil layers reaching maximum at 25 cm depth; however, soil was compacted to some extend down to 80 cm depth. The highest values of soil compaction in JD-JD variant can be explained by the applied work method – Bracke C16.b felling head produced undelimbed assortments, so there were no material to put below the wheels to improve driving conditions and both machines – harvester and forwarder, drove on a bare ground.

The results demonstrate that forest machines can compact forest soil significantly, compaction takes place not only in upper soil layers, but also down to 80 cm depth, and there are significant difference between different types of machines and working methods. The negative impact can be significantly reduced by broader utilization tracked forwarders as they have only limited impact on upper soil layer, which can rapidly return to initial state after repeated freezing of soil. Use of tracked harvester might be efficient only on very moist soils; however, in such extreme conditions forwarding still might be a problem even with tracked forwarder. Therefore the most beneficial combination to reduce environmental impact in early thinning is wheeled harvester (6 wheels with tracks if necessary) and tracked forwarder. If wheeled forwarders are used in thinning, it is important to put harvesting residues into tracks under the machine, therefore, production of undelimbed biofuel assortments in early thinning can only be recommended on frozen soil or in cases, when tracked forwarder will be used. However, this study only approves significant impact to soil, but knowledge about long term effect, especially in deeper soil layers, has to be improved to be able to provide economically and environmentally founded recommendations to forest management.

The study is done within the scope of the National forest competence center project “Methods and technologies to increase forest value” (L-KC-11-0004).

Keywords: *soil penetration resistance, compaction, thinning, harvesting, forwarding*

AVOIDING GROUND DAMAGES DURING LOGGING OPERATIONS USING DIGITAL MAPS

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One of the big challenges facing forestry is to minimise damage to the ground and water during logging operations. The solution is thought to be improved planning through better mapping and correct procedures when operating in wet areas with low bearing capacity. One way is to use a high-resolution Digital Terrain Model (DTM) produced from air-borne laser scanning. The DTM is used to extract and generate various digital layers, such as elevation, degree of slope, and aspect. From this information, we can calculate the position of wet areas (where the groundwater is less than 1 m below the surface) and create a DTW (depth-to-water map). We can also generate a layer showing 'no-go areas', where all logging should be avoided because the area is important for conservation and/or cultural heritage.

Surveys and assessments have shown that this kind of map information has potential to radically reduce damage to ground and water. In an evaluation of logging operations, more than 60% of ground damage was found to be in areas shown as wet on the DTW map, so the map could be used to predict the location of problematical areas where extra care should be taken. The evaluation also showed there is scope to improve methods and procedures applied in areas with poor bearing capacity. In logging operations where impact on ground and water was carefully considered, our survey showed almost 70% less ground damage, and damage to water was virtually non-existent.

Keywords: *Ground damage, laser scanning, ground moisture maps, environmental logging*

SOIL PHYSICAL CHANGES CAUSED BY DRIVING WITH HEAVY VEHICLES ON BOREAL REGENERATION AREAS

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During the last five decades there has been a steady development of forestry mechanization. Driving occurs all year round due to large demand of forest products and thus, the risk to induce undesirable effects on soils and waters increases. Driving by heavy forest machines may cause soil compaction, plastic soil disturbances and rutting. All these soil physical changes might have different ecological impact depending on the area disturbed. Soil compaction is identified as a major threat to soil quality in Europe (Commission of the European Communities, 2006). Compaction by forest machines has been found to increase soil density down to 50 cm (Eliasson and Wästerlund, 2007). The greatest concern with soil compaction from a plant perspective is the reduction in permeability of water, air and roots (Batey, 2009). Physical soil disturbances may affect biological processes like C- and N-mineralization in the soil (Booth et al., 2006, Finér et al., 2003, Mallik and Hu, 1997)

Soil compaction may also cause losses in productivity: reduced growth due to soil compaction after thinning operations was already decades ago identified as a major concern (Wästerlund, 1983). Moreover, damaged tree roots are more susceptible to attacks of pathogenic fungi, e.g. root-rot (Håkansson et al., 1988). Compaction in regeneration areas may also lead to rooting problems for the seedlings and thereby loss of productivity.

There are very few studies of how compaction of till soils influences soil physical properties in the Nordic countries. To our knowledge, there are no soil structure studies of boreal forests published based on *in situ* collected intact samples of till soils.

The aim of our study was to improve understanding of how off-road transports affect soil physical properties in regeneration areas. 84 soil samples of the top mineral soils in and besides the tracks were collected at two experimental sites in northern Sweden. The tracks were created by driving six times with a fully loaded forwarder (35 Mg). The intact soil samples were first scanned with Computed Tomography to acquire 3D pictures of the interior of the samples, which was quantitatively analyzed for structural changes of pore volume, pore length distribution and direction. After scanning, the samples were analyzed with traditional soil physical measurements to assess eventual changes in bulk density, hydraulic conductivity and pore size distribution due to driving.

We will present preliminary results and discuss them in the context of seedling establishment and growth. Changes in soil physical properties might also change the habitat for microorganisms, such as their access to oxygen, and thereby the flows of green-house gases. This and other environmental aspects will be briefly covered.

The study was carried out in cooperation with the Formas-project *A multi-disciplinary approach to reduce soil disturbance related to forwarder traffic at final felling* led by Eva Ring.

Keywords: *soil physics, forestry, Computed Tomography (CT)*

References

BATEY, T. 2009. Soil compaction and soil management - a review. *Soil Use and Management,* 25**,** 335-345.

BOOTH, M., STARK, J. & HART, S. 2006. Soil-mixing effects on inorganic nitrogen production and consumption in forest and shrubland soils. *Plant and Soil,* 289**,** 5-15.

COMMISSION OF THE EUROPEAN COMMUNITIES 2006. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - Thematic Strategy for Soil Protection [SEC(2006)620] [SEC(2006)1165] /* COM/2006/0231 final */. Brussels.

ELIASSON, L. & WÄSTERLUND, I. 2007. Effects of slash reinforcement of strip roads on rutting and soil compaction on a moist fine-grained soil. *Forest Ecology and Management,* 252**,** 118-123.

FINÉR, L., MANNERKOSKI, H., PIIRAINEN, S. & STARR, M. 2003. Carbon and nitrogen pools in an old-growth, Norway spruce mixed forest in eastern Finland and changes associated with clear-cutting. *Forest Ecology and Management,* 174**,** 51-63.

HÅKANSSON, I., VOORHEES, W. B. & RILEY, H. 1988. Vehicle and wheel factors influencing soil compaction and crop response in different traffic regimes. *Soil & Tillage Research,* 11**,** 239-282.

MALLIK, A. U. & HU, D. 1997. Soil respiration following site preparation treatments in boreal mixedwood forest. *Forest Ecology and Management,* 97**,** 265-275.

WÄSTERLUND, I. 1983. Growth reduction of trees near strip roads resulting from soil compaction and damaged roots - a literature survey. *Sveriges Skogvardsforbunds Tidskrift,* 81**,** 97-109.

WATERPROOF FORWARDING WITH LIDAR-DATASETS IN SOUTH SWEDEN

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Minimizing the damage to soil and water is a great challenge for mechanized forestry.

This study shows how LIDAR datasets from airborne laser scanning can help the forest sector tackle this challenge and at the same time may become more cost-efficient. By analyzing the LIDAR dataset in GIS, maps with information about wet areas, topography as well as the standing volume can be extracted and used as parameters for a route optimization for the forwarder.

At each harvest site two LIDAR-based map types, DTM (digital terrain model), and DTW (depth to water) constitute the premises for the optimization. Together with information about nature conservation, cultural relic sites and other “no-go-areas” where terrain driving must be avoided, a digital surface of the final felling site appears. Results show that these maps are helpful tools to avoid damage to soil and water.

Combining the digital surfaces with a LiDAR-data map over the distribution of wood over the site creates a dataset that can be used to optimize forwarding. The results of the optimization will be useful for the planner as well as for the machine operator.

In the study a few hauling scenarios at each site were composed for simulation and then the most cost efficient could be chosen. The differences did mainly concern where to cross water and where to put the roadside storage. The results show that there are savings to make when it comes to the total driving distance for the forwarder. The optimization construct a favorable trail network for the machine to use, every route the forwarder will go may be planned towards optimum, but to start with, placing the main trails will probably be the main use.

Keywords: *Forwarding, GIS, optimization,*

GROUND DISTURBANCE AFTER STUMP EXTRACTION UNDER DIFFERENT CONDITIONS

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Introduction

One long term political goal in Europe is more or less to replace all fossil fuel with renewable energy sources [1]. One renewable source is biomass from forests, the idea being that the carbon in the biomass is burnt to generate energy, and will be captured again when a new tree grows. Tree stumps are one possible source of renewable fuel, and are extensively used in Finland and on trial basis in Sweden. There are several benefits and drawbacks with stump harvesting [2]. One benefit with stump harvesting is the production of more fuel wood which can substitute fossil fuels. Other potential benefits are reduction of root rot in the next forest generation, improved quality of the soil scarification, and an extra income for the forest owner. The main drawback of stump harvesting is the soil disturbance, which reduces the carbon stored in the mineral soils and can also increase soil erosion [2, 3]. Other drawbacks are as follows: removal of nutrients from the site; increased soil compaction; and loss of habitat for fungi, mosses, bryophytes and insects through the reduction of dead wood in the forest. In the UK, an increase in non-forest vegetation has been feared. With climate changes, this could also become a problem in southern Sweden. There are also concerns about leaching of nutrients and heavy metals from the sites because of the ground disturbance [4].

Stump extraction is today only conducted during that part of the year when the ground is free from ground frost and snow [5]. This situation means that contractors cannot work year around with stump extraction. This problem makes stump extraction economically less attractive. It is therefore of interest to study possibilities to prolong the stump extraction season, which means that stumps would be harvested under winter conditions. Extracting stumps during winter conditions would be difficult on mineral soils as the soil would be frozen on to the stumps. This soil results in a fuel of low quality with high ash content [6]. Stumps from peat lands could be harvested under winter conditions, since as the peat that sticks to the stumps has a high fuel value [7]. The bearing capacity on peat lands is mainly made up of roots and vegetation that reinforce the ground [8].The low bearing capacity of peat makes it questionable to use conventional stump extraction heads during winter conditions as most roots are removed. It is therefore of interest to study the ground disturbance of different stump extraction heads in different conditions. The idea is that a lower disturbance should reduce the negative impacts of stump extraction.

Material and methods

Two studies concerned the ground disturbance of stump extraction. In the first study a Biorex30 stump extraction head was used to extract spruce stumps at two glacial till sites, one six and the other 18 months after clear-cutting. In the second study a conventional stump rake and a stump drill (while only extracts the stump centre) were used to extract pine stumps on peat land under winter conditions. Overlapping holes were not measured, but the area of total ground disturbance was. The diameter of the stump drill's disturbed area was perpendicular cross measured in two directions to an accuracy of 1 cm. The ground disturbance after the other heads was measured by placing a net with a 15x15 cm grid over the disturbed area and counting all cells with more than 50 % disturbance.

Results

In the study of the Biorex30 on glacial till soil, no differences in ground disturbance was found between the sites. The mean disturbed area was 6.1 m^2/stump (range, 1.3-21.1 m^2). On peatland, the mean area disturbed by the conventional stump rake and stump drill was 9.0 m^2 and 0.9 m^2 (ranges, 3.6-20.7 and 0.7-1.6 m^2), respectively. The ground disturbance of stump extraction seems to depend on the soil and extraction head used, but not on the lapsed time since clearcutting.

Discussion

It is likely that the ground disturbance of conventional stump extraction heads is larger on peat land than on mineral soil, even though there are differences between the Biorex30 and the conventional stump rake. There is a clear difference in ground disturbance on peat land where the stump rake disturbs ten times more ground than the stump drill. This results shows that conventional stump heads most likely cannot be used on peat lands at all as the ground disturbance will probably severely reduce the bearing capacity, making forwarding difficult. However, stump drills could be used on peat lands during winter conditions, but this could lead to a situation where the contractor needs two different stump extraction heads. The economic impact of such a situation needs to be investigated further. Stump extraction and forwarding during winter will also be hotter system as falling snow can cover stumps and heaps.

Keywords: *bioenergy, stump drill, conventional harvest, alternative technology*

References

[1] Anon. (2011). A Roadmap for moving to a competitive low carbon economy in 2050 In. EUROPEAN COMMISSION.

[2] Walmsley, J.D. & Godbold, D.L. (2010). Stump harvesting for bioenergy - A review of the environmental impacts. Forestry 83(1), 17-38.

[3]Grelle, A., Strömgren, M. & Hyvönen, R. (2012). Carbon balance of a forest ecosystem after stump harvest. Scandinavian Journal of Forest Research 27(8), 762-773.

[4] Egnell, G., Hyvönen, R., Högbom, L., Johansson, T., Lundmark, T., Olsson, B., Ring, E. & Sydow, F.v. (2008). Miljökonsekvenser av stubbskörd – en sammanställning av kunskap och kunskapsbehov Energimyndigheten; Rapport ER 2007:40).

[5] Laitila, J., Ranta, T. & Asikainen, A. (2008). Productivity of stump harvesting for fuel. International Journal of Forest Engineering 19(2), 37-47.

[6] Anerud, E. & Jirjis, R. (2011). Fuel quality of Norway spruce stumps - influence of harvesting technique and storage method. Scandinavian Journal of Forest Research 26(3), 257-266.

[7] Leckner, B. (2007). Co-combustion - A summary of technology. Thermal Science 11(4), 5-40.

[8] Uusitalo, J. & Ala-Ilomäki, J. (2013). The significance of above-ground biomass, moisture content and mechanical properties of peat layer on the bearing capacity of ditched pine bogs. Silva Fennica 47(3), article id 993.

CASE STUDY ON WOOD ASH PROPERTIES IN PELLET FACTORY

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According to different data on use of wood in households, district heating and industrial heat applications, the annual production of wood ash in Latvia is approximately 117 ktons, including 30 % in centralized district heating systems; however, no official statistics exists. Compared to 2002 production of wood ash in Latvia has increased by 30 % and the increase will accelerate in the near future due to the pellet industry and new CHP plants serving district heating systems. Wood ash is mainly utilized in landfills as household waste or special type of industrial waste. No common regulation exists for treatment and utilization of wood ash, therefore it is impossible to follow the whole chain to the end use or disposal site in the most cases, especially in district heating systems.

In spite of lack of regulations and the business environment favourable to semi-legal wood ash utilization schemes, there are several companies interested in development of wood ash recycling targeted on forestry and agriculture. A considerable advantage for Latvia is the absence of co-firing with coal; respectively, pure wood ash is produced in the most cases.

The scope of the study is to characterize properties of different wood ash fractions in a Latvian pellet factory producing about 100 ktons of wood pellets annually. The hypothesis of the study – screening of wood ash improves quality of fertilizer, reduces transport and application cost and produces fractions suitable for fertilization of forests and other uses. Both stored (one season) and fresh wood ash was evaluated in the study, 14 samples in total. Analysed properties are particle size distribution (> 45 mm, 16-45 mm, 3.15-16 mm, < 3.15 mm), moisture, bulk density, content of C, S, N, P, K, Ca, Mg, Mn, Fe, Cd, Pb, Cr, Ni and Cu. Chemical analyses were done separately for 3.15-16 mm and < 3,15 mm fractions and for combined coarse fraction. In 2014 the same analytical approach will be applied to ash from TOP 100 wood for energy users in Latvia.

Bulk density of fresh wood ash in calculation to dry mass is 1200 kg m^{-3} and of stored wood ash – 1007 kg m^{-3}. Relative moisture content of fresh ash is 0.3 % and in stored ash it increases to 13 %; respectively, weight of 1 m^3 of fresh ash is 1204 kg and of stored ash – 1138 kg. Significant difference was found in particle size distribution – in fresh ash share of particles with diameter (D) less than 16 mm, was 76 %, in stored wood ash – 99 %; however, the result might be determined by different conditions and fuel properties, not only by freezing and melting of the material during storage. Dominant fraction in fresh wood ash is the finest particles (D < 3.15 mm, 48 %). Bulk density of fine fractions (D < 16 mm) is smaller than of coarse fractions (D > 16 mm), respectively 1048 kg m^{-3} and 1200 kg m^{-3} of dry mass in fresh wood ash.

Chemical content of fresh and stored wood ash is different; however, most probably that this is determined by deviations if fuel properties and incineration regime, for instance content of potassium (K) in ash is increasing after storage (from 8 to 35 g kg^{-1}), which is not realistic. Further analysis of fertilizers' properties is done for the fresh ash only.

Content of nitrogen (N) in wood ash is 0.02 %, P – 0.3 %, K – 0.7 % (Table 1). Separation of coarse fraction (D > 16 mm) would not change significantly concentration of nutrient applied to soil with wood ash; however, it might be reasonable to split both fine fractions as the finest fraction contains about 3 times more P and 2 times more K than 3.15-16 mm fraction. Also, if compare content of heavy metals in fresh wood ash, than the finest fraction contains less Cd, Pb and Cr (Table 2).

Table 1: Chemical composition of fresh wood ash (% of dry mass)

Fraction	Sulphur (S)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Manganese (Mn)	Iron (Fe)
Fine ash (D < 16 mm)	1.7	0.3	0.8	6.0	1.2	0.1	0.3
All fractions	1.6	0.3	0.7	5.5	1.1	0.1	0.3

Table 2: Heavy metals in fresh wood ash (mg kg^{-1} dry mass)

Fraction (D)	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Nickel (Ni)	Copper (Cu)
< 3.15 mm	0.2	6.4	302.9	25.0	19.2
3.15-16 mm	2.9	72.8	374.9	9.3	22.7

The legal base for wood ash use doesn't exist in Latvia, however, there are rules on stock thresholds of heavy metals in regulations on wastewater sludge. According to these threshold values, maximum dosage of the finest ash fraction (D < 3.15 mm) is 4.8 tons and for the fraction with D < 16 mm – 6.9 tons (30 % more) of fresh material once per 5 years. Dosage in both cases is limited by content of Cr. Higher concentration of nutrients in the finest fraction secures application of higher dosages of K, P, Mn (by 30-35 %), Ca (by 20 %) and Mg (by 7 %) in compare to the combined fine fraction (D < 16 mm) if maximal wood ash dosage is used (Table 3).

Table 3: Nutrients applied with maximal dosage of wood ash (kg)

Fraction	P	K	Ca	Mg	Mn
< 3.15 mm	41.9	107.2	679.6	117.6	8.4
< 16 mm	31.1	78.3	565.8	109.4	6.5

The amount of K that can be applied with the maximal dosage of the finest ash fraction corresponds to recommended amount of the fertilizer in drained organic soils; P and N should be dded separately with mineral fertilizers (about the same amount of P, that can be applied with wood ash, and 100-150 kg ha^{-1} of N). Cost of transportation and application of wood ash can be reduced significantly, if the finest ash fraction only is applied. The fine fraction (D < 16 mm) can be used if the target is liming, because difference in stock of Ca and Mg is not so significant.

The study is done within the scope of the European development fund project project "Elaboration of methodological and technical solutions for utilization of wood ash in forest fertilization" (2DP/2.1.1.1/13/APIA/VIAA/034).

Keywords: *wood ash, forest fertilization*

LVM LOGGING SERVICE DEVELOPMENT STRATEGY AND TOOLS

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Introduction

JSC Latvia's State Forests (LVM) is a State-owned joint-stock company that manages the State forests in Latvia. The area managed by LVM is 1.62 million ha, of which 1.4 million ha is forest land. Each year LVM produces and delivers to the customers about 4.4 million m^3 of wood assortment. For the wood assortment production and delivery, LVM buys logging and timber transportation services from the private entrepreneurs. Over 70 logging and 40 timber transportation companies are providing the services for LVM. Given that LVM is a State-owned company, all the services required for the economic activity are purchased in open tenders under the Public Procurement Law. LVM service procurement procedures are created according to the company's objectives and taking into account the norms set by the Public Procurement Law.

Logging service development strategy

In order to ensure targeted logging service development, LVM elaborated and implemented service development motivation system. Development motivation system is based on "pull" strategy and the logging service payment separation into fixed and variable prices. Fixed prices apply to quantity of cubic metres which are produced and extracted to the landing. Variable prices apply to fulfilment of logging service quality criteria. There are four quality criteria which ensure targeted logging service development 1) work quality; 2) age of forest machines; 3) productivity of harvester operators; 4) training of employees. Each criterion has a different value in money. By fulfilling each criterion, the service provider receives additional payment. The total amount of additional payment depends on the level of fulfilment of criteria. Maximal additional payment or variable prices in final felling are 1.00 EUR per cubic meter and in thinning 1.70 EUR per cubic meter. Criteria and the remuneration for the fulfilment of the criteria pull the logging service development in the selected direction. The direction of development can be influenced by the selected criteria and the amount of remuneration for each criterion. The referred criteria LVM have been established for a period of five years. The trend of service development is evaluated on a regular basis in accordance with the criteria and objectives, but at the end of the period achieved objectives will be evaluated and criteria for the next development period will be established.

In addition to the pull strategy, LVM uses "push" strategy to promote the development of the logging service. It refers to LVM organised seminars and training for the service providers, to improve knowledge of forest works and raise awareness of the benefits of investment in development. Thus, quality criteria, variable prices and training seminars organised by the LVM are tools for the promotion of continuous development of logging service.

Logging service development has to provide the benefits to LVM as service buyer and private entrepreneurs as service providers. In order to achieve win-win situations, it is necessary to find out how the quality criteria affect private companies and does additional payment motivate to fulfil the criteria that are set out. The survey will be carried out for this purpose.

Keywords: *logging service development, strategy, criteria.*

THE COMMUNICATION PROCESS BETWEEN CONTRACTORS AND CLIENTS

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Today approximately 90% of all forest work in Sweden is performed by contractors. Contractor services account for an annual turnover of some SEK 10-15 billion. In recent years, the productivity development in forest work has stagnated, while the clients in the forest industry demand increased profitability but also long-term sustainability.

A survey was made to identify the most urgent perceived development needs for strengthening logging contractors' firms in Sweden. Among the identified needs were improved leadership and managerial skills, better business finance skills and improved practical workmanship of employees. The contractors also identified untimely and unclear communication from their clients as a common obstacle for improving precision and efficiency of their operations.

Based on this survey, studies have been made aiming to describe the communication process correlated to business agreements between clients and contractors. The objective is to describe how the given business agreements are perceived at different levels of the client company and among its contractors. The study, based on interviews, is hosted by one Swedish forest company and one forest owners' association. At all interviews the framework has been based on five stages in the process of business agreements. These are; 1) The clients selection of contractors 2) The process and situation of the negotiation 3) The model of agreements 4) The business situation after the agreement 5) The business relationship.

The preliminary results show that there was a larger significant difference, in the experiences of business agreements, between the various forests districts (different geographic areas) compared to the various functions (forest professionals and contractors), see figure 1. In district A and C it was a minor difference between contractors and forest professionals while in district B and D it was a significant larger difference. The structure within the human resources and the management within the clients and the contractor companies also affected the business agreement.

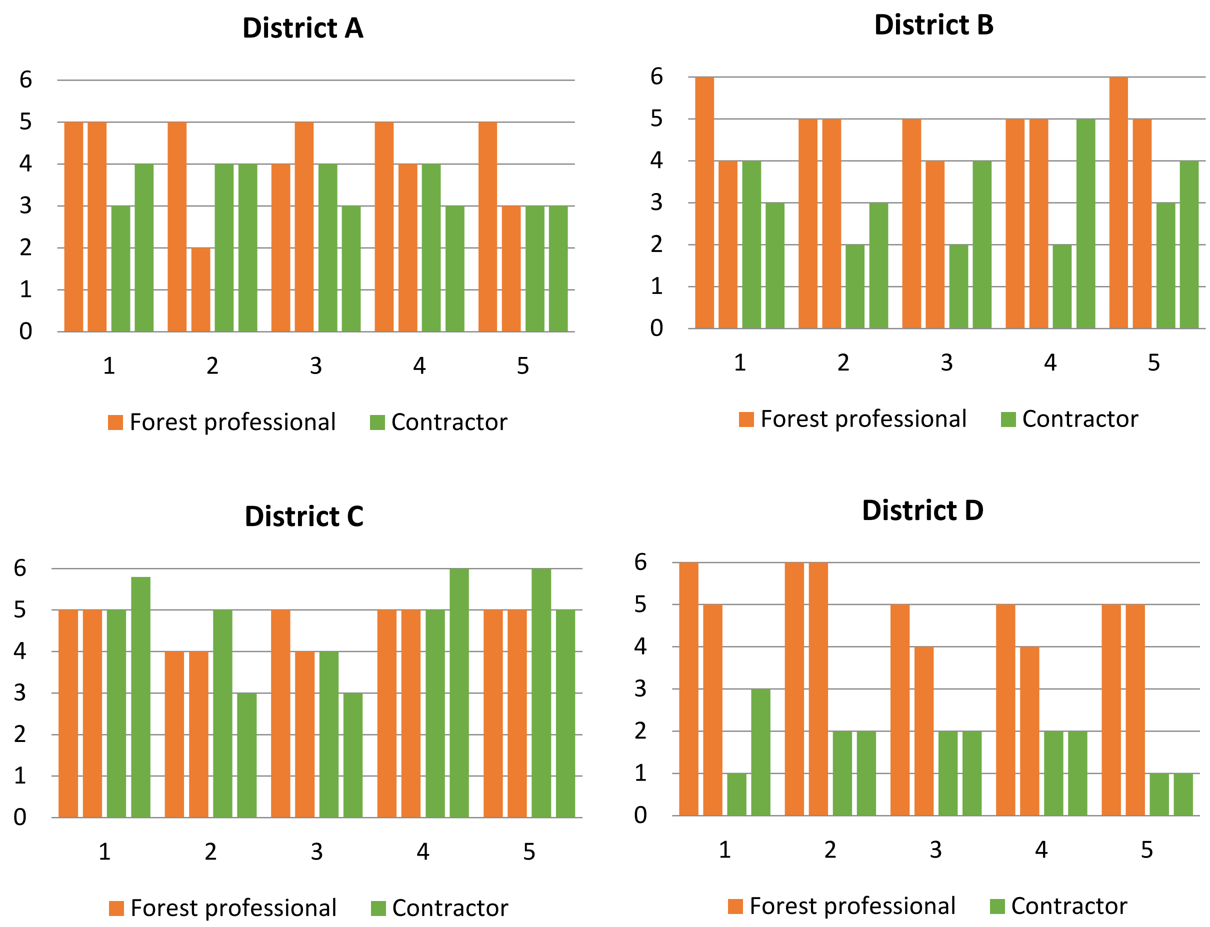

Figure 1. Results from forest districts A, B, C and D. The numbers on the x-axis represents different questions of the framework questionnaire within the process of business agreements. The y-axis shows the perception of the respondents. The number 6, denotes a positive perception, while a low number denotes the opposite.

A newly established forum for contractors and researchers plays an important role in improving the interface between contractors and clients. The state of the business agreement and the implementation is vital for how the capital-intensive contractor firms evaluate risks and rewards. The results will be used to improve the communication process, an identified weak link in the relationship between contractor and clients.

Keywords: *Contractor forestry, productivity in forest work, business agreements*

ENVIRONMENTAL AND QUALITY IMPROVEMENT THROUGH SELF-AWARENESS, COMMUNICATION AND FEEDBACK

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Background

The forest owner association Norra Skogsägarna ("Norra"), in the north of Sweden, is currently (2013-2015) conducting "The Environment and Quality Project", as a consequence of a broad dialogue project in the forestry sector. This dialogue project, initiated by the Swedish Forest Agency, had the purpose of finding – and producing very clear descriptions of - common environmental goals for forestry, as a consequence of not having been previously agreed.

Training day with contractors and forestry professionals

Contractors and forestry professionals are trained in various themes, for each of "Norra's" eight Forest Districts separately, with the aim to work along the target images.

The purpose of the one-day training in "communication and feedback" was to strengthen communication in general and particularly between the professionals and their hired contractors.

The activities of the training day alternated between plenary sessions and work in smaller groups. Initially, a foundation was laid out through topics like "What is our current situation, my personal baseline? What is my desired situation, my personal/company's vision?" and "What is characteristic of a well-functioning team?" This prepared the group(s) for a deepened discussion about "What are our obstacles for an even better performance?"

Fig 1. The five dysfunctions of a team (Lencioni, 2002, Jossey-Bass)

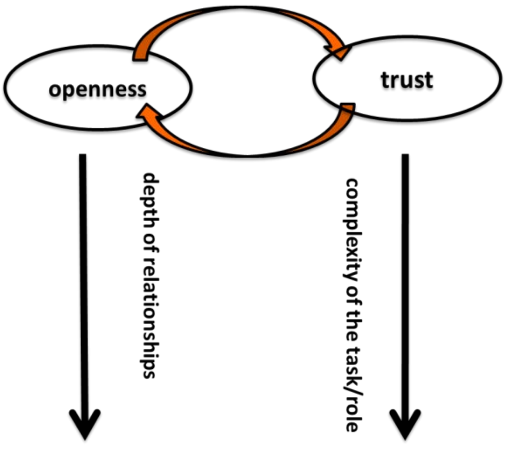

Fig 2. The more complex the task, the more depth of the relationship is needed (A. Wendelheim http://www.corecq.com/swe/modell2.htm)

According to the purpose of the project, the training focused on "How to follow-up our forest operations?" including the instructions given by the professionals. The participants used a specific method in professional feedback (Change Academy, http://www.cademy.se/en-US/podcast-blogg-21963853), applied to newly performed forest operations.

The multiple outcome of this training can be summarized in a few words:
Surprise, interest, excitement, tension, unease, resistance, laughter, inspiration, boredom, wanting more, not wanting to be there, enthusiasm, relief, optimism and faith in the future.

Reflections & Discussion

In general, this category of professionals is unaccustomed to this form of training. Some of the participants seemed to brace themselves for yet another boring day at school. A few just couldn't see how "my vision" had anything to do with "our common goals". Most of them were however curious and enthusiastic most of the time, inspired by talking and reflecting about human relations.

By exercising feedback, in a structured way and according to principles they are not used to, the participants could notice the difference in their own experience of meaning in every day work. For the contractors: To be personally responsible for the operations you have made, makes you more alert. For the professionals: To listen to the performers and to understand the circumstances under which they have done their job, gave the professionals a clearer view of their own part in the result.

Only one day per person on this topic doesn't make a revolution in communication and relational skills. Nevertheless the management of "Norra" has planted a seed and is now determined to continue sharpening the organization's ability to give and receive feedback, in order to meet their own quality ambitions and society's demands on environmental improvement.

How can the results effect Swedish forestry at large?

Relational development of customer-supplier relationship in Swedish forestry is needed, for the sake of profitability, recruitment and survival of the entire industry. If young people don't find it attractive to work in forestry and if those who are already here aren't enthusiastic and proud of their work, we will not be able to improve the image and status of Swedish forestry.

A thorough and methodical awareness and feedback training throughout the forestry sector can open up an, until now, relatively unexplored potential for improvement; By increasing the degree of openness and trust in the customer-supplier system and by training how to follow up performances - learning how to give and receive feedback - both parties will be able to operate more effectively within the system to gain advantages both economically and in terms of job satisfaction. Most likely misunderstandings are to be avoided, with beneficial consequences for the environment and along with that, an improved image of forestry.

These are effects we can expect from long term effective business relationships, high motivated performers of both parties, who have gained expanded insight into the conditions of the whole system and who have refined their ability to relate to each other.

Keywords: *contractors, feedback, self-awareness, environment, quality.*

DEVELOPING TRAINING FOR INDUSTRIAL WOOD SUPPLY MANAGEMENT

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An understanding of supply chain management in the forest industry is a prerequisite for efficient operations. This paper presents training currently used in Sweden to prepare masters-level foresters for managing supply operations. Based on a basic framework of professional tasks, eight key learning outcomes are targeted; one focuses on raw material requirements, three on securing supply, three on enabling delivery and one on control and coordination. Sixteen exercises are used to meet the eight learning outcomes. They are described as well as the pedagogical approach used. Current training is focused on developing student understanding of the industrial context as well as competences and skills required to solve common professional tasks. The paper couples current learning outcomes with different operations research areas in order to match tasks and applicable OR-methodology and identify priorities for further development.

Keywords: *education, forest engineering, operations management, operations research*

FOREST WORKERS AND STEEP TERRAIN WINCHING: THE IMPACT OF ENVIRONMENTAL AND ANTHROPOMETRIC PARAMETERS ON PERFORMANCE

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Winching is common in small-scale forest operations, especially on steep slopes, where tractors cannot reach the logs inside the forest. In this case, logs are dragged to the roadside with tractor-mounted winches, for later collection by transportation units. Winching is a heavy task, posing a high physiological stress on winching crew members. Perceived workload depends on work conditions and operator fitness. Fit, young operators experience a lower workload than older ones. Workload depends on winching direction, and it is higher when winching downhill than when winching uphill. In all cases, gravity is the main factor, and it has a stronger effect than task type and tool weight. Walking uphill with no tools is heavier than walking downhill and carrying a steel cable. As a consequence, tool weight reduction can palliate, but not completely solve the problem. New cable-recovery equipment may help solving the problem at the sources, by reducing the need for walking back and forth between the loading and unloading stations. Winching crews should be composed of fit, young workers. When the task is assigned to older workers it is necessary to allow for longer rest pauses, accepting a lower productivity.

***Keywords**: Steep terrain, winching, workload*

DEVELOPMENT WORK WITHIN SILVICULTURE CONTRACTOR FIRMS

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During the last 15 to 20 years the main part of silviculture activities within the Swedish large scale forestry sector has gradually been outsourced to small contractor firms. The outcomes from the outsourcing process has resulted in an increase of contractor firms within silviculture and the responsibility of development within productivity and development work now depends on individual contractor firms. Contractors within silviculture will henceforth be mentioned as contractor firms.

During the same period studies have been made aiming to facilitate the establishment and development of contractor firms. Three examples of such studies are;

The Seed – To start contractor firms.

The Plant – The development of contractor firms.

The Tree – Creating growth in contractor firms.

Based on these studies it has been found that CEOs, Chief Executive Officers, in contractor firms often possess a great deal of experience and are highly skilled practitioners but many have limited experience in managing development projects. This can result in delayed, more costly, or at worst not performed development work within the contractor firms.

To improve these components within the development process a project, The Crown – Managing development work within contractor firms, have started with the aim to create opportunities within the contractor firms to improve the management and ability to lead development work.

In the project, specific concepts containing educational objectives, method of instructions and materials for practice are produced. To guarantee the quality of the concept one test program has been implemented where six CEOs participated. The program consists of two parts, a theoretical and practical component where the participant's implements development work within their own contractor firm. During the process of implementation instructors are involved and supports the progression.

Increased sales, business with new clients and recruitment are examples of development areas addressed within the project. There is a need of commitment and continuity for a successful implementation, which are some of the challenges to succeed. The participants' development will be monitored in order to evaluate the importance of the program actions.

Keywords: *Silviculture, contractor forestry, leadership, development work*

WHAT AFFECTS THE MACHINE OPERATOR'S CHOICE OF THINNING METHOD? A STUDY ON THE IMPLEMENTATION OF THINNING WITH INTERMEDIATE PASSAGES AT HOLMEN SKOG

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In order to achieve increased productivity and quality in forest management operations there is a need for commitment and innovation in the development of both technology and methods. A step toward this end is the large thinning study that the forest company Holmen Skog conducted in 2010. Following the result from the study, the company revised its guidelines and changed the main method used in thinning to achieve increased productivity and lower harvesting costs.

According to the new guidelines, pine forests with suitable terrain should be thinned with intermediate passages. Intermediate passages as a method means that the harvester makes one or two meandering paths between strip roads in a thinning. Logs are placed close to the striproad, since forwarders are only traveling on those. In this way, the distance between strip roads is increased compared to if only strip roads are used. Moreover, the concentration of logs along striproads is increased, which improves the forwarder's productivity.

Holmen Skog experience, however, that the thinning costs have steadily increased over the last years, while the thinning quality has fallen. Follow-up studies indicate wide strip roads, short strip road distance and, thus, low possibility for tree selection. Therefore, the objective of this study was to investigate the extent to which the main method of thinning was used at Holmen Skog, and to identify what factors were behind the machine operators' choice of method. The objective made it relevant to also highlight the process of implementing the change of main thinning method as well as what should be required from Holmen Skog to make machine operators use the thinning method suitable according to prevailing stand conditions. The result was obtained through an analysis of Holmen Skog's follow-up of thinnings in 2013, and through interviews and questionnaire responses from employees and contractors/machine operators associated with the company.

It was found that the main method of thinning varied within and between the company's three geographical regions. Managers emphasized that all relevant staff at the company and contractors/machine operators had received information about the change of main thinning method, whereas many machine operators pointed out that they had not received any information or encouragement from the company to change method. Thus, manager's perception of the implementation of the new guidelines did not match with operator's image.

Opinions on thinning with intermediate passages differed both between employees of the company and between contractors/machine operators. The variation in the use of the main method for thinning seemed to originate from traditional differences. The variation could probably have been avoided, or at least decreased, by a more efficient (and more costly) implementation process.

Keywords: *strip roads, ghost trails, organization and organizational change.*

AUTOMATIC FEEDING SYSTEM FOR MECHANIZED PLANTING; AN EVALUATION OF THE RISUTEC AUTOMATIC PLANT CONTAINER (APC)

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Introduction

Modern planting devices are typically mounted on the boom of a base machine, usually an excavator. Planting machines prepare the soil and plant the seedling. Seedlings are manually reloaded piecewise to seedling cassettes from a seedling storage rack attached to the excavator. One of the main reasons why mechanized planting is not yet cost-effective compared to manual methods is lack of automated feeding system. Time taken to reload seedling cassette has been reported to be approximately 15% of productive work time.

Latest innovation in Finland is Risutec APC (Automatic Plant Container) in which seedlings are loaded in 16 BCC's Plantek 81 cultivation trays, 1296 seedlings in total (Figure 1). Risutec APC selects one row of nine seedlings from the cultivation tray at the time and loads them into the seeder from which they are planted one at the time. After the seventh seedling is planted, the machine starts to select another nine seedlings from the cultivation tray and during this time mounds could be formed. After the ninth seedling is planted, the seeder returns to resupply with seedlings. During laying of the nine seedlings into the seeder the whole planting device needs to remain in a place. Risutec is still a prototype and has been tested briefly in forest terrain.

Figure 1. Risutec APC in operation. Photo: Tiina Laine

The study evaluated Risutec APC in terms of work time distribution, productivity and quality compared to the commonly-used Bracke P11.a. Operating costs were evaluated and compared within these two machines as well as an idealized machine with automatic feeding system (AUT) under a variety of economic scenarios to determine the point at which an automatic feeding system became cost-effective. The experiment was designed according to the theory of comparative time study. Cost calculations were derived from results of the time study.

Results

Productive work time productivity of the Risutec APC (196 seedlings/h) was lower than that of Bracke (244 seedlings/h), making the unit cost 35.7% higher (0.38 €/seedling) than Bracke (0.28 €/seedling). A large portion (17.6%) of the productive work time of Risutec APC was spent interruptions due to malfunctions, thus productivity including interruptions <15 min were even lower (163 seedlings/hour). Both operators performed better with the machine they were more familiar with. Unit costs of an idealized machine (AUT) with an automatic feeding system were 7.1% lower (0.26 €/seedling) than the same without automatic feeding system due to its higher productivity. Quality of the planting work was reasonable with both machines, even though more seedlings suffered a minor planting defect planted by Risutec APC than by Bracke.

In principle, an effective automatic feeding system could increase the productivity of mechanized planting substantially. The importance of an automated feeding system empathizes as productivity increases, because relatively more time is spent reloading of the seedlings (Figure 2). At a productivity of 100 seedlings/h, the proportion of productive work time spent handling seedlings was 7.1% for Bracke and 1.3% with AUT, whereas at 300 seedlings/h the corresponding figures were 18.5% and 3.7%, respectively. Appropriate and effective automatic feeding system could increase productivity substantially.

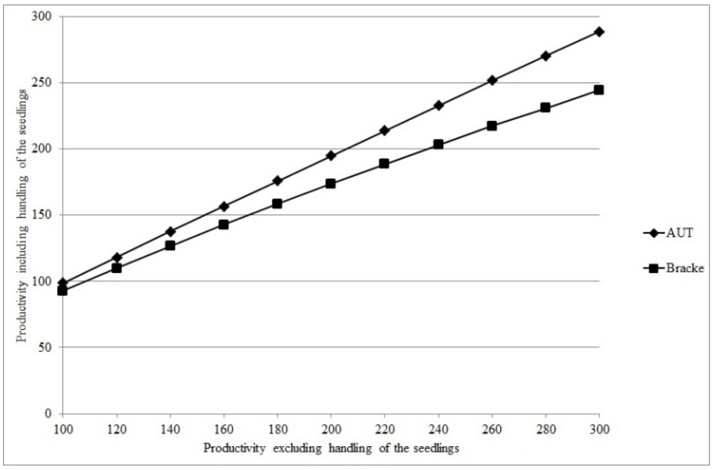

Figure 2. Productivities (seedlings/h) for planting machines with (AUT) and without (Bracke) automatic feeding system when excluding (x-axis) and including (y-axis) time used for handling the seedlings.

Capital investment is justifiable when productivity and demand are high enough. An investment of 80,000€ (a planting device 45,000€ + automatic feeding system 35,000€) on an idealized planting machine (AUT) requires a minimum productivity of 109 seedlings/h in order to compete with a basic planting device without an automatic feeding system. An additional investment of 55,000€ would require a productivity of 186 seedlings/h, and 75,000€ requires 263 seedlings/h.

Discussion

As it currently exists, Risutec APC performance was not at the same level compared to the Bracke, both in terms of productivity and planting quality. However, it remains possible to reduce operating costs with an effective automatic feeding system but the technology is not yet sufficiently developed to realize that goal because Risutec APC cannot be considered a technically reliable yet. Automation of the feeding would be an essential component for continuously advancing planting machines with productivity rates several times higher than machines in use today. In that case, automatic feeding system should work continuously instead of Risutec intermitted work method. Optimization and integration of the entire planting service supply chain from nursery to outplanting could lower costs when developing an automatic feeding system for mechanized planting.

Keywords: *mechanized tree planting; regeneration; productivity; cost-efficiency; planting cost.*

THE FEASIBILITY OF CRANE-MOUNTED TREE PLANTING DEVICES WITH MORE THAN TWO HEADS

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In Finland and Sweden, today's tree planting machines reforest clearcuts with equal (Luoranen et al. 2011) or better quality (Ersson & Petersson 2013) than mechanical scarification and manual tree planting. These planting machines advance intermittently and comprise a base machine, generally a tracked excavator, and a tree planting device attached to the crane. The productivity of current planting machines, however, is generally too low for them to compete with manual planting. Thus, higher productivity levels for planting machines are key for increasing both the mechanization level and the quality of reforestation in Fennoscandia.

Practical experience since the 1990s has shown that planting machine productivity can be increased by using two-headed rather than one-headed planting devices. But it is not known if three-headed devices are more productive than two-headed, or if four heads could be even better than three. Equally important, would the productivity of three- and four-headed devices remain higher than today's devices even on obstacle-rich terrain? What other potential disadvantages of three- and four-headed devices might there be? Excavators have the capacity to use heavier planting devices, which makes the idea of multi-headed devices technically feasible. To get some guidance on these thoughts, we used a discrete-event simulation tool (Ersson et al. 2014) to measure the time needed for excavator-mounted planting devices with one to four heads to mound and plant seedlings on clearcuts with varying frequencies of obstacles (i.e. stones, stumps, roots) and different thicknesses of humus layer. The obstacles could hinder the planting heads from both mounding and planting, thus causing queuing delays for multi-headed devices on which the planting heads were linearly oriented perpendicular to the crane (Figure 1).

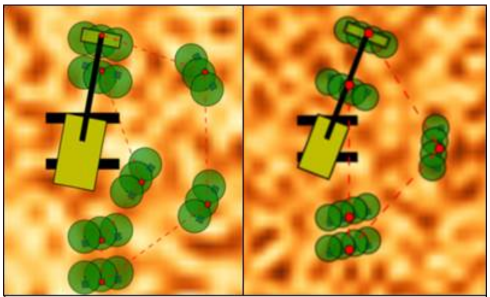

Figure 1. The ideal planting pattern of the three- (left) and four-headed (right) planting device models as depicted in the discrete-event simulation tool of Ersson et al. (2014).

As expected, the simulation results showed that productivity increased significantly with increasing numbers of planting heads on terrain with sparse or moderately many obstacles (Figure 2). However, on obstacle-rich terrain, three-headed planting devices were more productive than four-headed, while one-headed were as equally productive as two-headed devices. Many obstacles slowed down the task of finding acceptably large microsites for the two- to four-headed devices, and also caused frequent queuing delays. Being over 3 m wide, four-headed devices were especially impeded by many obstacles. Indeed, the largeness of the four-headed devices sometimes inhibited the model from finding a large enough microsite to plant even one seedling at a machine stationary point. Meanwhile, on the same obstacle-rich terrain, three-headed devices planted significantly more seedlings per ha than both four- and two-headed devices since the four-headed devices were so large and the two-headed devices were modelled as being today's M-Planter. The M-Planter is a relatively large planting device with the same total width as our three-headed device model had.

The overall high performance of three-headed devices and its comparative insensitivity to obstacle-rich terrain suggests that three heads per planting device is a highly feasible option to increase the productivity of intermittently advancing planting machines. Given the questionable silvicultural result of four-headed devices on obstacle-rich terrain, we conclude that even more heads per device, e.g. five or six heads, are not relevant.

Nevertheless, we can already now identify three factors that will be important for the feasibility of real-life three-headed planting devices, namely the configuration (geometric design) of the planting heads, the distance between planting dibbles, and the device's mass. Our simulation models assumed linearly arranged planting heads, but arranging them in a triangle would reduce the area required per microsite plus produce more evenly dispersed planting patterns. The distance between planting dibbles directly affects the planting device's total width, size, and mass. In our simulations, we assumed a 1 m dibble distance for three- and four-headed devices because this is the minimum seedling spacing accepted by Sveaskog and SCA, Sweden's largest forest owners. Alternatively, Bergvik Skog and Södra Skog has 1.5 m as their minimum seedling spacing, and Salminen & Varmola (1993) have shown that conifer growth is unaffected by a 0.8 m spacing. Our three-headed model became significantly larger and less productive with the 1.5 m dibble distance, while 0.8 m did not significantly improve productivity. Still, the narrowest biologically acceptable dibble distance probably allows for the lightest possible device, which in turn allows for smaller and more cost-efficient base machines.

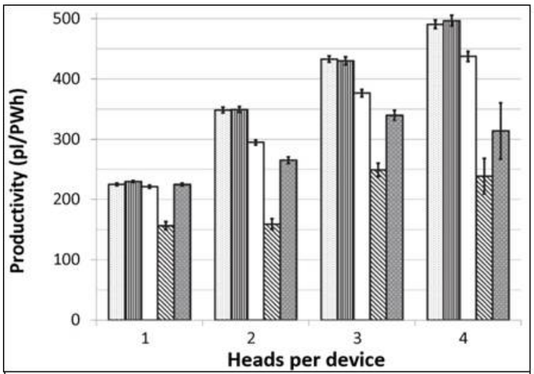

Figure 2. The mean productivity (planted seedlings per productive work hour) and 95% confidence intervals for one- to four-headed planting devices when mounding on five terrain models. The two leftmost bars of each group: obstacle-spare terrain; white bars: moderate terrain; the two rightmost bars of each group: obstacle-rich terrain.

Ultimately the cost-efficiency of three-headed planting devices will also rely on factors like investment cost, mechanical availability, and expedience of seedling reloading systems.

References

Ersson BT, Jundén L, Lindh M, Bergsten U. 2014. Simulated productivity of conceptual, multi-headed tree planting devices. Submitted manuscript.

Ersson BT, Petersson M. 2013. Återinventering av 2010 års maskinplanteringar – 3-års uppföljning. Skoglig service, Södra Skog. Rapport S048.

Luoranen J, Rikala R, Smolander H. 2011. Machine planting of Norway spruce by Bracke and Ecoplanter: an evaluation of soil preparation, planting method and seedling performance. Silva Fennica. 45:341-357.

Salminen H, Varmola M. 1993. Influence of initial spacing and planting design on the development of young Scots pine (Pinus sylvestris L.) stands. Silva Fennica. 27:21-28.

Keywords: *mechanized tree planting, planting machine, discrete-event simulation, productivity, silviculture*

MECHANIZED TREE PLANTING IN FINLAND

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Ten years ago Metsäteho Ltd conducted a wide survey of mechanized tree planting in Finland. Metsäteho reported that, in 2003, the area of mechanized tree-planting work was 1,420 hectares, which covered 1.6% of the total planting area in Finland. Moreover, Metsäteho's research identified 16 planting machines utilized in Finnish forests in 2003. After the survey by Metsäteho, such a comprehensive study of the use of state of the art mechanical tree planting in Finland has not been conducted within the past decade.

In the research of Stora Enso Wood Supply Finland and the University of Eastern Finland, the volumes and machinery of mechanized tree planting in Finland were investigated during the planting season of 2013. Furthermore, working conditions in tree-planting operations were clarified. Research data was collected during March and April, 2014. All machine entrepreneurs who produced mechanized tree-planting services in 2013 were interviewed.

The results displayed that 31 planting machines operated in regeneration areas during the planting season of 2013 in Finland. A total of 22 machine entrepreneurs provided mechanized planting services in 2013. Typically, a planting machine entrepreneur owned only one planting unit. Of the entrepreneurs interviewed, 32% operated with two planting machines. Only one entrepreneur owned three tree planters. The most commonly used planting device (58% of the total machinery) was the Swedish Bracke P11.a planter in 2013. The Finnish M-Planter and Risutec planting devices were also used. The base machine of the planting devices was primarily a tracked excavator of 14–17 tonnes. While, some excavators of 21 tonnes were applied for planting work in Finland. A wheeled harvester was utilized as a base machine for two planting devices.

The planting entrepreneurs interviewed had 1–3 customers for their planting services. More than 80% of the entrepreneurs planted for large silviculture and forest industry companies, i.e. UPM, Tornator, Stora Enso, Metsähallitus, and Metsä Group, in 2013. The shares of local forest management associations and non-industrial private forest owners were 8% and 6%, respectively.

Total area planted by the entrepreneurs interviewed in the study was 2,663 hectares and 4.69 million seedlings during the planting season of 2013. Hence, the average planting density was 1,761 seedlings per hectare. The planting season in 2013 typically started at the beginning of May and ended late September or the beginning of October. The average length of the planting season was 19.6 weeks (4.9 months) in 2013. Less than half of planting machines worked in two shifts and one third of the machines operated primarily in one work shift. During the planting season of 2013, there were stoppages and other excavator works (i.e. soil preparation, ditching and stump lifting), on average, 1.2 and 0.8 weeks, respectively.

The entrepreneurs estimated that 90% of the total planted seedlings in 2013 were Norway spruce (*Picea abies* (L.) Karst.); the rest of seedlings planted were Scots pine (*Pinus sylvestris* L.). Furthermore, the planting entrepreneurs reported that almost two thirds of the area planted were without logging residues, and one third of the planted area occurred on sites where stump harvesting was conducted in 2013. On average, one fifth of the mechanically planted regeneration areas were heavily littered with rocks or boulders. Correspondingly, more than one fourth of the planting areas in 2013 were almost without occurrence of disturbing rocks or boulders.

The average planting area for the planting machines utilized within the study was 86 hectares, with the variation in range being 25–177 hectares/machine. There was also a large variation in planted seedlings per one unit in 2013: 45,000–320,000 seedlings/machine. On average, each machine planted 151,000 seedlings during the planting season of 2013 in Finland. The average productivity of planting work was 1.0 hectare/working day/machine, with a variation in range of 0.3–1.7 hectares/working day/machine (i.e. 490–3,160 seedlings/day/machine). The entrepreneurs interviewed forecasted that their planting areas in 2014 will be, on average, 96 hectares/planting machine.

When a total area of 76,900 hectares of the area under artificial regeneration was planted in 2013, according to our survey, the share of mechanized tree planting was 3.5% in Finland. Consequently, the volumes of mechanized tree-planting work have doubled during the past decade, but it can be evaluated that the increase in mechanically planted areas has been quite slow.

The main reason for this modest progress is the fact that the utilization rate of planting capacity has been extremely low, meaning weak cost-competitiveness for the mechanized tree-planting business. The annual planting areas should be around 130–150 hectares per planting machine when operating in two work shifts. Furthermore, improved working conditions of mechanized planting are needed, i.e. no rocky sites and areas with recovery of slash and stumps for mechanized planting. Additionally, mechanized tree planting must be introduced more effectively for non-industrial private forest owners through various education and marketing activities, as well as through field demonstrations in the future.

Keywords: *Finland, mechanization, silviculture, state of the art, tree planting.*

HARVESTING OF A BIRCH SHELTERWOOD

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Introduction

In frost prone areas in Sweden birch shelterwoods (*Betula pendula* or *Betula pubescens*) are often used as a nurse crop for the new generation of spruce (*Picea abies*). In 1994-1997, 1.2 % of the young and middle aged forests in Sweden were characterized as birch shelterwoods by the Swedish National Forest Inventory (Bergqvist 1999). The spruce trees are grown under the shelterwood until they reach a frost safe height and the birches are large enough to be harvested for pulpwood. However, as a large part of the biomass often is of too small dimensions to be suitable for pulpwood an interesting alternative is to harvest all biomass for energy purposes. With the current prices, a combined harvest of both pulpwood and biomass assortments is seen as a tempting option.

Skogforsk has been studying a thinning to remove the birch shelterwood in order to evaluate harvester and forwarder productivity as well as the harvested volumes in each assortment.

Material and methods

The shelterwood removal was done close to Ljungby (lat. 57°03'N) in May 2014. The operation was a combined harvest of pulpwood and energy assortments. Harvesting was done with a Komatsu 901 harvester equipped with a SP 250 multi-tree handling harvesting head. Forwarding was done using a John Deere 810 and the operator loaded one assortment in each load. Upon un-loading, the weights of the loads were measured using crane tip-scales.

Three plots of 105-115 meters length were established with the strip road in the center of each plot. In each plot (strip road) tree species, diameter, height and number of trees (Table 1) were measured on four 5.64m radius plots. The minimum diameter at breast height registered was four centimeters. The plots were remeasured after harvest and forwarding when also the number of damaged spruce trees were counted.

Table 1. Stand data before and after shelterwood removal

	Initial stand		After harvest	
	Birch	Spruce	Birch	Spruce
Stems ha^{-1}	2390	1750	270	1700
Damaged stems ha^{-1}				100
DBH (cm)	7.1	4.3	6.8	4.5
Height (m)	9.2	4.3	9.1	4.2
Volume ($m3*ha^{-1}$)	50.7			

Fifteen samples were taken to measure the moisture content in the material. Continuous time studies were made for defined work elements of harvest and forwarding. The general instruction to the experienced machine operators was to work at a normal pace, using their preferred techniques. The exceptions were the transport and un-loading work elements where the forwarder was delayed due to the weighing. To enable comparison with Eliasson & Nordén (2009) their time for these work elements were used in the analyses.

In the study of the harvest, all trees were registered regardless of diameter. The average stem volume and number of harvested stems are affected accordingly (Table. 2). The time consumption is presented per work element in centiminutes per oven dry tonne (ODT) harvested material.

Results

The harvested number of stems was 3110 stems per ha and the average stem volume was as low as 16.2 dm^3. This resulted in a harvester productivity of 2.4 $ODT*E0h^{-1}$. Although felling-accumulation is the largest element, a large part of the time is spent on processing (Table 3). Multi-tree handling was used in 81 % of the crane cycles.

Table 2. Time consumption by element in harvesting ($cmin*ODT^{-1}$)

Boom-out	322
Felling-accumulation	1131
Boom-in	228
Processing	731
Travelling	122
Miscellaneous	32
Total	2567

Forwarder productivity was 4.5 $ODT*E0h^{-1}$ when forwarding energywood and 4.69 $ODT*E0h^{-1}$ when forwarding pulpwood. This is a relatively high productivity and is strongly affected by the relatively high concentration of material. There was on average 2.25 ODT energywood and 1.57 ODT pulpwood per 100 m strip road. Since the general breaking point between the assortments (8 cm DBH) is close to the average diameter of the stand, this was expected.

*Table 3. Time consumption by element in forwarding (cmin*ODT-1)*

	Energywood	Pulpwood	Eliasson & Nordén
Boom-operations $cmin*ODT^{-1}$	898	996	1163
Movement $cmin*ODT^{-1}$	164	201	458
Transport and un-loading $cmin*ODT^{-1}$	481	481	481
Total	1331	1279	2102

Conclusion

The removal of the shelterwood was successful and only 5.9 % of the remaining trees were injured. From an economic view it is doubtful if the harvesting of two assortments is profitable compared to harvest of only an energy assortment in a stand with as small trees as the studied one.

References

Bergqvist, G. (1999) *Stand and Wood Properties of Boreal Norway Spruce Growing under Birch Shelter*. Acta Universitatis Agriculturae Sueciae: Silvestria vol 108.

Eliasson, L., Nordén, B. (2009) *Fyra studier av A-gripen*. Skogforsk Arbetsrapport no 688:2009

Keywords: *Small tree harvest, early thinning, harvester productivity*

ENVIRONMENTAL IMPACTS OF MOUNDING METHOD IN FOREST SITE PREPARATION

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Mounding trials were done in Eastern part of Latvia, in three different forest soil types (*Myrtillosa mel., Myrtillosa turf. Mel., Myrtillosoi-polytrichosa*), in spring and autumn with three different buckets: conventional excavator bucket (width 110 cm), mounding bucket Karl-Oscar (width 50 cm) and mounding bucket MPV-600 (width 60 cm, produced by LSFRI Silava and ORVI SIA). All devices were mounted on the same New Holland E165 excavator. Karl-Oskar was used only in autumn trials.

To evaluate ecological impact of the buckets utilized in the study for site preparation, the number of planting spots in sample area percentage of scarified area and penetration resistance of planting spots was estimated.

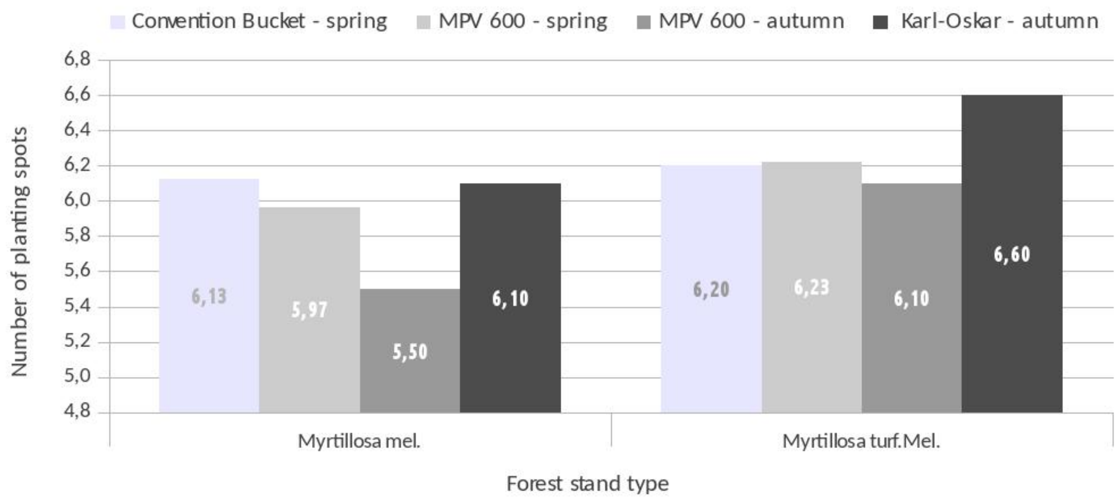

Figure 1: Number of planting spots in different stand types in 25 m² sampling plots depending from scarification season

The average number of acceptable planting spots (mounds) in different forest stand types in 25 m2 sampling plots were: in *Myrtillosa mel*. forest stand type – 5.9; in *Myrtillosa turf. Mel*. forest stand type – 6.3; in *Myrtillosoi-polytrichosa* forest stand type – 4.9. Preparation of planting spots using mounding method ensures reaching of threshold values set by laws for spruce seedlings, and about 50 % of the necessary spots – for pine, which means that mounding can be applied in areas, where spruce hasto be used in forest regeneration. Scarification of soil using mounding method in areas, which has to be regenerated with pine can be done, if considerable natural ingrowth is expected

There are no substantial differences in penetration resistance between two different bucket types in one season, nor between seasons, where the work was done in spring and autumn. In areas, where the soil preparation was done in spring, the penetration resistance near the root zone (5-20 cm) was 0,5 MPa, in sites prepared in autumn – 0,4 MPa (Fig.2). Both values are suitable for root growth. The conditions unfavourable for growth of roots (> 2 MPa) observed close to 80 cm depth. There is no decrease in resistance peaks observed, indicating that there are no air chambers under the mounds. During the vegetation season no changes in penetration resistance was observed, indicating that no compaction or weathering of mounds takes place.

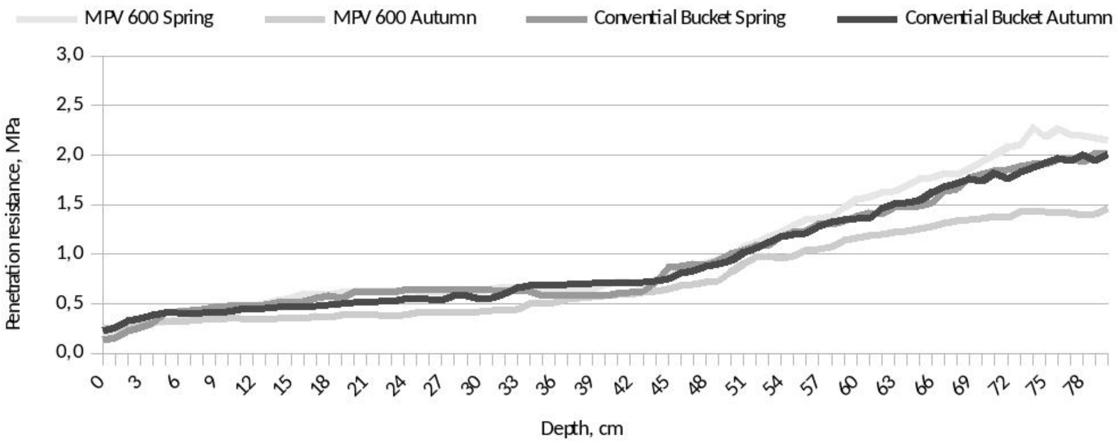

Figure 2: Mound resistance in spring and autumn sites

If 2000 planting spots per ha^{-1} are prepared, share of scarified area with conventional excavator bucket is 44 %, with MPV 600 – 23-29 %, with Karl-Oscar – 12-17 %. If 3000 planting spots per ha^{-1} are prepared, share of scarified area with conventional excavator bucket is 66 %, with MPV 600 – 34-41 %, with Karl-Oscar – 19-25 %. According to requirements share of scarified area should not exceed 30 %, which means that Karl Oscar and MPV 600 fulfils the requirements if up to 2000 planting spots per ha^{-1} are prepared and Karl Oscar fulfils the requirements if up to 3000 planting spots per ha^{-1} are prepared.

The study is done within the scope of the National forest competence centre project "Methods and technologies to increase forest value" (L-KC-11-0004).

Keywords: *MPV 600, mounding, mound resistance*

MANAGEMENT STRATEGIES FOR REDUCING BROWSING DAMAGE BY MOOSE

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Abstract

Forestry is a main land use in Sweden and contributes significantly to the country's economy. The Swedish moose (*Alces alces*) population is among the densest in the world and moose hunting is culturally, socially and economically valued. One of the most important tree species for Swedish forestry is Scots pine (*Pinus sylvestris*), which also constitutes the most important winter forage for moose. Moose browsing on young Scots pine may affect the trees in terms of retarded growth, increased risk of mortality and reduced stem quality. This may be costly for forest owners, both at present time by e.g. replanting and in the future by lower value of the trees when harvested. A current challenge for forestry researchers is to find means for reducing browsing damage in young pine stands by various forest management actions. We studied spatial distribution of browsing and damage by moose in young pine stands in central Sweden and possibilities of using selective thinning of damaged stands as a tool for reducing the economic losses for forestry. Our results revealed complex relationships between damage levels and explanatory variables depending on spatial scale. In conclusion, pre-commercial and commercial thinning can be used to reduce damage levels in pine stands, but the actions should be evaluated in relation to additional factors, such as stem density and tree species mixture, on relevant spatial scales. Our findings are discussed in the light of other studies of forest management practices for reducing browsing damages and related economic costs within the Nordic countries.

Keywords: *forest damage, herbivory, spatial,*

TOWARDS CAPTURING THE FULL VALUE OF THE TREE THROUGH IMPROVED HARVESTER MEASUREMENTS

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Accurate measurements of length and diameter during processing of a stem at harvesting are crucial in order to fulfil the needs of the customer while recovering maximum value for the forest owner. At processing, the measurement system in the harvester head continuously measures stem diameter and length. Based on these dimensions, and together with additional information that the operator provides, such as tree species and damages, the harvester computer decides which logs to produce from the stem. Accurate measurements allows for production of highly specific assortments as well as decreased safety margins, e.g. trimming allowance, meaning more value to the customer and less waste in the system.

The technology for measuring length and diameter has basically been the same since the 1980s. Even so, after following a group of harvesters over time, we conclude that the best harvesters sustainably succeed in measure both diameter and length with really high precision.

But how can we decide on the measurement quality of a harvester? In Sweden, a system for quality assurance of harvester measurements is in place since 2006. The system builds on self-monitoring through manual control measurements of diameter and length of randomly selected stems. The results of the control measurements are reported according to the StanForD standard. An independent auditor is responsible for following up the measurement result of the harvester and for communicating the results with both the harvester operator and the employing forest company. The auditor also visits the operators in the forest at least twice a year to follow up the quality of the manual control measurements. To fulfil the demands of the quality assurance system, at least 50 % of the harvester's diameter measurements need to fall within ± 4 mm from the manually measured reference. For length measurements, at least 60 % of the harvester's measurements must fall within ± 2 cm from the reference.

For research and development purposes, the quality assurance system provides an excellent opportunity to study the development of measurement quality in harvesters over longer periods of time without costly separate data collection. The random selection of control measured stems ensures a representative sample of stems, allowing us to draw conclusions regarding the average measuring quality. In our work, we have used standardized information from the quality assurance system and combined it with data from the control system of the harvester. By taking this approach, we want to study the relationship between measurement quality and factors like machine settings or calibration status. So far, we haven't been able to identify any strong general relationship between one single factor like e.g. machine settings and measurement quality. The reason is most likely that there is a range of different factors that can have an impact on measurement quality. However, for specific harvesters, we can form hypotheses on probable causes for the lower measurement quality, e.g. deviating pressure settings.

Most harvester heads measure stem diameter by monitoring the position of the delimbing tools as the stem passes through the head. Therefore, pressure settings for the upper delimbing tools are probably relevant for measurement quality. By comparing the pressure settings of one of the harvesters with a lower measurement quality with the best ones, we can assume that for this machine, at least part of the explanation why the measurement is deviating is because of the relatively lower pressure on the upper delimbing tools.

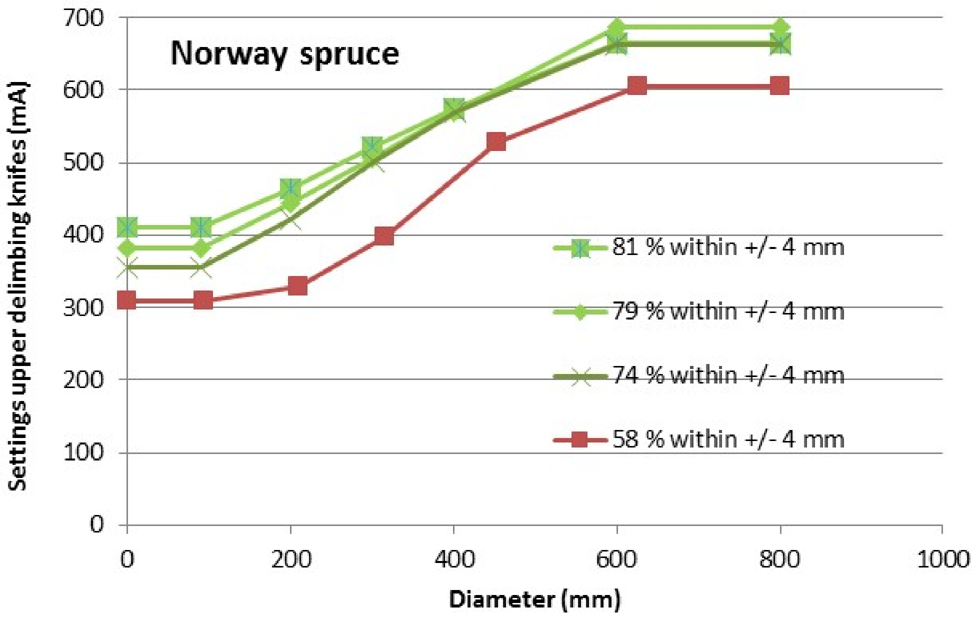

Figure 1. Pressure settings for three harvesters with high measurement quality (green) and one with a lower quality (red). All harvesters are John Deere harvesters equipped with the same type of harvester head.

Additional to the factors closely connected to the harvester, like physical shape of the measurement system, current machine settings and calibration status, there are other factors that we believe can be just as important for measurement quality. This could be things like operator skills, outside temperature and forest stand characteristics. To help the operators to keep high quality harvester measurements, advanced decision support tools are needed. These tools could help identifying deviating measurement quality and the cause for that. If adjustments of the system are required the operator should be advised how to make these adjustments. Such a decision support tool must be fed with relevant information, and we hope that our current activities around harvester measurements will help identifying relevant key performance indicators.

Keywords: *Measurement system, wood value, quality assurance, harvester.*

CALIBRATION OF FOREST INVENTORY DATA BY PRECISE PRE-HARVEST MEASUREMENTS

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Foresters start pre-harvest planning with choosing eligible stands for harvesting. Choice is based on stands' characteristics: age, volume, species mixture etc. Traditionally, the data base of forest inventory is used with information about each stand or compartment. The characteristics of each stand are estimated by ocular standwise inventory method. When eligible stands have been chosen, field assessment is realized – by estimating volume, product structure, harvesting conditions etc. However, standwise forest inventory has shortages with measurement accuracy. The reasons of inaccuracy are various: stands heterogeneity, surveyors don't visit every part of the compartment etc. The typical systematic errors are: volume is overestimated or underestimated, the volume of some species is overestimated and other species is underestimated. This is the reason for additional harvesting sites re-planning activities and additional activities to decrease profitability and efficiency of forest operations.

The accuracy of standwise forest inventory can be improved (calibrated) by using the sample of precise measured stands and by using the regression techniques. The pre-harvest measurements - stands measured by callipers could be used for precise data (each tree's diameter was measured and height of number of trees was measured in stands). The aim of the research is to find out calibration functions for improving the accuracy of standwise forest inventory of mature stands' first storey volume.

Study was realised in the whole territory of Latvia, in the joint stock company's "Latvijas valsts meži" managed forests. The data of pre-harvest measurements was collected during the period from 2010 – 2012, the calibration functions were made in year 2014. Totally 728 mature stands were selected randomly from 4500 stands precisely measured by callipers. Stands represent all regions, site indexes and species: pine (*Pinus sylvestris* L.), spruce (*Picea abies* (L.) Karst.), birch (*Betula* spp.), aspen (*Populus tremula* L.), black alder (*Alnus glutinosa* L.).

The correlation analysis was used to find out the characteristics improving accuracy of standwise forest inventory. The regression analysis and analysis of covariance were used to set linear relationship (calibration function) between standwise forest inventory and precise stand measurements. The calibrations functions were made for each species height and for basal area: each dominant species, each no-dominant species and stands of each dominant species. The last calibration function was made to calibrate the impact of the no-existing species in standwise forest inventory (~10% from stands total volume).

The height calibration function was made with standwise forest inventory characteristics: species height and dominant species. For basal area calibration, functions were made with standwise forest inventory characteristics: each species basal area, basal area of dominant species stands, and sawlogs outcome regions (3 –4 regions per species that characterize sawlogs outcome). The calibration functions and coefficients significantly ($p<0.05$) calibrate height and basal area from the standwise forest inventory data.

The improved accuracy (volume) was estimated by comparing the difference of dominant species, volume groups and each species volume between precise pre-harvest measurements, standwise forest inventory and calibrated data. Firstly, the height of each species and the basal area of each species and stand were calibrated. Secondly, the each species and stands volume was calculated. Finally, the difference was calculated between original data, calibrated data and pre-harvest measurements. The results are given in the tables below.

Table 1.The difference of stands' first storey volume of dominant tree species between precise pre-harvest measurements (PPHM), standwise forest inventory (SFI) and calibrated data (CD)

Characteristics	All species	Pine	Spruce	Birch	Aspen	Black alder
Difference $\left(\frac{PPHM}{SFI}-1\right)$, %	-17.4	-18.8	-11.2	-19.2	-15.2	-27.2
Difference $\left(\frac{PPHM}{CD}-1\right)$, %	-3.2	-1.9	-2.2	-4.3	-2.7	-7.2

Table 2.The difference of stands' first storey volume of volume groups between precise pre-harvest measurements (PPHM), standwise forest inventory (SFI) and calibrated data (CD)

Characteristics	Volume groups, m^3ha^{-1}			
	<200 m^3ha^{-1}	200 - 300	300 - 400	>400
Difference $\left(\frac{PPHM}{SFI}-1\right)$, %	5.9	-6.9	-17.7	-28.7
Difference $\left(\frac{PPHM}{CD}-1\right)$, %	21.8	8.9	-3.9	-15.5

Table 3.The difference of species' first storey volume between precise pre-harvest measurements (PPHM), standwise forest inventory (SFI) and calibrated data (CD)

Characteristics	Pine	Spruce	Birch	Aspen	Black alder
Difference $\left(\frac{PPHM}{SFI}-1\right)$, %	-8.8	-23.9	-5.9	-18.6	-26.3
Difference $\left(\frac{PPHM}{CD}-1\right)$, %	9.0	-9.1	1.1	-2.8	-6.4

The results show that volume of dominant species' stands is calibrated close to precise pre-harvest measurements. The calibration functions don't increase the accuracy in the stands with volume less than 200 m^3ha^{-1} and don't increase accuracy enough for stands with volume more than 400 m^3ha^{-1}. The calibration functions overestimate the volume of pine and not enough calibrate the volume of spruce. The most precise result is for birch and aspen. Nevertheless, it's possible to calibrate – to increase accuracy of standwise forest inventory data with calibration functions.

Moreover, efficiency of forest operations could be increased by using more accurate data to choose stands for harvesting. In addition the factors impacting accuracy could be used for education and training of the employees involved in standwise forest inventory and field assessment of harvesting sites.

Keywords: *calibration, standwise forest inventory, pre-harvest measurements, callipering*

DECISION SUPPORT IN HARVESTING OF NORWAY SPRUCE

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Maximizing margins using an app-based decision support system for choosing harvesting system and assortments

Introduction

The Danish Forestry Extension, Division East has launched a number of different initiatives focusing on optimizing the company's business and increasing the forest owner's revenue. One of these initiatives is to trade directly with sawmills; another is to develop logistic management programs.

Changes in demand and supply for varying assortments and varying exchange rates makes the decision of harvesting system and assortments very dynamic and complicated, and decisions are mostly based on intuition and past experience that very rarely is being followed up-upon.

Therefore the Danish Forestry Extension has asked for a simple 'decision support tool' that can collect the most important information required for bucking decision-making and answer the question; what bucking will result in the highest revenue? As more and more other tools are based on apps in smartphones the Danish Forestry Extension has asked for a solution that could be programmed as an app. The tool was developed using Microsoft Excel 2010 that could be transferred into an app.

Material and methods

All the calculations were based on a mean tree model and stand size in hectares. The tool contains models that calculate tree height based on the mean tree basal area and stem number per hectare. However both the height and the stem number can be changed manually. The total wood volume is calculated based on the mean tree volume and the total stem number. The wood volume is distributed into assortments based on requirements for minimum top diameter by a theoretic bucking program specially developed for the tool. In accordance with this information, expenses, income and revenue can be calculated and presented in a bar-chart. The tool is able to run on iPhone and iPad through the program "Numbers", or on PC directly in Microsoft Excel. Simply by clicking on and off each assortment can be accepted or rejected based on the calculated margin for each assortment.

An important part of the task has been to test the functions and models used in the decision support tool. The following tests have been undertaken:

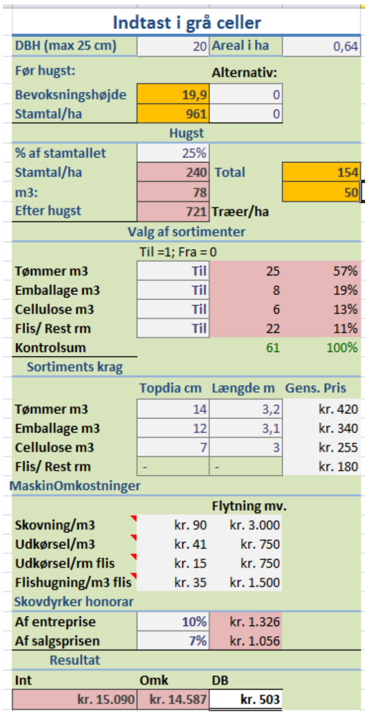
- Test of the used form factor against the more complicated and more precise ones.
- Test of how the simplified model for stem volume perform against empirical data on single tree measurements
- Test of how the method for bucking matches those from the Danish Nature Agency's empirical data on assortments.

Results

The simplified model for calculating volumes for the different assortments is very simple, but gives acceptable results anyway.

The elements of the decision support tool have generally shown good compliance with existing data but have not been tested in the field on actual logging.

The Danish Forestry Extension is satisfied with the relative few input needed and the way results are presented.



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	Til =1; Fra = 0		
Tømmer m3	Til	25	57%
Emballage m3	Til	8	19%
Cellulose m3	Til	6	13%
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Emballage m3	12	3,1	kr. 340
Cellulose m3	7	3	kr. 255
Flis/ Rest rm	-	-	kr. 180
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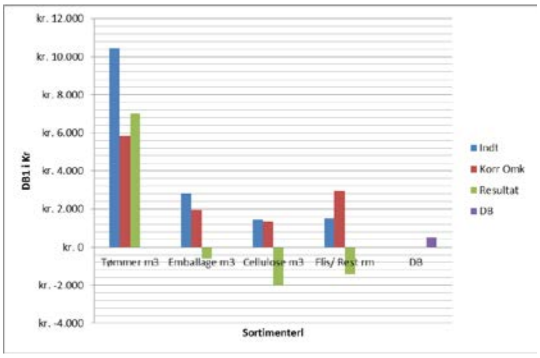

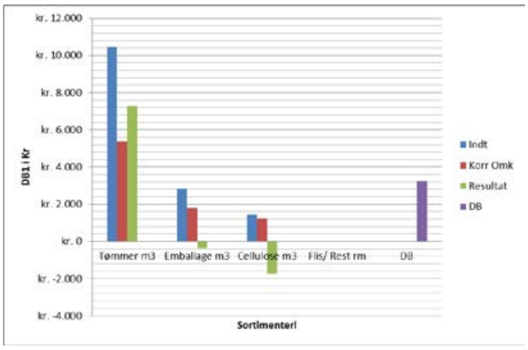

Input page User interface

Figure 1. The input page and the user interface of the programme.

Discussion

The programme can be extended for the use in other tree species and be improved by including more precise volume functions and stem taper functions. However the uncertainty in other parts of the model such as the uncertainty of the input data and the difficulties in adjusting the theoretical bucking model might be more serious problems.

The user interface might be improved in dialog with the users and IT experts.

Keywords: *decision-support, thinning Norway spruce.*

SUCCESS FACTORS FOR LARGER FOREST FUEL TERMINALS

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Terminals serve an important function for forest fuel logistics, both in single mode road transport and where a transport involves a combination of road and rail. Structural changes in Sweden, such as new regulations for measurements of forest fuel, have triggered a need to find out more about what makes a terminal successful. A review of the current terminal structure for handling forest fuel was also required.

Structured in-depth interviews were held with 13 respondents from forestry companies, energy companies and logistic companies (who were running open terminals). The interviews concerned the following matters:

• What factors lie behind successful establishment of terminals?

• When is it advantageous to own a terminal, and when is it better to make use of an open terminal?

• What do forestry companies think about their ownership of terminals?

A geographical analysis was also carried out, to compare the catchment areas of existing terminals with locations of forest resources in Sweden.

Location was clearly chosen as the most important success factor by all respondents and also by literature. It is closely related to the volume passing through the terminal. A larger forest fuel terminal for seasonal storage holds around 50 000 – 100 000 m^3 of chipped material, but a railroad terminal with big investments must revenue that volume many times per year.

But criterion for a good location can vary depending on the purpose of the terminal and the viewer. Locations close to forest resources create value by making onward transport and comminution more efficient, while location close to industry allows joint utilization of resources and possibly return transports. For the energy companies, control and proximity to their own furnaces is most important. Therefore a location close to the energy plant is preferred by this group. For some logistic companies, access to railroad remained the base of their entire business model, but also forest companies that didn't have present use for railroad valued railroad access as strategically important. The aspect of strategic localization between forestry resources and customers were mentioned, since terminals lengthen road transports if they are not optimally located in the supply chain. Figure 1 describes the different strategies for localization conceptually.

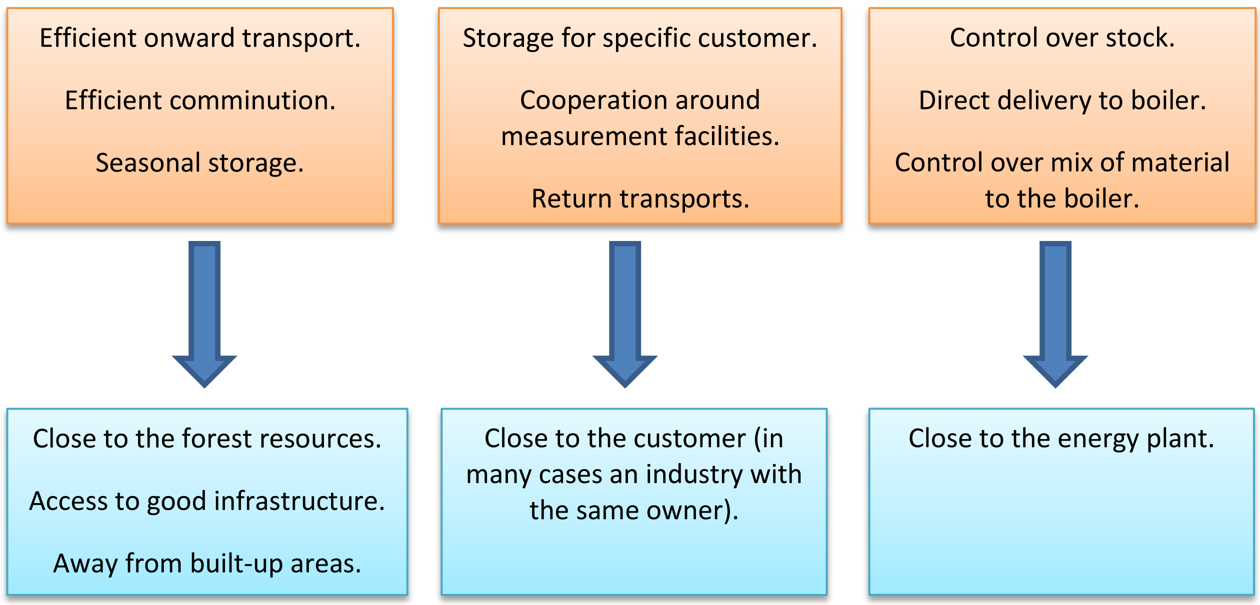

Figure 1. Different purposes for terminals and views of different respondent groups, give diverse strategies for localization.

Four additional success factors are listed below. The comparative importance between them could not be determined from the study.

- Facilities for measurements, such as scale for trucks, a measuring bridge or a drying oven. New requirements for measuring chipped material necessitates new technology, collaboration or merging of smaller terminals.
- Asphalt surface for chips handling is an important factor for ensuring quality by avoiding contaminants such as stones or gravel. However, chipped material is sometimes handled on gravel surfaces since end-customers rarely demanding or paying extra for asphalt.
- Skilled, flexible and customer-oriented personnel is an aspect frequently mentioned by the logistic companies running open terminals where forest companies are customers.
- Good internal logistics and order on the terminal is important for many reasons. Old material should not be locked in by new, drivers should easily find their way to the right place, cautions against fires should be taken and rail road loading should be organized in order to minimize loading time with available resources.
-

The interviews and the map analysis show that forestry companies often use too many terminals. The map analyze showed that approximately 95 % of the Swedish forest fuel were to be found within the catchment areas of existing terminals. Consequently, new initiatives primarily involve mergers to create sufficient volumes for investments.

All respondent groups reported coordination gains generated by large, open terminals, still some of the forest companies felt that control, independence and competitive advantages tipped the balance in favor of owning their own terminals.

Keywords: *Terminals, forest fuel, best practice, establishment*

CHARACTERISTICS OF SWEDISH FOREST BIOMASS TERMINALS

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Abstract

Traditionally, forest terminals serve as storage and transition points for round wood deliveries within forest industry supply chains. However, demands of forest terminals have been changing over time. The use of forest terminals for round wood supplies still represents the largest share today. Due to unpredictable challenges, such as weather change, affecting not only energy demand, but also the harvesting operations and supplies of the raw materials, and the imbalance between supply and demand, terminals play an increasingly crucial role as storage and buffer points for the delivery of biomass to combined heat and power plants (CHP). Additionally, the emergence of bio-refineries depicts an uncertain factor for the future forest raw material supply chain, since different concepts of bio-refining put different constraints on raw materials.

The aim of this work was to characterize existing Swedish forest biomass terminals in terms of location, size, assortment structure, infrastructure and basic management routines. In total 18 forest companies were asked to provide data on their forest biomass terminals. Responses were received from 15 companies which represent about 67 % of the estimated total of terminals in Sweden. Terminals were grouped according to their area size in four groups. Additionally to the terminal area only terminals which provided related information such as volumes, number of customers, equipment etc. were considered in the analysis.

Total biomass for energy production passing the 229 analyzed forest terminals was 2.03 M oven-dry tonnes (OD t). An average terminal in Sweden is 2 ha big with 0.9 ha of paved area and is delivering to three different customers and handling 9 644 OD t. 61 % of total biomass at the forest terminals is energy wood followed by logging residue chips. Terminals < 2 ha play an important role in the supply of raw materials to the energy sector. They supply more than half of the total volume and account for 35 % of total terminal area. Terminals up to 5 ha account for a further 19% of total volume and a further 30% of total terminal area. Within each terminal size class between 9 and 17 assortments are handled; the assortment range is biggest for terminals < 2 ha and smallest for terminals 5 – 10 ha. Terminals > 2 ha seem to be more specialized in bulk deliveries. Terminals up to 5 ha more often have mobile equipment such as e.g. wheel loaders while bigger terminals have better measuring facilities. On average 81 % of terminals up to 5 ha use terminal's personal to conduct inventories while only 39 % of these terminals are using a third party to do it. Contrary to this, on average 36 % of terminals > 5 ha are using terminal personal and 89 % of terminals are using only the Timber Measurement Association as third party inventory maker. Terminals > 5 ha tend to be older than smaller terminals.

The gathered data improves knowledge about the state of forest biomass terminals in Sweden. There is great variety of handled biomass at terminals and their management between terminal size classes. Knowledge about different terminal classes allows focusing on different future terminal designs and machine systems at each of these categories to improve their operational and economic performance and to better integrate them into the total supply chain of forest biomass for bio-refineries.

Keywords: *bio-refineries, CHP, forest fuels, energy wood, supply-chain, terminal*

THE IMPORTANCE OF DRY MATTER LOSS AND CAPITAL COSTS IN ENERGY WOOD SUPPLY CHAIN

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Dry matter loss caused by biological decomposition is a well-documented problem of wood storing. Exact measurement of dry matter loss is difficult. Small test batches can be investigated but real size storages are difficult to study. Constant weighing based methodologies with thorough moisture measurements enable exact definition of dry matter losses of bigger storages during storing. Constant weighing of storages was done to study natural drying of energy wood and, simultaneously, dry matter losses were observed. Surprisingly high dry matter losses started discussion about costs and benefits of storing of energy wood. Higher energy content per weight, better balance of supply and lower transportation costs versus capital costs and smaller total amount of energy need to be compared, in order to choose the appropriate storing period. Together with annual fluctuation of demand and changing storing conditions around a year the decision making situation is challenging.

According to results of Routa, Kolström & Sikanen dry matter losses in energy wood storages vary roughly between 0.5-2.5 % per month for logging residues and delimbed stems. For forest chip storing, Hirvonen, Juntunen & Paukkunen (2013) reported losses of 3% per month. These figures are supported by, for example, Jirjis (1995) who presented figures of 1.2-6.4 % per month for comminuted materials. Nurmi (1999) found 0.5-1.7 % per month losses for residues. Hamelinck et all. (2005) gave a rough figure of 3% per month of their energy balance study. Results of Petterson & Nordfjell (2007) were 1-1.8% per month for compacted residues. VTT in Finland suggest to use 2% losses per month for first two months and then 1% per month for chips and saw dust.

According to the above mentioned findings, we conclude that for residues and comminuted materials dry matter losses vary between 1-3% per month and 1% can be given as a minimum figure for all cases if not frozen or below 20% MC. For stemwood, the corresponding figures are estimated to be 0.5-1% per month. Are these dry matter losses stable or varying through storing period? Thermal activity in piles can be monitored and by that, the length and intensity of microbial processes can be found out. It is important to be able to estimate the costs and profits of storing in monetary terms. In this piece of research, estimates of dry matter losses and capital costs of storing are presented in monetary terms and related to the timing of operations.

Keywords: *energy wood, wood chips, quality, storing, natural drying, dry matter loss*

THE EFFECT OF MACHINE FACTORS ON HARVESTER PRODUCTIVITY IN THINNING AND FINAL FELLING

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Introduction and methods

Productivity development in Swedish forest operations has been a success story for several decades, but has stagnated or even decreased over the last few years. This study will search for productivity differences among harvesters of different sizes, and with different equipment, as an aid to practitioners who wish to turn this trend by choosing the optimal equipment for their operation. The data used in the study represents follow-up production data from over 400 individual harvesters that worked in SCA Skog AB's harvesting operations in northern Sweden, cutting over 20 million m^3 of wood between 2009-2012. For each individual stand in the data, productivity; mean stem size; and a variety of other stand-related factors that could presumably affect productivity was recorded. Further, data on the harvester that cut each stand was recorded. This data included brand and model for the base machine; and information on whether the machine was equipped with stem-accumulating equipment or not. The base machines were subjectively classified according to size into six classes, from S to XXXL, to facilitate analysis (Table 1).

Table 1: Harvester classes with typical representatives and specifications for each class.

Class	Typical base machine	Typical gross weight (tonnes)	Typical engine Power (kW)	Typical gross lifting torque (kNm)
S	Rottne H8	8-12	80-120	80-100
M	JD1070	14-17	130-140	140-160
L	JD1170	17-18	145-150	160-200
XL	Ponsse Ergo	17-21	170-210	190-230
XXL	JD1470	19-22	190-195	210-220
XXXL	Komatsu 941	24	210	270

Productivity functions was developed for thinning and final felling, respectively, using both stand and machine variables as independent variables in multiple ordinary least squares regression analyses (Eriksson & Lindroos, unpub.). The effects of machine related variables on productivity are presented in the results section below, followed by a short discussion.

Results

For final felling, significant differences in productivity were found between all six harvester classes, even when adjusted for, for instance, mean stem size. The general tendency was that productivity increased with harvester size for all mean stem sizes, with the exception of size L, which was slightly less productive than class M for all mean stem sizes. Harvesters equipped for stem accumulation averaged 8 % higher productivity than those that were not (significant at the p=0.001 level, Table 2).

Table 2: Harvester productivity in final felling per harvester size, measured in m^3/PMH.

	No stem accumulation equipment						Equipped with stem accumulation					
m3/stem	S	M	L	XL	XXL	XXXL	S	M	L	XL	XXL	XXXL
0,1	10,9	13,4	13,1	13,7	13,9	14,7	11,8	14,5	14,2	14,8	15,0	15,9
0,2	18,1	20,9	20,6	21,3	21,6	22,6	19,6	22,6	22,3	23,1	23,3	24,4
0,3	23,5	26,4	26,1	26,8	27,1	28,1	25,5	28,5	28,3	29,0	29,3	30,4
0,4	28,0	30,6	30,4	31,2	31,4	32,4	30,3	33,1	32,9	33,7	34,0	35,1
0,5	31,9	34,1	34,0	34,7	35,0	35,9	34,5	36,9	36,8	37,6	37,9	38,9

Similarly, productivity of the four harvester classes used in thinnings were found to differ significantly from each other, with a similar tendency towards larger harvesters being more productive for all stem sizes. Harvesters equipped for stem accumulation were on average 5 % more productive than those that were not, which was significant at the $p=0.001$ level (Table3).

Table 3: Harvester productivity in thinning per harvester size, measured in m^3/PMH.

	No stem accumulation equipment				Equipped with stem accumulation			
m3/stem	S	M	L	XL	S	M	L	XL
0,05	6,5	6,8	6,9	7,4	6,8	7,2	7,2	7,8
0,10	10,4	10,8	10,9	11,5	10,9	11,3	11,4	12,1
0,15	13,6	14,1	14,2	14,9	14,4	14,8	14,9	15,6
0,20	16,6	17,0	17,1	17,9	17,4	17,9	18,0	18,8
0,25	19,3	19,7	19,8	20,6	20,3	20,7	20,8	21,7

Discussion

This study show that there can be significant gains made in harvesting productivity by choosing the best available equipment, with results favouring the largest suitable harvesters equipped with stem accumulation, regardless of mean stem size. However, the recorded differences between harvester sizes were comparatively small in relation to differences recorded by other more controlled experiments. For instance, Arlinger et al. (2014) recorded a ca 16 % difference between two harvesters of sizes L and XXL in final felling at mean stem size 0,22 m3/stem, a difference that increased with increasing stem size. As a comparison, this study recorded an average difference of ca 4 % at similar mean stem size, a difference that declined slightly with increasing stem size (Table 2). The difference between controlled experiments and follow-up data may be explained if the productive large harvesters more often than their smaller peers are outperforming their forwarder. If so, it is likely that the larger harvesters more often need to reduce their pace to avoid building excessive stocks, which would explain the observed difference, and point out improved harvester-forwarder interaction as a big potential for future productivity gains.

Literature

Eriksson, M., Lindroos, O. Productivity of harvesters and forwarders in CTL operations in Northern Sweden based on large follow-up datasets. Unpublished.

Arlinger, J., Brunberg, T., Lundström, H., Möller, J. 2014. Jämförelse av JD1170E och JD1470E i slutavverkning hos SCA Skog AB hösten 2013. [Comparison of JD1170E and JD 1470E in final felling at SCA Skog AB, autumn 2013] Arbetsrapport 817-2014, Skogforsk

Keywords: *Harvester, productivity, thinning, final felling, follow-up data*

SIZE MATTERS! IMPROVING OPERATIONS BY ANALYSING THE EFFECTS OF MACHINE SIZE

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Introduction

With the aim of developing a strategy for allocating the "right size machine" depending on the tree size etc of the logging site, Skogforsk conducted a comparative study in Cooperation with SCA and John Deere, of two similar harvesters, but where the size of machine, crane and felling head were different.

The initial hypothesis was that a larger machine would be beneficial for larger average tree sizes, while a smaller machine would be more cost efficient in smaller dimension stands.

Material and Methods

The studied machines were the average sized JD 1170E harvester equipped with a H754 head on a CH6 crane and the large 1470E with a H480 head on a CH8 crane. Both machines were carefully adjusted by JD technicians before the study.

Two operators took part in the experiment, driving both machines in the two spruce dominated tests stands (0,15 and 0,28 m^3sub, respectively). The operators were both skilled and normally drove one of the two machine types included. Through the study design the operator effect becomes manageable.

In addition to the conventional work study, a test of automated work study, utilizing Timberlink and StanForD 2010 was performed. Costs, wood value, fuel consumption and performance, also during multi-tree harvesting, were included in the work study. The ergonomics were subjectively rated by the operators.

Results

The larger machine, JD 1470 E had a higher performance and was the most cost efficient alternative in both stands. Analyses of the cost and performance (Fig 1) also over varying mean tree sizes indicate that the JD 1470E was the most economic choice at least down to an average tree size of 0,1 m^3sub.

The ability to recover maximum wood value was also better for the JD1470E. The more powerful H480 head controlled processing and measurement better than the JD 1170E/ H754 combination. However, other studies have shown that the operator and the instruction matrix has a much more decisive effect on value recovery than the technical properties of the head.

The automated time study, to be comparable with a conventional "the-highest-priority- timer-factor"-study worked extremely well (Fig. 2) The result indicates that time studies may be automated, leaving more time for the time study man to do qualitative and complex judgements while element time are recorded.

The fuel consumption, expressed as l x m^3sub^{-1} was ~10 % higher for the larger machine in the 0,15 m^3sub stand, but there was no difference in the 0,28 m^3sub stand. Multi-tree harvesting increased performance by 4 – 5 % for both machines and in both stands. The 1470E was perceived as significantly smoother and more comfortable platform by both operators, also the one used to 1170 in his normal work.

Discussion and conclusions

Forest work is a hard task. The use of a powerful and stable tool gives many advantages. The alternative of downsizing inevitably leads to more frequent situations where the operator needs to use the machine close to the maximum of its capacity. This is unfavourable both from the perspective of machine reliability and downtime as well as ergonomics. This study shows that a larger machine may enable higher work pace, better possibilities to recover wood value without inducing higher operating costs. It seems worthwhile to analyse this further in order to optimize the forest machine fleet.

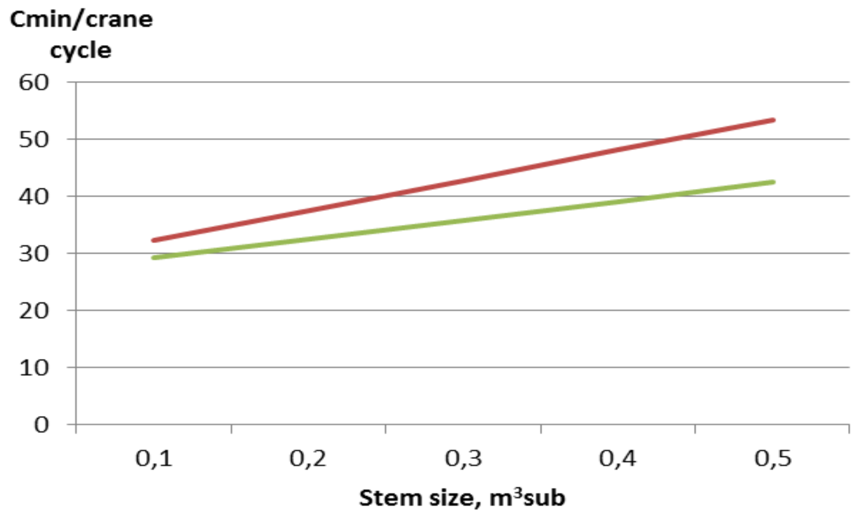

Figure 1. Time, cmin x crane cycle^{-1}, for JD1470E (green) and JD 1170E (red) in the 0,28 m^3sub stand.

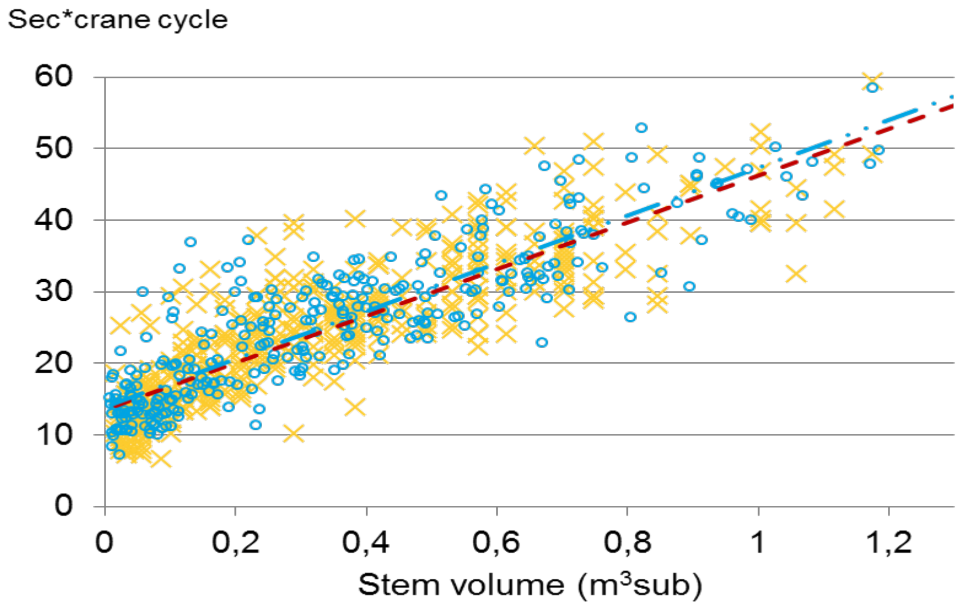

Figure 2. The time consumption, sec x crane cycle^{-1}, for JD 1170E (red) in the 0,28 m^3sub standaccording to the conventional (x) and automated (o) time study respectively.

Keywords: *Machine size, harvester performance, productivity, wood value, automated time study*

SIMULATION OF THINNING WITH ZERO, ONE OR TWO INTERMEDIATE PASSAGES BETWEEN THE STRIPROADS AND COMPARISON OF LOGGING COSTS

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Abstract

Zero, one or two intermediate passages between the strip roads are normally used for thinning operations. The work methods have been empirically studied, but with rather large restrictions in each study. The advantage with simulation as study method is that machine productivity can be compared under controlled impact from a great number of variables. In this study, a mathematical performance model was designed to do deterministic comparisons of the methods in first thinning of pine. A spatial part was designed for the harvester for e.g. distance calculation while felling. A work time calculation part was also constructed for both the harvester and the forwarder. Mean stem volume, strip road distance, transport distance and stem removal are examples of variables in the model, which was built from available productivity standards, own time studies and field observations.

The results showed small difference in machine system costs but with greater variation between individual machines. A slight cost benefit was observed for thinning with one intermediate passage followed by thinning without intermediate passages. Average volume per stem had a substantial impact on the cost of all machines, but showed no clear difference between the methods (Figure 1).

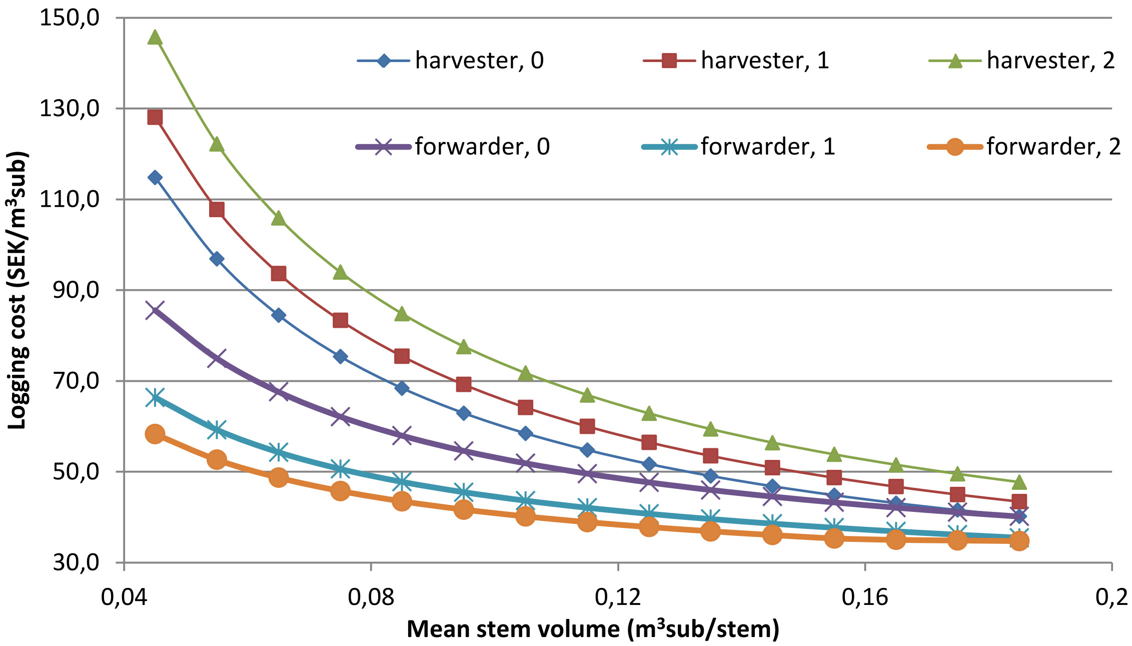

Figure 1. Logging cost as a function of mean stem volume. The number after the machine type (harvester or forwarder) shows method, were; 0 = thinning without intermediate passages, 1 = thinning with one intermediate passage, and 2 = thinning with two intermediate passages.

Strip road distance had a substantial impact on forwarder productivity. Forwarder had higher productivity when the strip road distance was increased (regardless of method) since it increased the wood concentration at strip road and hence fewer crane cycles was required to fill a load. The opposite was observed for the harvester, which decreased its productivity with longer strip road distance as it required longer crane movement of felled stems (Figure 2).

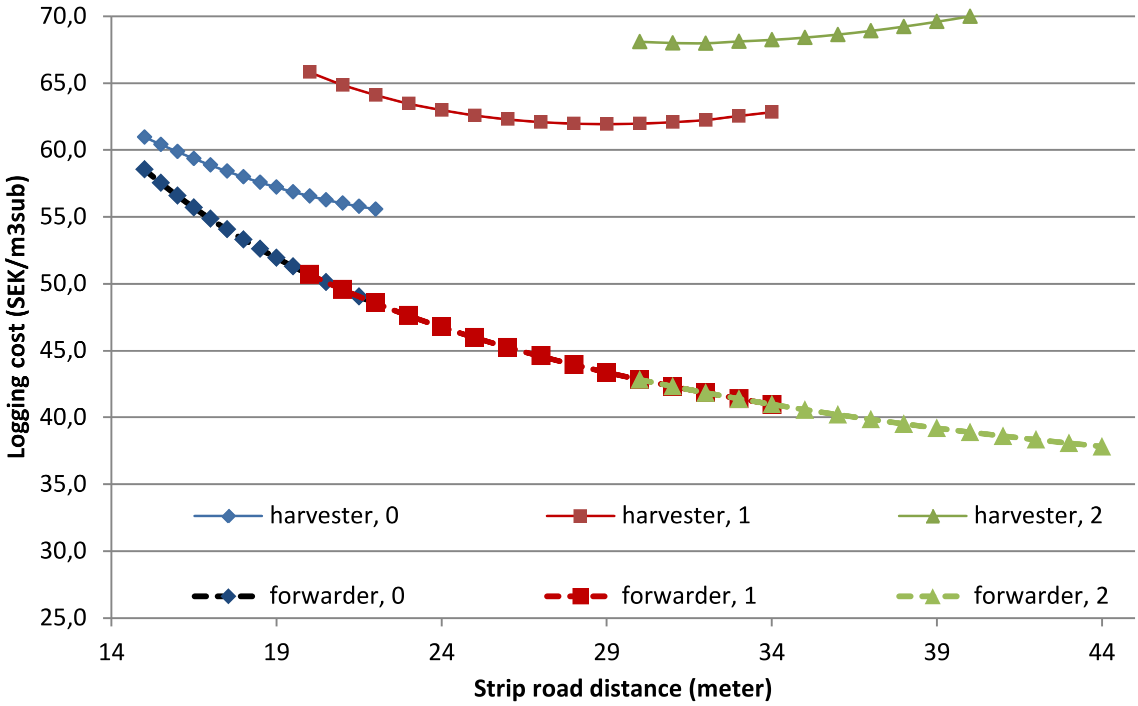

Figure 2. Logging cost against as a function of strip road distance. The number after the machine shows method, see figure 1 for explanations.

An increased cost of the harvester work was often compensated by lower cost for the forwarder work. This demonstrates an important balance between the harvester and forwarder, where a longer strip road distance can be achieved by using intermediate passages to favor the forwarders work efficiency. An increased cost for the harvester in thinning with intermediate passages can be compensated with a decreased cost for the forwarder. The study showed that thinning with one intermediate passage is the cheapest method but that strip road distance is an important variable to control.

EVALUATION OF IMPACT ON ASSORTMENTS' STRUCTURE ON PRODUCTIVITY OF TIMBEAR HARVESTER IN EARLY THINNING

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The study aims to compare 4 work methods of solid biofuel and standard roundwood assortment production in early thinning, and to identify factors that influence the cost of mechanized thinning, including the assessment of environmental impact (soil compaction and rut formation). The work methods compared in the study are: (1) standard thinning (production of sawn timber, pulpwood and firewood) with no use of accumulating device; (2) production of standard roundwood assortments and partly delimbed biomass from undergrowth trees and tops of trees using accumulating function for undergrowth trees; (3) production of sawn timber and partly delimbed biomass from undergrowth trees and trees utilized for pulpwood production in the 1st and 2nd method and using accumulating function for all trees except those utilized for sawn wood production; (4) production of partly delimbed trees from all extracted trees considering the most intense utilization of accumulating device. The experiments were implemented in August – September, 2013 using Timbear harvester equipped with Keto 51 Supreme felling head and boom length 8.5 m.

The average productive working time of Timbear harvester is 64 % of the total working time. The average direct working time (duration of work cycles resulting with standard roundwood assortments or partly delimbed trees) is 88 % of the effective working time. Both indicators are significantly lower than the ones of other harvesters used in similar studies. Share of the productive working time decreased due to frequent harvester's repairs and other technical problems. The direct working time was negatively affected by the high proportions of unsuccessful work cycles (no assortments produced), which is most likely due to the problems with felling head. If these issues are ignored productivity of Timbear is similar or even higher compared to other tested machines. It would be reasonable to try another felling heads in order to improve work efficiency indicators of the Timbear harvester. Proportion of the effective working time can be increased by improving the problematic parts in design of the machine in collaboration with the manufacturer.

The comparison of work methods demonstrates an significant increase of productivity of harvesting as the number of assortments are reduced. The average direct working time to process 1 tree is 48 seconds, if the 4th work method is applied. If the 1st work method is applied, average time consumption to process 1 tree is 63 seconds. Similarly, the least consumption of direct working time to produce 1 m³ of roundwood is characteristic for the 4th work method (11 minutes). The highest consumption of direct working time is found, when the 2nd work method is applied (14 minutes). Production of a partly delimbed biofuel assortment significantly increases the productivity of mechanized young stand tending. The 3rd work method may be the most efficient solution for early thinning, if the price of pulpwood and biofuel are equalized. According to the study results delivery of wood chips to the consumer is significantly cheaper than delivery of pulpwood. At the same price level for pulpwood (under bark) and biofuel (with bark), delivery of biofuel is significantly more profitable than delivery of pulpwood.

In total 79 loads (458 tons of wood) were extracted with Timbear in forwarder version; the average load is 5.1 tons (2.6 tons of dry mass or 5.6 m^3 of roundwood). The average forwarding time of 1 load is 60 minutes of effective working time. The consumption of efficient working time to transport 1 ton of naturally wet material is 14 minutes. Forwarding of material from 1 ha (about 100 m^3) takes 8.9 hours of the efficient working time. Application of harvesting methods related to increased share of biofuel assortment significantly increases productivity of forwarding. The average loading time in 4th method is 43 minutes, the average unloading time – 9 minutes. The average driving speed with a load is 30 m per minute, without load – 49 m per minute.

If two scenarios of biofuel delivery (chips and roundwood) are compared for the 1st and the 2nd thinning method, both scenarios are economically viable. If those scenarios are compared for the 3rd and the 4th thinning method – only wood chips delivery scenario is economically viable. Incomes from deliveries of small diameter roundwood for 1st and 2nd work methods exceeds expenses, if a diameter of average sawn tree is not less than 7 cm. Positive balance cannot be reached by the 3rd and 4th work method, if small diameter wood is delivered. The wood chips delivery scenario ensures positive balance by the 1st and 2nd work method, if an average diameter of a sawn tree is larger than 6 cm, by the 3rd and 4th work method – if an average diameter of a sawn tree is larger than 7 cm. The scenario of wood chips delivery, depending on a work method, provides reduction in the cost price of wood chips from 0.27 EUR LV m^{-3} to 0.36 EUR LV m^{-3} compared to the delivery of a small diameter wood.

The most of the assortments left in a stand are pulpwood and fire wood, however these amounts are not significant. It means that theoretically the 4th work method has an advantage over traditional methods because assortments are placed in relatively larger heaps and probability to lose something is smaller.

The experiment demonstrates, that the main advantages of Timbear harvester in young stands is minimal soil damages (no ruts and no compaction of deeper soil layers). There is no need to leave branches and tops of trees in strip-roads to be able to extract the rest of material, which provides opportunity to reduce cost per unit if biofuel assortments are produced. Ability to continue operations in worst climatic conditions reduces downtime and relocation cost. However, the most of benefits of the Timbear machine relates to its forwarder version. In harvesting it might be more reasonable to use medium size wheeled harvesters with boom length 10 m.

The study is done within the scope of the National forest competence centre project “Methods and technologies to increase forest value” (L-KC-11-0004).

Keywords: *Timbear, work methods, early thinning*

PRECISION MEASUREMENT OF FOREST BIOMASS MOISTURE CHANGE AND DRY MATTER LOSSES BY CONSTANT WEIGHT MONITORING

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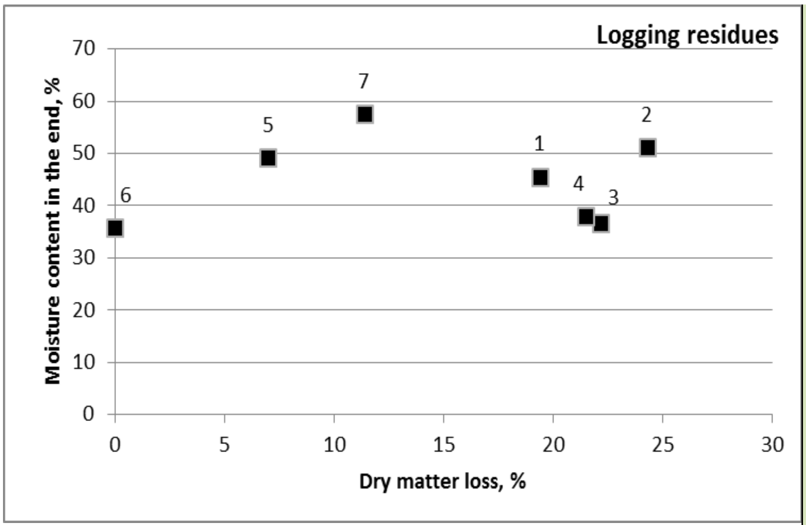
In the research on natural drying of forest biomass, numerous studies have been conducted based on traditional sampling of piles or weighing. The latest methodology for moisture change monitoring has been constant weighing of piles in racks built on load cells. This methodology allows moisture changes to be monitored in much more detail than previous sampling methods do. The method also gives the moisture of the whole pile, which is challenging to determine using sampling methods. Measurements can be taken automatically and as often as needed. This also enables exact investigation of the effect of weather on energy wood storage and its moisture content. Constant weight monitoring shows the drying of the biomass, but the monitoring can be disturbed by dry matter losses. The weight change is the sum of the water to be added or removed and the dry matter (mainly) removed from the pile by microbiological processes.

Figure 1. Drying experiment at Mekrijärvi Research Station

At Mekrijärvi Research Station of the University of Eastern Finland (62°46’N, 30°59’E), drying racks with continuous measuring systems have been built for research purposes. At first (I) experiment (15.11.2011-6.6.2013) there were logging residues: branches, tops, and some pieces of stem from a clear cut area of Norway spruce (*Picea abies*) in four of the racks, and small diameter stem wood, Scots pine (*Pinus sylvestris*) in two of the racks and birch (*Betula pendula*) in two of the racks. In the second (II) experiment (26.6.2013-24.2.2014) there was logging residues in four racks and small diameter stem wood (spruce and birch mixture) in three of the racks. Our data from the drying racks and the meteorological station shows that between wettability of energy wood and precipitation is clear connection. We observed that the net evaporation (the difference between evaporation and precipitation) seems to be a good determining variable for energy wood drying. We developed the drying models to forecast the energy wood moisture content for different energy wood fractions. We also observed remarkable dry matter losses during the storage period, with logging residues; they were between 0-24 % during storage period 8 months and with small diameter stem wood between 3-15 % during storage period 14 months.



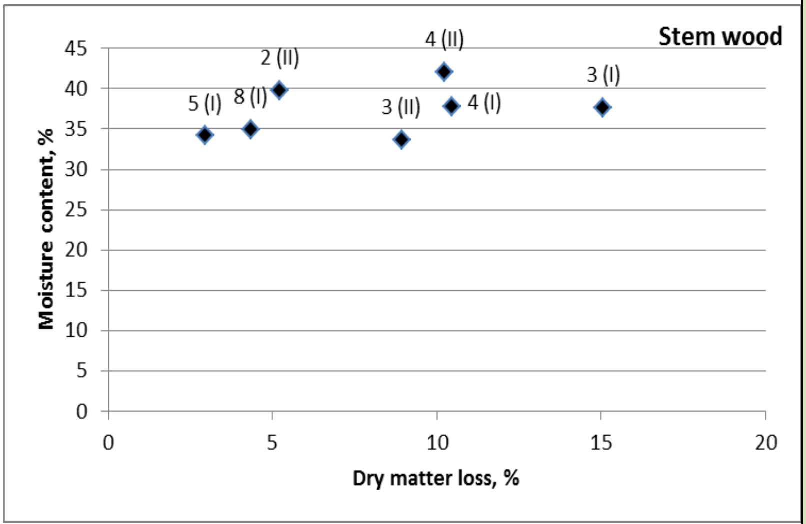


Figure 2. Moisture content in the end of experiment and dry matter loss during storage in different study piles.

Pile	Material; logging residues	Cover
1(I)	Fresh	paper
2(I)	4 weeks in the logging area	fabric
3(I)	4 weeks in the logging area	paper
4(II)	1 week in the logging area	paper
5(II)	1 week in the logging area	fabric
6(II)	6 weeks in the platform	paper
7(II)	1 week in the logging area	no cover
Pile	**Material; small diameter stem wood**	**Cover**
3(I)	Pine	paper
4(I)	Pine	no cover
5(I)	Birch	paper
8(I)	Birch	fabric
2(II)	Mixed	fabric
3(II)	Mixed	paper
4(II)	Mixed	no cover

Keywords: *energy wood, wood chips, quality, storing, natural drying, dry matter loss*

DETERMINING OF THE MOISTURE CONTENT OF ENERGY WOOD DURING FOREST FORWARDING AND STORING

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Few years ago started a wide research of mechanized moisture measurements in Finland. The purpose of this paper is to report the moisture determination methods of energy wood during forest forwarding and storing based on sawdust samples.

In the research of Metsäteho Ltd and the University of Eastern Finland, the efficiency of mechanized moisture determination methods was investigated during the wood procurement season of 2013-2013. Besides, the working conditions in energy wood forwarding and storing operations were clarified. The objective of this study was to research the functionality of the new sampling device of saw-dust and Humimeter BLL moisture meter. The efficiency of the new moisture determination method was tested in field conditions. The sampling device was developed and built by Sakari Mononen. The second objective of the study was to estimate the accuracy of the moisture meter. The third objective was to make the expense analysis for the moisture determination method.

The data of the study was collected in October and November 2012. The work study data was collected during normal energy wood procurement from six different logging areas. Four of the logging areas consisted of logging residues and two of the areas consisted of energy round wood. The moisture data consists of sawdust samples which were collected with the new sampling device. The moisture of the sawdust samples were measured with the Humimeter BLL moisture meter. The measurements were made in field conditions. Reference samples were taken from the sawdust samples. The real moisture of the sawdust samples was determined in laboratory with heating oven method. The statistical analyses were made with the SPSS statistic software. The calculations of the expense analysis for the moisture determination method were made by Excel.

The dependence between the moisture values determined by the heating oven method and the moisture measurement values which had been measured by the moisture meter was analyzed. The average moisture result of the data which were measured with the Humimeter BLL moisture meter was 35.4 percent. In proportion the average moisture result of the data which were measured with the heating oven method was 50.1 percent. Thus, the moisture results which were measured with the moisture meter were on average 14.7 percent lower than the results measured by the heating oven method. The usage of the new sawdust sampling method increased on average 21.1 percent of the working time for forest forwarding of logging residues.

As a conclusion the accuracy of the Humimeter BLL moisture meter was found to be inaccurate to determine the moisture of recently felled logging residue and energy round wood in field conditions. The main reason for the inaccuracy of the meter was probably that the moisture samples were too moist for the meter. The moisture of the sawdust samples were on the upper limit of the moisture scale which the manufacturer of the meter has announced. The moisture determination method which was studied in this study has potential, but the biggest problem is to find solution to the moisture measurement problems. In the future main goal is to find reliable moisture meter which is accurate enough and suitable for measuring moistures over 50 percent (even 70 percent).

Keywords: *logging residues, energy wood, moisture, forwarder, sampling method, cost-efficiency.*

PRODUCTIVITY OF MULTI-TREE CUTTING IN THINNINGS AND CLEAR CUTTINGS OF DOWNY BIRCH (*BETULA PUBESCENS*) IN THE INTEGRATED HARVESTING OF PULPWOOD AND ENERGY WOOD

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Background

Thinnings are a standard silvicultural practice in the Baltic Sea region, and are performed to guarantee a good supply of industrial roundwood, especially saw and veneer logs, for the future. An exception to the silvicultural standard seems to be downy birch (*Betula pubescens*), because recently it has been studied that both pulp and energy wood production as well as incomes are the highest in unthinned or very lightly thinned dense downy birch stands with a rather short rotation period of 30-40 years. Downy birch growing on peatlands and wet mineral soils produces rather low quality timber that is often inappropriate for veneer or sawing purposes but it is important raw material for the pulp and paper industries and as a fuel. In Finland the growing stock volume of forests dominated by downy birch, where downy birch accounts for more than 50% of the volume, is 82 million m^3 and 1.15 million hectares . The percentage of downy birch stands is highest in drained areas in North Ostrobothnia and West Lapland, where birch-dominated forests account for approximately 20% of forest land.

Material and methods

In order to improve the reliability of the above-mentioned silvicultural and economic analyses and especially to transfer silvicultural knowledge into practice, the Finnish Forest Institute organised a comparative time study with regard to the cutting productivity of downy birch in thinnings and clear cuttings together with the Finnish forest industry company Metsä Group. Harvested assortments in the integrated harvesting were birch pulpwood (5 m) and energy wood (5 - 7 m), which consisted of undelimbed tops of pulp wood stems and undersized small trees. Time studies were carried out both in winter and summer conditions and tree stands were located on drained peatlands in North Ostrobothnia near the geographical centre point of Finland.

The study utilised a 6-wheel Komatsu 901.4 harvester with an attached Komatsu 350.1 harvester head and a CRH 15 crane with a maximum reach of 10 m. Multi-tree handling in the Komatsu 350.1 harvester head was based on software utilising the MaxiXplorer control and information system that enables the synchronising of the feed roller and delimbing knife functions to operate as an accumulating device. The harvester-operator was skilful and he had 20 years' work experience in driving wheeled harvesters .The time study's plot-wise mass and volume of harvested timber fractions (for both pulpwood and energy wood) were measured during forwarding, with the crane scale. Forwarding was completed immediately after cutting trials with a Ponsse Wisent forwarder equipped with a Ponsse LoadOptimizer crane scale.

On the basis of time-study data collected during field work, the structure of time use was established and time consumption models were prepared for thinnings and clear cuttings carried out using the two-pile cutting method. According to the harvesting time consumption models, productivity was explained in terms of tree volume (dm^3) and harvesting intensity (number of trees removed per hectare). Productivity was expressed in solid cubic metres per effective hour (m^3/E_0h).

Results

In clear cuttings, the total number of trees harvested during the time study was 3234 and of the total volume 107.6 m^3 was considered to be pulpwood and 76.4 m^3 non-delimbed energy wood. In thinnings the total number of harvested trees was 1870 and of the total volume 38.6 m^3 was pulpwood and 27.1 m^3 non-delimbed energy wood respectively. On the clear cutting time-study plots, the average volume of the harvested trees varied in the range of 16–96 dm^3, the harvesting intensity was 1253–4072 harvested trees per hectare and cutting removal was 49–211 m^3/ha . On the thinning time-study plots, the average volume of the harvested trees varied in the range of 28–69 dm^3, the harvesting intensity was 475–2101 harvested trees per hectare and cutting removal was 23–109 m^3/ha . The average forwarder payloads of pulpwood and energy wood were 9.3 m^3 and 4.7 m^3 (full), and the payloads were noted to be equal both in thinnings and clear cuttings.

As expected, clear felling enhanced harvesting productivity in comparison with thinning, but multi-tree cutting only had a minor effect on productivity in the case of both harvesting methods due to the low percentage of multi-tree cutting. On the time-study sample plots, the lowest and highest values recorded for multi-tree cutting productivity per effective hour were 5.6 m^3/E_0h and 17.4 m^3/E_0h in clear cuttings and 4.8–10.9 m^3/E_0h in thinnings, respectively. On average, the harvester head processed 1.2 trees per grapple cycle, while grapple loads processed by means of the multi-tree method accounted for 16% of all time-study data in clear cutting and in thinnings 1.1 trees per grapple cycle and for 14% of all time-study data.

Conclusions

The study highlighted the need to improve the suitability of current harvesting equipment for the harvesting and multi-tree harvesting of birch and other bent trees. This is because harvesting conditions more favourable to clear cutting than thinning are the main factors underlying the observed leap in productivity: 1) The tree-specific moving time shortened when more trees could be harvested on the same spot than during thinning, 2) the removal of trees was systematic, 3) the remaining tree stand did not hamper the delimbing, cutting or piling of trees.

Since downy birch stems are often bent, they are ill-suited to multi-tree cutting using feeding and delimbing harvester heads. This has led to the fairly frequent use of the single-tree method when processing downy birch. In multi-tree cutting, non-simultaneous feed-in of trees is a common problem, i.e. the delimbed trees do not pass through the grapple at the same pace. This results in unwanted variation in the lengths and top diameters of pulpwood.

The results of the study were highly promising and favour the more extensive application of the studied harvesting method in practical harvesting. With regard to harvesting logistics, it would be interesting to examine whether clear cutting facilitates the transformation of some stands marked for cutting in winter into stands marked for cutting in summer. This is because, compared to thinning, clear cutting allows greater freedom in the location of forwarding routes on site, as well as in organising route schedules. More efficient utilisation of peatland forests requires determined efforts to prolong the harvesting season, since seasonal variation in harvesting results in high harvesting and timber storage costs, and complicates the recruitment of a professional workforce.

Keywords: *Multi-tree cutting, integrated harvesting, peatlands, first thinning*

A CHIP-TRUCK TROJAN CHIPPER – A SOUND SOLUTION FOR FUEL-CHIP SUPPLY FROM SCATTERED RESOURCES?

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The location and method for comminution of forest fuels has been a focal point in wood fuel supply research and practice for decades [1]. Nordic studies indicate that chipping at roadside next to the forest stand is a cost-efficient solution in most cases[2,3]. At least five systems are used for this purpose. The perhaps most common is a truck-mounted pure chipping unit working together with one or several chip-trucks or container trucks (alternative 1). Using this solution a spacious area large enough for the chipping unit, the container truck and several containers for swapping empty and filled containers is necessary. The second (2) is similar to (1) but uses a self-loading chip truck (by boom-crane and chip-bucket). This solution reduces the interdependence between the chipper and the chip transport, but requires an even surface for intermediate storage of the woodchips at roadside. The third (3) alternative is a "chipper-truck", which is a chip bin truck where a chipper is mounted on the mid part of a truck chassis and carried on board both when chipping and when transporting wood chips to terminal / end user. The fourth (4) alternative is the "chipper link" [4], where the chipper is mounted on a wheeled link between the truck and trailer. The chipper is left at the landing while the truck is transporting wood chips to terminal / end user. Compared to the chipper-truck, this solution reduces the transport of dead mass, but payload and volume is nevertheless reduced compared to a pure chip-truck or container truck because of constraints on overall length. However, these two solutions (chipper-truck (3) & chipper link (4)) are flexible and may also work together with dedicated chip transport trucks in situations where this would be beneficial (large volume at landing and/or long transport distance). The fifth alternative, which despite high chipping costs is widely used in Norway, is the terrain-going chipper solution. One important reason for choosing this alternative is, as compared to all the other options, the ease of finding suitable locations to set up the wood piles for storage, drying and chipping.

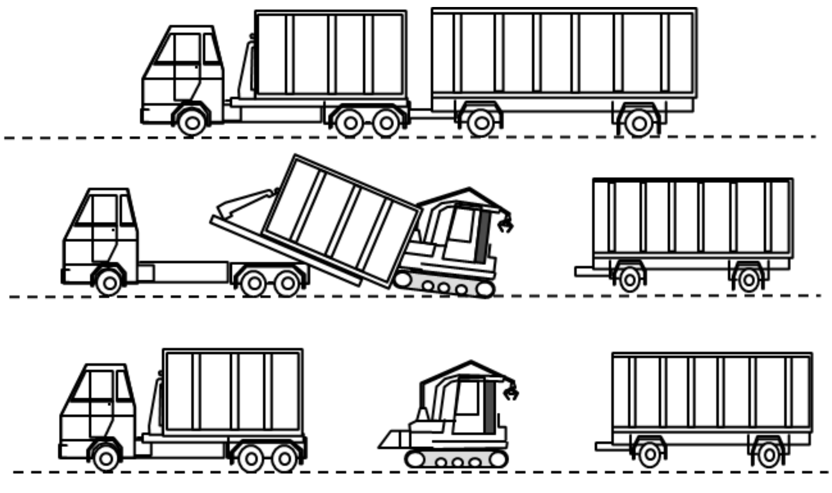

Figure 1: Illustration of the Trojan chip-truck chipper concept.

The Trojan chip-truck chipper proposed in this paper aims to retain the major benefits of the chipper-truck (independence of other machine units), the chipper link (less dead mass transport when transporting fuel chips), and the terrain chipper (less requirements for the landing area) in one concept. The concept implies a self-powered tracked chipper equipped with boom and grapple, small enough to be transported in a woodchip container. The size and mass of the chipper is limited to the size and payload of a conventional chip container, implying a maximal width of ~2.2 m, length ~6 m, height ~3m and mass 12 t.

The characteristics of the different systems are indicated in the table below. In this study we will compare the Trojan chipper concept against the other alternatives, to estimate the value of the pros and cons of the various alternatives, as well as the minimum performance required (i.e. power) of the Trojan chip-truck chipper to be a competitive alternative.

Chipping unit	(1) Chipper	(2) Chipper	(3) Chipper-truck	(4) Chipper-link	(5) Terrain chipper	Trojan chipper
Chip transport unit	Chip-truck(s)	self-loading truck	Chipper-truck	Chip-truck(s)	Chip-truck(s)	Chip-truck(s)
Dependency on other unit(s)	☹️	🙂	🙂	🙂	☹️	🙂
Payload & load volume	🙂	😐	☹️	😐	🙂	🙂
Chipper power & productivity	🙂	🙂	😐	😐	😐	☹️
MU chipper	😐	🙂	😐	😐	😐	😐
MU chip transport unit	😐	🙂	😐	😐	😐	😐
Set-up & take-down cost	☹️	☹️	🙂	😐	☹️	😐
Requirements for landing area;						
Levelled surface	☹️	☹️	😐	😐	☹️	🙂
Size & bearing capacity	☹️	🙂	😐	😐	😐	🙂
Distance wood pile - roadside	☹️	☹️	☹️	☹️	🙂	😐

Keywords: *bioenergy, chipping*

1. Björheden, R., Optimal point of comminution in the biomass supply chain In The Nordic-Baltic Conference on Forest Operations, Suadicani, K.; Talbot, B., Eds. Copenhagen 2008.
2. Laitila, J.; Heikkila, J.; Perttu, A., Harvesting alternatives, accumulation and procurement cost of small-diameter thinning wood for fuel in central Finland. Silva Fennica 2010, 44, 465-480.
3. von Hofsten, H.; Lundström, H.; Nordén, B.; Thor, M. System för uttag av skogsbränsle - analyser av sju slutavverkningssystem och fyra gallringssystem; Skogforsk: Uppsala, 2005; p 38.
4. 4.Eliasson, L., Chipper trucks increasingly common. In Efficient forest fuel supply systems, Thorsén, Å.; Björheden, R.; Eliasson, L., Eds. Skogforsk: Uppsala, 2010; pp 70-71.

TIME AND PERFORMANCE CONCEPTS IN CHIPPING STUDIES

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Many contractors and machine operators, and especially in forest fuel operations, have difficulties distinguishing work time from productive work time. For this reason experienced chipping contractors tend to regard productivities reported in research reports as unattainable. This leads to a low confidence in research results. There is also a risk that new contractors may use reported productivities and work time in their investment calculations, assuming that results based on productive time are attainable on a work time basis, and get frustrated when these goals cannot be reached. This is an effect of contractors working in with biomass extraction and comminution are less familiar with the time concepts used in work studies than forestry contractors (has been?), but the problem also exists in traditional operations. Therefore it is essential that it is clear how the performance measures are calculated. The problem is aggravated by two facts; 1) that the product is not measured in a standardised way and as a result different units of produce is used in the biomass area, i.e. different types of m^3 and tonnes, which increases the difficulty to interpret results, and 2) that researchers in the biomass research are not fully aware of the existing work study nomenclature and therefore definitions starts to drift away from the definitions in the nomenclature.

Common and standardised time concepts are, thus, vital for an effective communication with practice. They are also a vital part of forest operations research, enabling comparability of studies made by different researchers. To ensure comparability of results in the Nordic countries a standardisation work was started in the mid 1950ies (NSR 1955) that led to the first NSR standard in 1963 (NSR 1963). This standard had its last revision in 1978. In other parts of the world national standards for forest work studies emerged, e.g. the REFA standard in Germany. In 1990ies a test edition of an IUFRO standard intended to replace national and regional standards was presented (Björheden 1991, Rickards & Björheden 1995). The IUFRO standard time definitions (figure 1) is well adapted to chipping operations and work element times are easy to sort in under the existing definitions as can be seen in the example in table 1. When time consumption per unit of output is presented in MW we have an excellent measure to compare the performance of machines when chipping, if we instead are interested in the performance per productive hour we have to look at the times included in PW. Finally, if we are interested in the time to chip entire objects to be able to plan operations we should look also on WT. Introducing new time concepts for biomass studies would only increase the risks for misunderstandings and risk to decrease the comparability of our studies. To increase comparability I suggest that we use the second (s) as smallest time unit and send the centiminute into retirement.

Standardization of times and time concepts is, however, of little value if we do not use comparable units when we measure the output. Ideally such a unit should be easy to measure, independent on the type of chipper or the chipper setup, or how the material is handled. Varying output units are causing a lot of confusion in the biomass business, not least among land owners and contractors. In fact just by changing the output units the results of a comparative study may change dramatically. My suggestion is that we present the output in a unit of our choice and in metric oven dry ton in our future works.

References

Anon. 1955. NSR nom 1: arbetsstudienomenklaturen. Rapport från NSR's nomenklaturkomité. Ås, Norge.
Anon. 1963. Skoglig arbetsstudienomenklatur i Danmark, Finland, Norge og Sverige. NSR medd. nr 1. Ås, Norge.
Anon. 1978. Forest work study nomenclature. The Nordic Work Study Council, NISK, Ås, Norge.
Björheden, R. 1991. Basic time concepts for international comparisons of time studies. J.For.Eng 2(2): 33-39.
Rickards, J. & Björheden, R. 1995. Forest work study nomenclature. Test edition valid 1995-2000. Garpenberg, Sweden, SLU, Dept. of operational efficiency. 16 p.

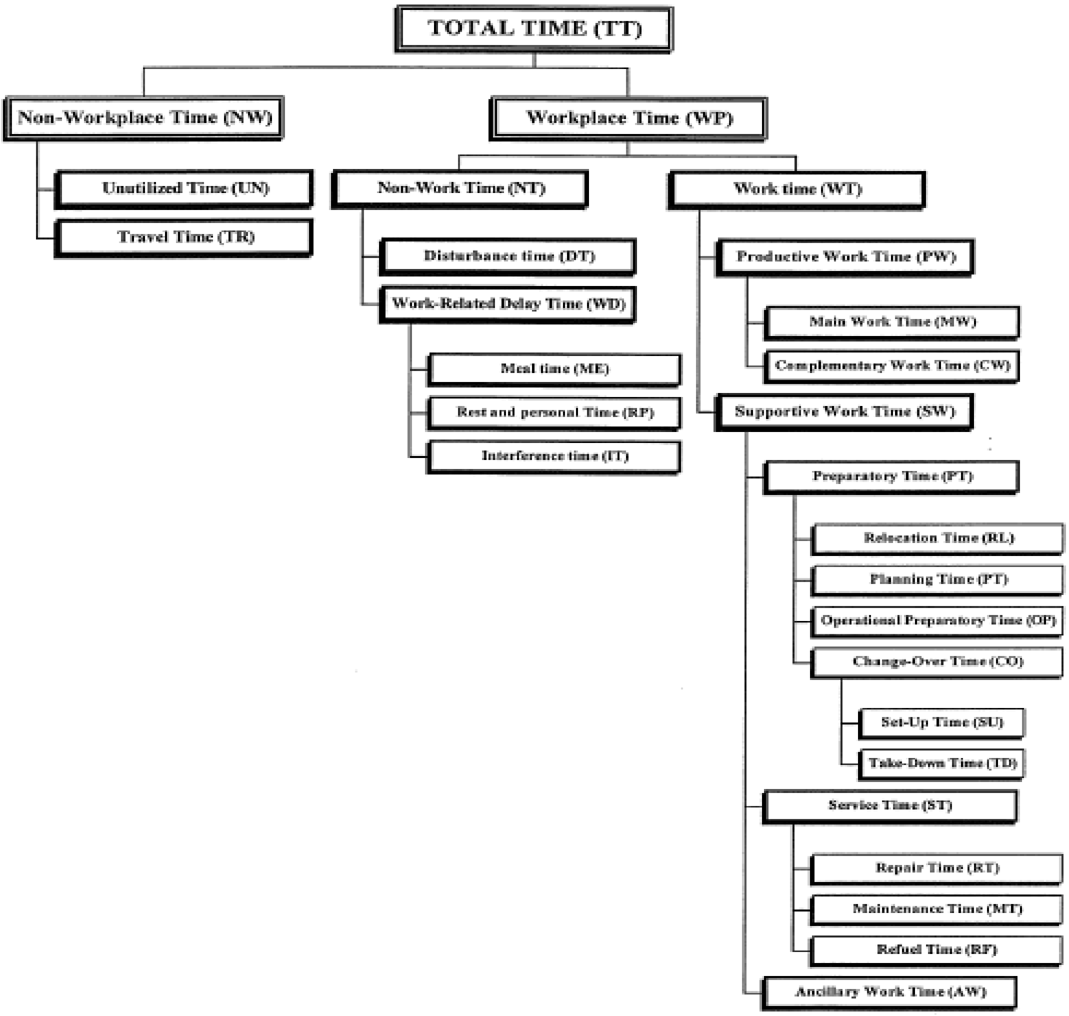

Figure 1.

The basic time concepts according to the IUFRO standard (Rickards & Björheden 1995).

Table 1. Definition of work elements and where they fit in the basic time concepts

	Element	Definition
MW	Boom out	Boom movement from the chipper to the piled material
MW	Grip	Gripping of material
MW	Boom in & Feeding	Boom movement from the pile to the machine and using the boom to assist in feeding the chipper
MW	Release & adjustment	Releasing the grapple load and adjustments of the material on the feeding table
MW	Chipping	Chipping while the loader is idle
CW	Move w. load	Move from the piled material to the reloading point
CW	Unloading	Dumping the chips into containers
CW	Move unloaded	Move unloaded from the containers to the piled material
SW	Other	Set up times and other work not covered above needed to complete the work task
NT	Delays	All that is not productive work

Keywords: *Time studies, productivity, standardisation.*

A PARAMETER ESTIMATION APPROACH FOR FORWARDER PRODUCTIVITY

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Abstract

Functions describing the productivity of forest machines are of vital importance for forest planning and optimization. Traditionally, such functions are found by manual time studies, but the forest operations research community is slowly exploring automated approaches. The FORMEC 2014 preliminary program has one session named 'From traditional to automated work studies'.

Forwarding may be viewed as three independent tasks: driving, loading and unloading. Here, the loading and unloading is assumed to be independent of driving distance and terrain. The cost of driving, on the other hand, can be considered a variable forwarding cost, and is the focus of this study.

In recent literature, the variable forwarding cost is modelled as a sum of costs for driving between neighbouring grid points (i.e. a network model). The variable forwarding cost is assumed to be a function of micro-topography and driving distance, but no detailed studies of this relationship exist.

In this study, a novel approach for identifying forwarder productivity functions is presented. Variable forwarding cost functions from the literature are selected, and a network model is optimized by a shortest-path algorithm. By varying function parameters and comparing with costs and transportation distances surveyed at the National Forest Inventory (NFI) plots, the function and parameters with the best match can be selected.

The approach will be tested using NFI plots in a county in Norway, using a 16m x 16m digital terrain model. Preliminary results are promising.

Keywords: *productivity studies, forest operations, forwarding, parameter estimation.*

EFFECTIVE ESTIMATE OF BIOMASS VOLUME IN YOUNG STANDS AND ON ROADSIDES USING LASERDATA

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The aim of the project was to develop a method to support planning of biofuel harvest in neglected young forest, particularly a) young forest in edge zones along roads, and b) young forest stands, based on criteria from the Skogforsk calculation tool. The method used laser-scanning data in combination with reference sample plots with GPS coordinates, and where data was entered in the field. The analyses were carried out using the area method, based on multiple linear regression. A large number of metrics were calculated using laser data for each sample plot. The key measurements were height percentiles and density.

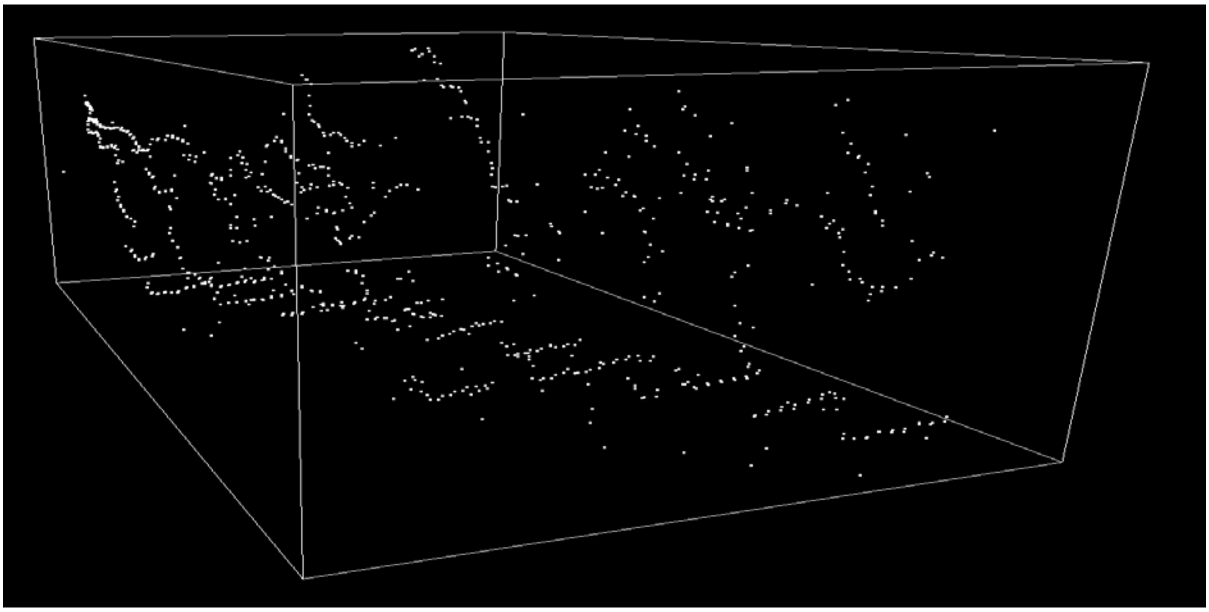

Figure 1. Cut-laser data at the roadside. The average height 3.85 m. Average tree height > 40 mm = 8.33 m.

In order to evaluate how well laser data can be used as a reliable base for profitability calculations of biofuel harvest, the regression models were adapted for five fundamental forest-related variables: basal area weighted mean height (Hgv), basal area weighted mean diameter (Dgv), arithmetic mean diameter (Da), total biomass (B) and total number of stems (S). As an alternative to first estimating forest variables using laser data and then using these estimates to calculate profitability, the method estimated profitability directly using laser data.

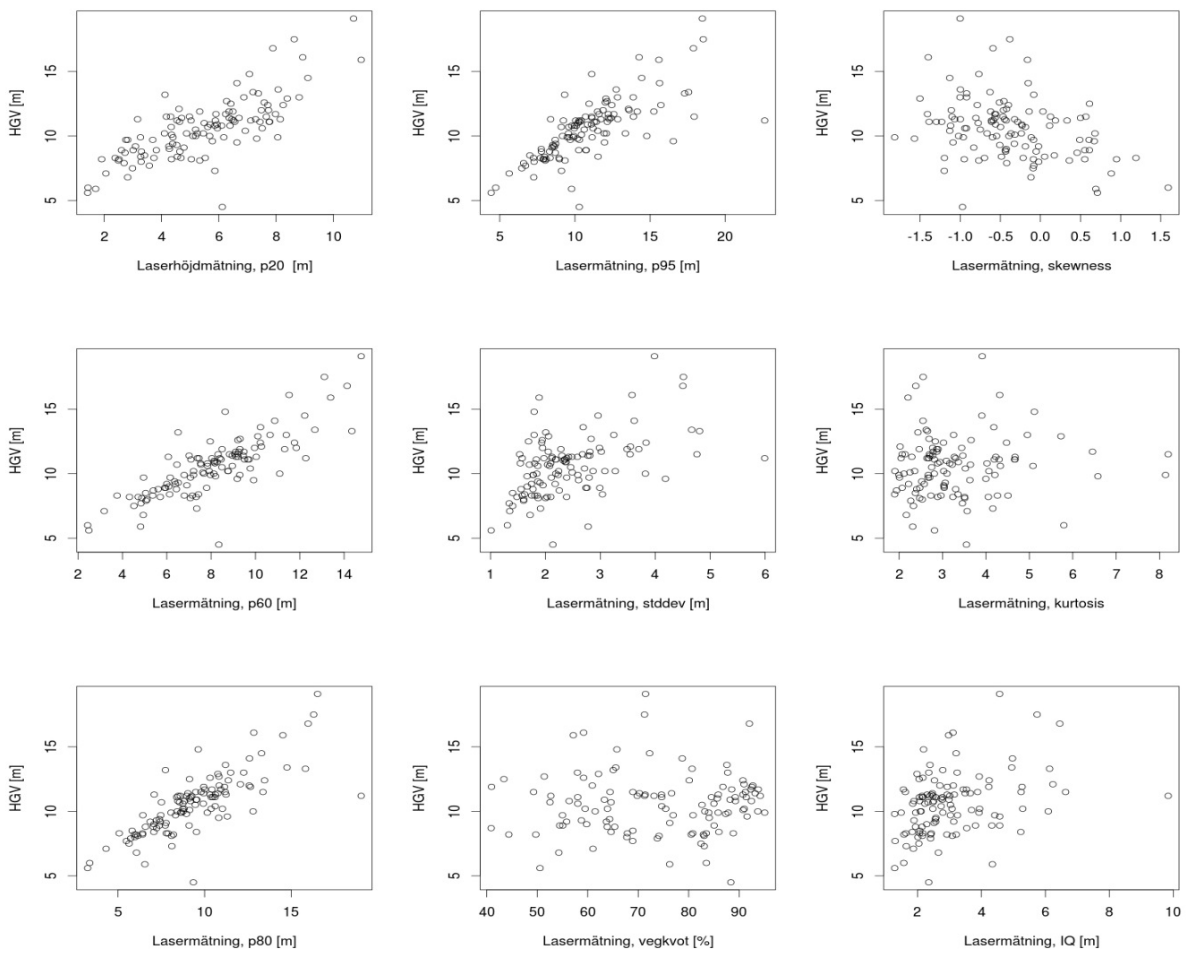

Figure 2. Lasermetrics for basal area weighted mean height measured on sample plots in young stands.

The method shows clear potential for improving the efficiency of biofuel harvest in young forest, by physically identifying profitable areas and by delivering high levels of spatial accuracy. The method could probably be further improved by combining new national elevation model (NNH) data with another data source containing information about the species mix.

Keywords: *Volume estimation, laser data, area method, biofuel harvest, neglected young forest, roadsides.*

REACHING FOR THE FUTURE - BY ESTIMATING THE HARVESTER HEAD'S POSITION

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Abstract

Forest machines used for fully mechanized cut-to-length (CTL) harvesting are technically advanced, with, for instance, automatic mechanical measuring of stem diameters and lengths during harvest. This information is processed in real-time optimization algorithms to support value maximizing cutting of stems into logs. Moreover, the information is transferred from the machines and used in central systems for managing wood supply of forest industries. These information management systems have been present since the 1990-ies in Sweden and Finland, and are constantly being refined.

Initially, there was only aggregated information at the stand level, whereas data currently starts to be disaggregated spatially within stands based on the machine's position. However, actual position of the harvester head relative to the machine's position is not known, besides that is must be somewhere within the cranes reach. Albeit the poor accuracy, there are already some practical applications developed with the current positioning. However, we are confident that the full potential of existing data gathering is not yet embraced due to insufficient accuracy in harvester head positioning. Moreover, we are confident that increased precision will unlock many intriguing possibilities for the forestry of the future and for other related areas. These possible benefits are diverse, both in terms of precision requirements, feasibility and added value for forestry.

In this study, we investigate the possible benefits of having high precision spatial data for the harvester head's location, and compare these benefits with the efforts necessary to collect and compute such data. We also analyse what benefits that are the likely drivers of increased accuracy in harvester head positioning. Or in other words, we point out the benefits that are likely to pay off and thereby motivate forestry to reach for the future's precision forestry.

Keywords: *Spatial modelling, ALS, timber traceability, automation, StanForD, IMU, joint sensors, laser.*

DERIVING THE POSITION AND MOTION PARAMETERS OF A FOREST MACHINE USING MONOCULAR VISION.

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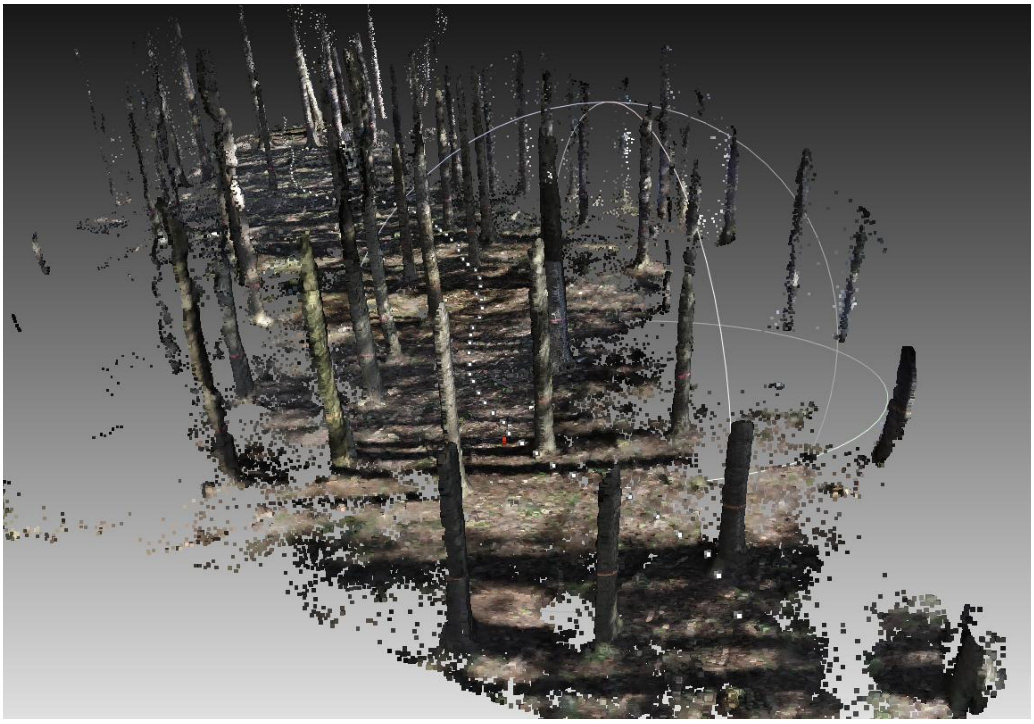
Improving the precision of estimates on the position of forest machines under the tree canopy attracts considerable research attention due to the obvious benefits of such data; i.e. avoiding the transgression of ownership boundaries , navigating planned extraction trails, avoiding damage to cultural heritage sites or biotopes of special importance , monitoring impacts of traffic on the site, contributing to the determination of rolling resistance and wheel slip geo-referencing harvested timber for later extraction and traceability in the supply chain, or for capturing data for machine productivity modelling.

In this study we present several possibilities of using visual sensors as a remote sensing tool and motion sensor. Cameras can play a significant role in deriving the information on the machine motion and terrain under forest canopy. We apply Structure From Motion (SFM) in order to derive the positions of the camera centres in 3D space. This method was applied for retrieving the arbitrary position of a machine in the forest in its forward motion as well as the position of the cable carriage with the lens oriented towards the ground. For both cases it was also possible to retrieve dense point clouds of the scene which might be used for different purposes (Figure 1).

Figure 1. Dense reconstruction of a scene from a terrestrial image acquisition and positions of the cameras in that scene (white points).



Both models were scaled to the real units. Calculated camera positions were transformed to a geographic coordinate system using a direct geo-referencing method with use of ground control points (GCP) established with differential positioning. Reconstructed positions of the carriage are used to calculate the line deflection for a single turn.

Camera pose estimation is also used to describe the Euler Angles that represent the 3D rotation of a machine (table1). This information reflects the pitch & roll of the machine as a rigid body.

Table 1 Camera stations and their rotation matrix R(x,y), translation (T) and focal length (f)

#R(0,0)	R(0,1)	R(0,2)	R(1,0)	R(1,1)	R(1,2)	R(2,0)	R(2,1)	R(2,2)	Tx	Ty	Tz	F(mm)
0,85	0,52	0,01	- 0,52	0,85	0,01	- 0,00	- 0,02	1,00	- 0,07	- 0,10	- 0,05	2,80
1,00	0,00	- 0,00	- 0,00	1,00	- 0,01	0,00	0,01	1,00	0,01	0,02	0,01	2,80
0,56	- 0,83	- 0,03	0,82	0,56	- 0,14	0,13	0,05	0,99	0,66	0,12	0,11	2,80
- 0,84	- 0,52	0,15	0,49	- 0,85	- 0,19	0,23	- 0,09	0,97	0,86	- 0,81	0,01	2,80
- 0,58	0,81	0,01	- 0,81	- 0,58	0,12	0,10	0,06	0,99	0,60	0,78	0,35	2,80

Keywords: *pose estimation, harvester, point clouds, precision forestry*

ARISING RADICAL AND INCREMENTAL INNOVATIONS FOR SUPPLY CHAINS OF RESIDUAL FOREST BIOMASS

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The main challenge in EU's forest biomass supply for energy is the mobilization of the existing forest biomass potential in a competitive and sustainable manner. Fuel costs typically contribute 60-80% of the total energy production costs of a CHP or bio-oil plant.

The economic viability of feedstock supply has been found to be the key barrier to increase the use of forest biomass in energy generation. Forest based bioenergy is competitive against oil in heat and power markets in many parts of the EU, but replacing coal with biomass is more difficult and requires either taxation of coal or direct subsidies for biomass supply. The growth of forest chip use seems to be close towards saturation e.g. in Sweden and Finland and new driving forces both at the demand side and in supply chains are needed to resume the growth.

FP7 funded INFRES project develops, demonstrates and transfers technological, logistical and fuel quality solutions that can significantly improve the competitiveness of residual forest biomass supply for energy. This paper presents a list of potential innovations that reduce fuel consumption, raw material losses and costs of operations in harvesting, chipping, storage and transportation of residual forest biomass. Innovations are placed on the S-curve to illustrate their development potential in relation with invested R&D efforts (Figure1). Hybrid technology in forest machines, heavy vehicles and chippers, improvements for larger load volume and densification technologies and emerging quality prediction and precision supply solutions are presented and evaluated. The key challenges of forest biomass supply chain are identified for further research, development and demonstration activities and list of potential winning technologies presented.

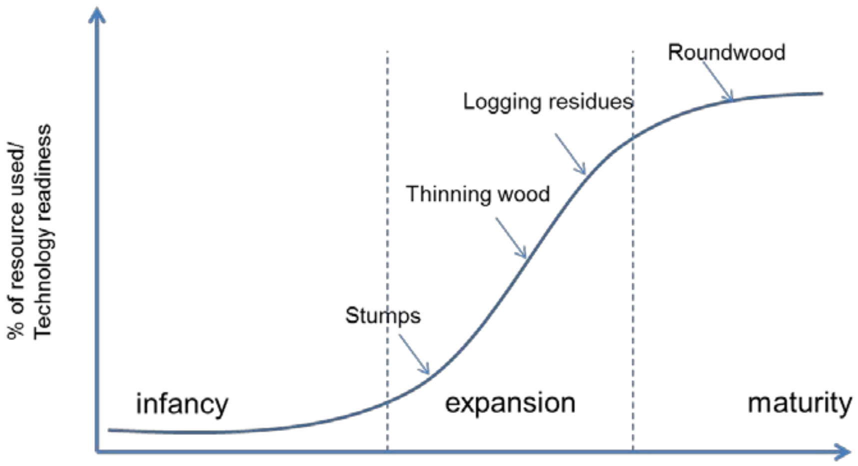

Figure 1 Technology readiness of harvesting systems for biomass assortments.

Keywords: Biomass, production costs, cost-efficiency, innovative technology

STANDARDIZED HARVESTER DATA AS A BASE FOR PLANNING OF FOREST OPERATIONS AND FEEDBACK TO PLANNING SYSTEM

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Background

Modern CTL harvester computers collect standardized production data and other supplementary information during harvesting. Data is automatically gathered from the measurement system in the felling head, GPS receiver, harvesting directives and records of operators decisions. All data are stored in standardized StanForD files (Arlinger 2013). This is a base for efficient management and control of forest operations, immediate feedback to forest owners and updates of forest plans.

When the harvesting operation is completed the forest owner can get a preliminary receipt on the harvested volume and the value, harvested area, average stem size, diameter distribution, damage frequency and a prognosis of forest fuel products (branches, tops, stumps). After cutting operation the harvested volume per hectare, strip road percentage can be presented and a prognosis of remaining stand parameters after felling can also be estimated.

Computers in harvesters were introduced in Scandinavia in the middle of 1980s. The first standard (StanForD) for communication with harvesters was released in 1988. The use of data in harvester can be described by three phases:

1. 1990's: The only use of data was to control the bucking optimization (dimensions and pricelists).
2. 2000's: Production data started to be used as a base for planning and logistics.
3. 2010's: Data now starting to be used as a base for planning and control of the following processes in the supply chains like prognosis of forest fuel, regeneration planning after final felling, transparent information to forest owners and updates of forest plans. Wide use of standardized individual stem and log information (transition from pri-files to hpr-messages for harvested production data in StanForD 2010)

Objectives

The objective of this abstract is to present test results from utilization of harvester data for improved planning and accounting. Tests have been made on predicted volumes of forest fuels based on harvester data and following up of harvesting operations. The specific goals for these tests were:

- To compare predicted volumes of forest fuels (tops, branches and stumps) with measured volumes at heating plants. Based on stand level and sample plots.
- To test and develop a model based on harvester data for calculating harvested area compared with manual follow up with GPS.
- To present felled volume and other stand parameters such as height, species distribution and estimated site index based on harvester data compared with manual measured data.

Materials & methods

Several different studies and tests have been carried out where individual stem and log measurements were registered. Additional automatic or operator controlled decisions connected to each felled tree were also stored in the harvester's pri/ hpr files (Arlinger 2013). For each tree DBH, species, biofuel stacking and coordinates of the harvester at felling are recorded. For each produced log tree number, log number, assortment, diameter, length and volume are stored. It is possible to re-create the stems from that information. Figure 1a illustrates the cut logs up to the last cut at the top of the stem (Möller 2009). By using the coordinates it is also possible to re-create the whole stand.

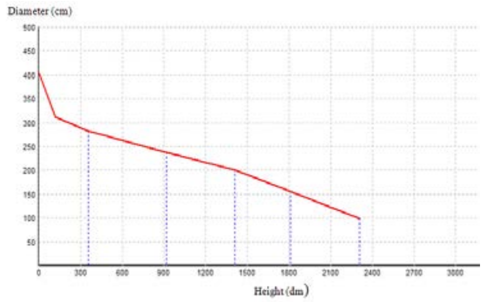

Figure 1a. Stem re-created based on log data measured by the harvester and stored in hpr/pri files.

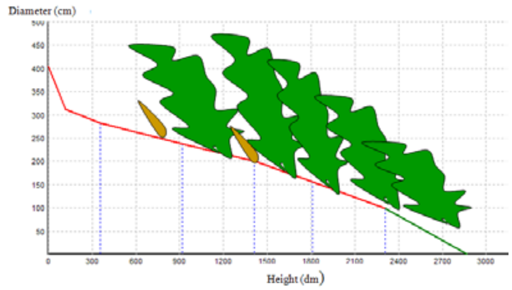

Figure 1b. Top of stem estimated by function (Kiljunen 2002). Branches and top quantity calculated with bio mass functions (Marklund 1998).

The top part of the tree above the last cut is estimated by using a function (Kiljunen 2002) and the branch and needles is recreated by using different bio mass functions (Hannrup 2009). The studies were geographically based on data from the north of Sweden to the south of Sweden.

Results

Calculation of harvested area and other calculated data such as tree height and tree species distribution will be presented (Möller et. Al 2011, Bhuiyan et al 2014 (not published). Also results of forest fuel estimation based on harvester data will be presented (Hannrup 2009).

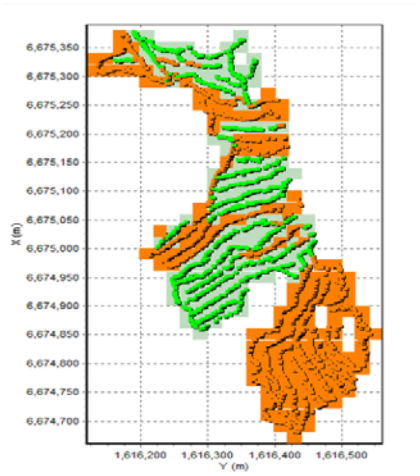

Figure 2a. An example of map with harvester reported bio-fuel adaptation.

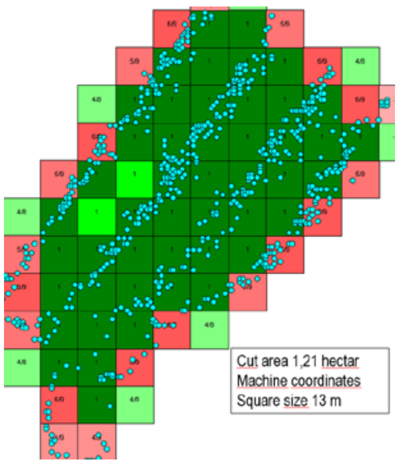

Figure 2b. Calculated area based on harvester data (Bhuiyan 2014 not published). Model based on pixels where harvester has cut trees (harvester position during processing of trees).

Keywords: *StanForD 2010, harvester data, forest planning system*

ANALYSIS OF HUMAN GENERATED CRANE MOTION PATTERNS – TOWARDS THE AUTOMATION OF FORESTRY MANIPULATORS

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Abstract

Using techniques of robotics for upgrading forestry crane control is a concept that has attracted the attention of this industry for a long time. Increasing efficiency, easing the learning process, and reducing operators fatigue, are some of the expected benefits. From the aspect of robotics, a variety of procedures exist for generating motions that can be used to this end, but not all are suited for the complex dynamic environment of the forest work.

Using human input has become a well-accepted approach for introducing automated motions that are difficult to plan otherwise. This is known as learning by demonstration and is an approach that can be adapted into forestry manipulators to provide automated functionalities that are easily adaptable according to needs.

To develop this concept, we equipped a forwarder with motion sensors for capturing the patterns performed by the crane when it is being operated during normal work. The resulting visualisations of the crane work reveal large similarities in the repetitive movements, but also some differences between how operators used the crane to conduct given movements. Thus, the method enables new in-depths analysis of crane work. Moreover, based on the recorded human data we developed a standard 3D crane work procedure, via a computerized trajectory planning algorithm widely adopted in robotics.

The methods used proved useful to capture, analyse and merge human, empirical crane work data into optimised movements that can be used for automation – and naturally also to improve human crane work.

Keywords: *Hydraulic manipulator, motion sensors, trajectory planning, boom-tip control, joystick control, motion optimization, learning by demonstration, forwarder.*

ANALYSIS OF A MECHANISED CUT TO LENGTH HARVESTING OPERATION THROUGH USE OF DISCRETE EVENT SIMULATION

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Introduction

South Africa has experienced recent acceleration in the drive to mechanise harvesting operations in South African plantations (Hogg *et al.*, 2010). This fact coupled with the lack of national benchmarks in mechanised harvesting has generated a need for research which will lead to the identification of improved operating practices in South African harvesting operations (Hogg *et al.*, 2010).

The aim of this study is to analyse a typical South African cut-to-length harvesting system using discrete-event simulation programmed in R while making changes to certain operational aspects (e.g. felling pattern, number of harvester movements, width of swaths felled, while removing the use of depots and increasing the grapple size of the forwarder) of the cut-to-length system and analysing the effect of such operational changes on the systems productivity.

The system to be analysed is a mechanised cut-to-length system, comprising of a Hitachi Zaxis 200 excavator based harvester fitted with a SP 591 LX harvesting head and a TimberPro TF 840-B purpose built forwarder fitted with a 0.84 m^3 Matriarch grapple.

The stand, located in the Kwa-Zulu Natal midlands, is 9.8 ha in size and is planted with poor form *Eucalyptus smithii,* 9 year old trees. The study took place on a flat area ranging from 0-3% in gradient.

Methodology

Swaths of 4 and 5 trees across were laid out according to contractor's harvest plans. Trees were individually numbered with heights and diameters recorded for individual tree volume calculations. Time studies were conducted on the harvester and the forwarder; the forwarder had an additional GPS tracking unit installed in the cab in order to track its movements and distances travelled.

A virtual stand was created by generating random volumes based on the actual stands volume distribution. Harvester and forwarder work elements and delays <15min were modelled by using random values based on each individual elements time distribution; this was done to represent the current operation.

Harvester productivity models were created with a random tree volume or boom distance as inputs and in return generate a time for each of the harvester's respective elements (boom out, boom in, fell, process (debark and crosscut), and move). The harvesters felling pattern is controlled through a sequence function which creates the ability to modify the felling pattern for the alternative scenarios. Boom travel distances and angles to the trees were measured through use of spatial functions linked to shape files which contain both machine travel paths and virtual tree positions; the measured distances and angles were used as input variables to the equation for calculating boom out time as found in Eliasson & Lageson (1999). The harvester loop fells and processes trees in alternating swath widths (5 and 4 trees wide) until all trees generated have been felled and processed.

Once a tree is felled, it is placed onto a log pile. These log piles were measured for volume in field, and again a sampling function is used to generate *n*-stacks. The stacks will have an additional control function to ensure that the random total volume does not exceed the total harvested volume.

The forwarders movements were individually modelled (travel on-road empty, off-road empty, between stacks, off-road loaded and on road loaded). Predicted travel times are generated by using travel distances as input variables. Travel distances were measured using spatial functions linked to shape file data. The loading time was created by using a model based on log pile volume. The forwarder would enter the compartment and travel to the first specified stack where it would begin loading until the bunk is at capacity after which it would leave the compartment and head to the depot for unloading to begin. This cycle would be repeated until all the stacks have been extracted.

The number of grabs required for a stack to be loaded has been calculated by taking stack volume and dividing by the volume the original grapple can pick up at any one time. The stack volume can thus be divided by the new grapple volume; this will then be multiplied by the time per grab recorded infield. The forwarding pattern can be specified using the sequence function which controls the pattern in which the machine works.

Results

Preliminary results indicated that processing is the most time consuming element for the harvester using 60% of the total productive time. This is attributed to the poor stem form and large variation in the sample trees. Boom out time accounted for the second most time consuming element taking up 11% of the harvester's total productive time. The most time consuming element for the forwarder was loading accounting for 44% of total productive time. The second largest time consuming element was unloading using 17% total productive time. The elements on road empty/loaded accounted for 14% of the total productive time. Results of alternative scenarios are still to be generated and will be presented at the conference.

Conclusion

The preliminary results indicate that there is a strong possibility to achieve significantly reduced productive element times through better work structure and boom movement (tree selection) for the harvester while using a larger grapple and travelling shorter distances with the forwarder. Poor tree form will still remain a problem but through using improved harvesting and stacking techniques system productivity should be increased.

References

Glynn A. Hogg, Reino E. Pulkki and Pierre A. Ackerman (2010):Multi-stem Mechanized Harvesting operation Analysis – Application of Arena 9 Discrete-event Simulation Software in Zululand, South Africa, International Journal of Forest Engineering, 21:2, 14-22

Lars Eliasson & Håkan Lageson (1999): Simulation Study of a Single-grip Harvester in Thinning from Below and Thinning from Above, Scandinavian Journal of Forest Research, 14:6, 589-595

R Core Team (2014): R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, URL http://www.R-project.org/.

Keywords: *cut-to-length, discrete-event simulation, spatial analysis.*

THE IMPACT OF THE FORWARDING TECHNIQUE ON FORWARDING OUTPUT – A CASE STUDY BASED ON THE PONSSE FORWARDER GAME

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Background

Large differences, up to 300% have been noticed in forwarding productivity between operators (Ylimäki et al. 2012). Differences in production increase in challenging conditions, such as in steep terrains and soft soils. Moreover, the increasing amount of timber assortments make forwarding much more complicated even for experienced operators. The differences among operators can be explained partly by the skillfulness to use the crane, thus the forwarder work is largely handling the grapple loads with the crane during the work phases of loading and unloading. Nevertheless, high differences in productivity between operators have been noticed to turn up even with the similar boom handling capabilities of the operators. According to the recent findings from the studies and the practice, the operators with higher efficiency have a tendency to forward more multi-assortment loads with less driving at the site. Thus, the interest in recent studies is focused on the work planning and forwarding techniques as well as on the operator's abilities to cope with multi-assortment loads on sites with several wood assortments.

The objective of the study was to explore the influence of used forwarding technique among operators in three experience clusters in terms of forwarding productivity and total driving at the site. Moreover, the fundamental reasons for the differences were clarified and magnified at some extent. A Ponsse forwarder game was used for carrying out the study in an identical working condition for all operators.

Material and methods

All together 18 forwarder operators were selected to the study. Three separate operator clusters were created; clusters of students, teachers and experienced forwarder operators, each of them having six operators. The operators from student and teacher clusters were obtained from the forest machine school of Valtimo, North Karelia. In addition to the initial operator material, one performance following the driving minimization technique was obtained to the results.

The Ponsse forwarder game with the purposely compiled forwarding environment, which correspond the real harvested site, was used in the study. The Ponsse forwarder game is a software application with PC game specified features. With the use of mouse functions and a screen display user controls both the driving and the loading/unloading tasks of the forwarder in a displayed environment. Displayed harvesting environment contains a strip road network, a specified number of different pile assortments distributed to the site and a landing area with a specified number of pile buffers for the timber to be forwarded. Refreshing information of the amount of wood assortments to be forwarded as in cubic meters, cross-section of the load space with loaded wood assortments in colors and the main performance values of forwarding are displayed on the screen as well. Game will end once all the wood assortments have been loaded and forwarded from the site and unloaded to the pile buffers of the landing area. An output report of the main indicators of forwarding performance is displayed at the screen in the end of the game. The Ponsse Forwarder Game has been originally designed for aiding the teaching in strategic work planning to be used in forwarder operator training for young people and adults alike.

Each operator had the same instructions and learning period before the actual study. Operators played the study site two times and the best result was taken into further analysis. The harvesting site used in the Ponsse forwarder game corresponded to site characteristics of the real case. The size of the study site was 150 m³ consisting eight wood assortments with the 38 % and 1 % of biggest and smallest wood assortment shares from the total volume. The size of forwarder's load space was 16 m³. In addition to the study site, the parameters for the forwarder functions were identical for all operators. Therefore, the occurred differences originated only from the difference of planning and executed forwarding techniques of the operators.

Results

The difference in total driving in kilometers among operators was 2.3 km varying from 8.13 km to 10.43 km resulting the maximum difference of 28 % in total driving. Correspondingly, the estimated forwarding productivity varied from 18.4 m³/h to 21.6 m³/h resulting 17 % and 3.2 m³/h maximum difference. The correlation of total driving and forwarding productivity was clear (R^2 = 0.729) (figure 1).

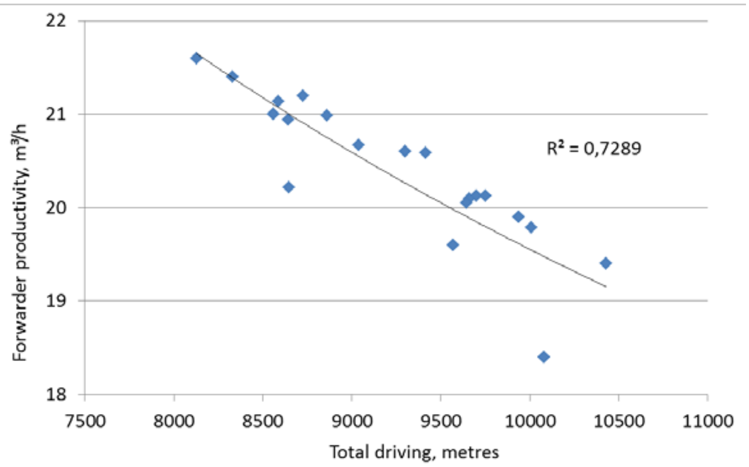

Figure 1. Forwarding results among study operators in terms of total driving and hourly productivity values (19 observations).

Exceptionally, experience level did not correspond on the forwarding result directly proportional, as it was predicted. The average values in total driving and forwarding productivity for the operator clusters of students, teachers and experienced operators were 9.28 km and 20.37 m³/h, 9.17 km and 20.62 m³/h and 9.65 km and 19.82 m³/h, respectively. The variation was biggest within experienced drivers including also the best result in terms of above-mentioned values. The forwarding technique with minimized driving, tested as separately, resulted the lowest total driving as well as the highest productivity; 8.13 km and 21.6 m³/h. The technique follows as much as possible minimized driving technique with multi-assortment loads which, in practice, requires spatial map based information of wood assortment bunches at the site in order to utilize the technique efficiently. As an interesting remark, the best operator performance followed closely technique of minimized driving as well.

Further analyses revealed that in order to utilize forwarding of multi-assortment loads successfully, the loading of assortments had to be well planned and executed in an order which facilitates the unloading. Otherwise same amount of assortments in a load turns out to be as mixed-assortment load resulting more relocations between piles and smaller grapple loads during unloading.

Comparably, single or two assortment loads technique required often longer driving during the loading phase, which did not fit well into the harvesting site used in a study.

Conclusions

Despite of the pinpointing of wood assortment bunches on the map and unlimited time use for the planning of forwarding, the study revealed big variation in driving distance and forwarding productivity among forwarder operators in the identical study environment. The differences originated by the operator specific differences in planning, decision making and executing processes during forwarding. Operators, who followed the driving technique with minimized driving and multi-assortment loads, performed best. Experience level did not have any positive correlation on productivity in this study. On the contrary, experienced operators tended to execute more single or two-assortment loads than others resulting more driving at the site. Test and results were obtained from one case environment, thus similar study should be carry out in different conditions.

Ponsse forwarder game proved to be efficient, valid and reliable tool in detecting the reasons for the differences in performance between the forwarder operators as well as in exploring the development potential of forwarder assistance systems. In order to detect the improvement potential of map based visualization of log bunches in forwarding productivity, a comparative time study with the visualization of log bunches on the screen and the prevailing forwarding procedure without any spatial information of separate log bunches should be carried out. Moreover, the validity and the impact of the parameters used in the game have to be studied in further tests in different forwarding conditions.

INCREASING THE VALUE OF FOREST PRODUCTS BY INCREASING EFFICIENCY OF HARVESTING OPERATIONS

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Aiming at valuable products and efficient processing

Improvements of logging operations commonly have focus on productivity in terms of harvested m^3/hour i.e. commonly referred to as work productivity. Operating in Scandinavian forestry a modern Cut-To-Length harvester produce logs with an annual market price of between 1.5 and 4.5 M€ while the annual machine owner costs for harvester depreciations, operational costs and operator salaries may be between 180 to 450 k€. This means that cutting and processing trees into sorted log products piled at strip road for forwarding will commonly cost somewhere from 1/3 (small diameter thinning) up to 1/20 (final cut, large diameter, high proportion of valuable sawlogs) of the market price for the processed logs. A professional handling of the log values is important for the customers who pay and live on adding value to the delivered log products, and for the forest owner who expects to get revenues for covering 30 to 120 year of costs for land and sustainable management by biologic production accumulated into finally harvestable trees. Finally by creating an increased gap between revenue and cost from the harvesting operations machine owners' and operators would preferably get paid on this basis as well.

Productivity of forest operations in a value chain perspective

General productivity is defined as output/input i.e. revenues/costs. If both current revenues and costs can be fairly monitored at stem processing and production of logs this can be assembled to a guiding tool supporting the harvester operators'. Modern harvester computers, measurement and positioning systems, routing tools, standardised information/communication protocols (StanForD 2010, papiNet) and further developed value chain monitoring all deliver new conditions for supporting improved productivity distributed to operational guidance in each link but based on an integrated value chain approach. An overall objective that all partners likely will accept is to increase the common productivity of a defined production chain and to share the benefits based on fair agreements. Such a concept is not created over a night but can become a reality if different components are designed to reach the same overall objective, i.e. in principle maximizing system revenue/cost (productivity) by sustainable methods, including environmental concern, high energy productivity, low emissions and a good working environment.

Improved data quality and information

In a set of Skogforsk projects (also partly presented at this conference) components and a system for quality assurance of harvesting operations including a reporting standard (StanForD 2010) have been developed. Routines for current control and calibration of the felling head measurements (diameter and length) including quality assurance (hqc) is directly connected to efficiency in utilising revenues. The product instruction message (pin) for harvester computers sets all automatic and supporting information needed for felling head processing of stems to requested log products. Other components under development are based on monitoring of the recorded log production in comparison with the requested (pin) including price list, assortments, apportionment requirements etc. In this comparison the available information on the current forest conditions may be taken into consideration. New methods for efficient forest inventories like aerial and terrestrial sensing and harvester based monitoring of thinning operations are means to make efficient yield calculations at the log product level at the planning stage. Today, during the actual harvesting operation detailed information on the current forest conditions is recorded at an accuracy determined by the information sources: tree species (operator), stem diameter and height distributions including tapering (measurement), spatial distribution (GPS), recorded frequency of stem defects and operator controlled cross-cuts (operator). In the production file every log will be recorded by its assortment code based on automatic (production control by pin and the harvester computer) or operators' decisions (commonly stem defects).

StanForD 2010 provides current standardised operational recordings of harvested production (hpr), forwarding object (foi) and forwarding delivery (fdi) instructions and forwarded production (fpr). It also provides messages for operational monitoring (mom) of both harvesters and forwarders and an object geographical report (ogr). However in the current (mom) version details concerning individual log processing at harvesting are not included. Even though it's not yet standardised, this high resolution information can be extracted from sources like John Deere Timberlink©.

The logging econometer

The accuracy and relevance of current recordings will determine the possibilities to support the machines operators in gaining productivity (revenue/cost) of the logging operations. An operational "logging econometer" concept where actual harvesting productivity (e.g. Pricelist Log value/ harvester cost by operational time per log, tree etc.) is currently alternatively compared e.g. with a normative productivity or individual harvester operator's productivity. The objective is to support the logging team to gain both value chain and own productivity (revenue/cost) by means that are under operational control at harvesting and forwarding. A model concept of a basic harvester econometer built on actual vs normative productivity is shown in the fig 1. It is built on a standard pricelist (log values), spruce trees from the Swedish National forest Inventory and productivity norm functions (Brunberg/Skogforsk) applied on individual trees and allocated to logs by log volume/(merchandized tree volume). Displayed parameters should be seen as conceptual and can be altered to fit different purposes for supporting operational logging.

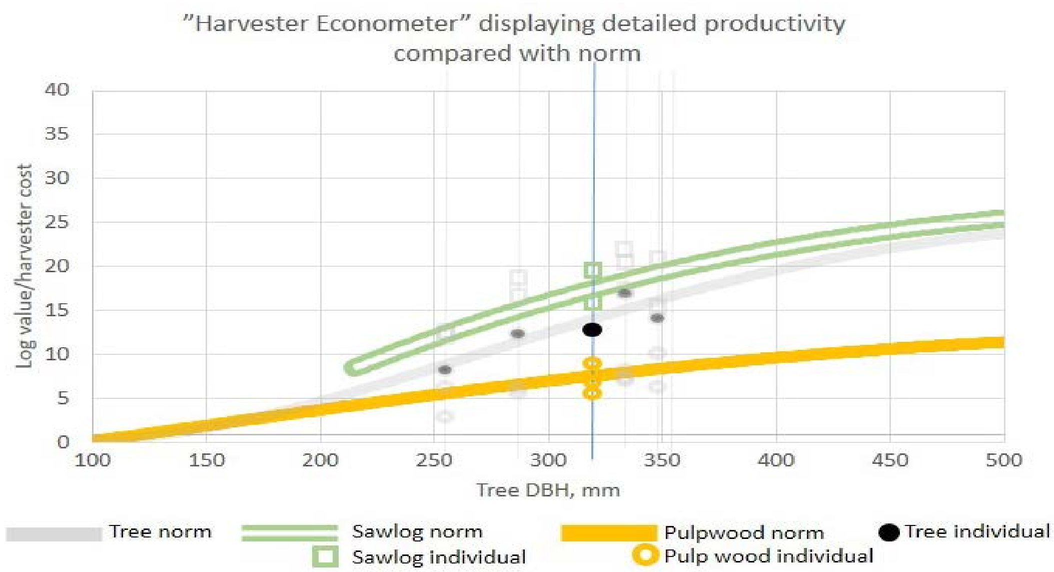

Fig. 1. "Harvester econometer" here displaying productivity (Log value by pricelist divided by harvester cost by monitored processing time of individual sawlogs or pulplogs (and other assortments when applicable) and processed tree (black dots compared with gray curve). Colored markers represent the latest processed tree, while dimmed gray markers represent the four most recent.

TARE WEIGHT VARIATIONS FOR CONVENTIONAL SELF-LOADING LOGGING TRUCKS IN SWEDEN

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Truck payload capacity has a direct impact on roundwood transport costs. Given the current limit of max gross vehicle weight for conventional logging trucks, the reduction of tare weight is an important measure for countering the historically rapid increase in transport costs. There exists considerable tare weight variation in the Swedish logging truck fleet. The goals of this study were threefold: first to map current variation in tare weight, second to map the components choice causing this variation, and third to map the owners' motivation for the choice of components. The study was limited to self-loading logging trucks.

The study was done at Holmen Skog with a geographical coverage on the eastern part of Sweden. The work was divided into three parts corresponding to the respective goals. First, vehicle tare weights for were collected from the national transport information database for all of Holmen Skog's regions and districts (n=414 trucks). Second, based on the mapped variation, the component selection giving rise to the tare weight variation was mapped for a sample of different stratums (region and average hauling distance) through a questionnaire survey (n=69 trucks). Third, the owner's motivation for components selection was mapped via personal and telephone interviews (n=32 trucks).

Tare weights from the first part of the study (for the empty truck when leaving the scaling station) ranged from 15,0 to 24,9 tons. The districts were grouped into 5 classes of average tare weight and these are show in Figure 1, as well as corresponding average hauling distances.

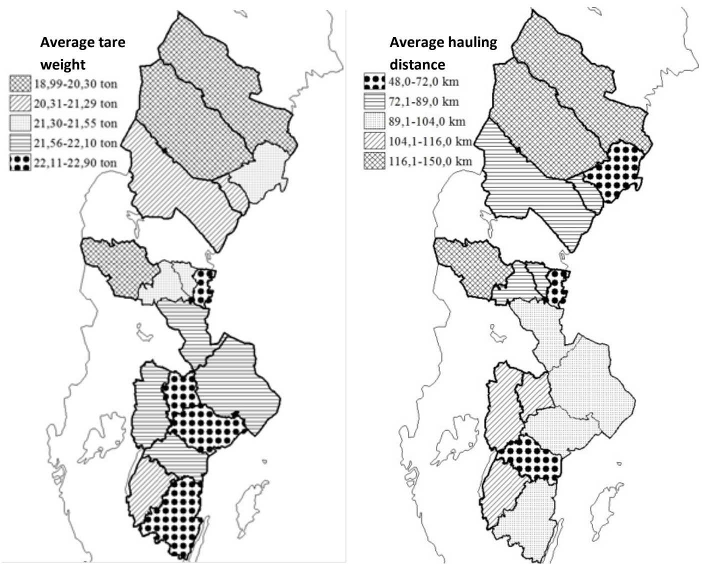

Figure 1. The average truck tare weights (left) and hauling distances (right) per district.

Tare weights from the second part of the study (total tare weight including loader from the questionnaire survey) ranged from 20,3 to 23,8 tons. A PCA-analysis identified 2 groups of typical truck component combinations. These 2 groups were significantly correlated with two principal components (Figure 2), where principle component 1 (p[1]) captured primarily the north-south gradient of regions/districts and principle component 2 (p[2]) captured primarily variation in average hauling distance. The typical truck component combination in the south included the heaviest trucks and was indicated by more powerful motors (593-625 hp), larger tanks (508-540 litres) and more bunks (10). The typical truck component combination in the north was indicated by higher proportions of large cab types, steel trailers and detachable loaders. The typical truck component combination for longer average hauling distances included larger tanks and a higher proportion of steel trailers and detachable loaders. The average loader weight was higher for detachable loaders than for the fixed loaders in all three regions.

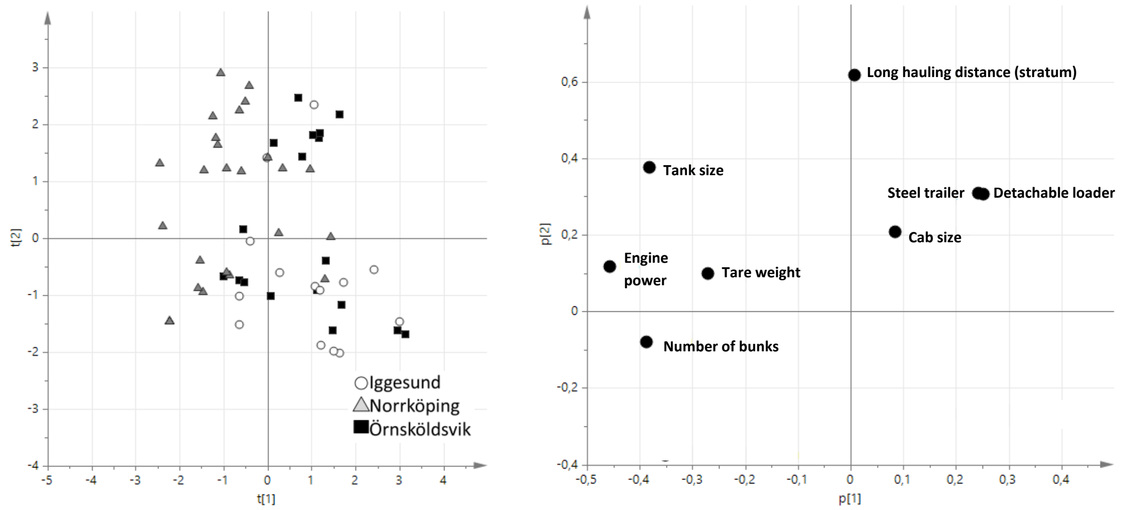

Figure 2. A PCA score plot of the different regions (left) and loading plot of the typical truck component combinations underlying tare weight (right). Principle component 1 captures the north-south gradient and principle component 2 captures the variation in average hauling distance.

The respondents' motivation for the chosen engine power was a perception of optimal fuel efficiency in the specific geography (which can include both physical topography, loaded proportion of total driving distance and frequency of acceleration/deceleration). The motivation for choice of tank size was linked to the need for only one refueling per shift for the chosen engine power and typical driving conditions (e.g. average hauling distance). The motivation for choice of detachable loaders was the increased payload capacity under medium- and longer hauling distances. The motivation for choice of fixed loaders was either a high proportion of backhauling or short average hauling distances. The respondents indicated a future increase in the proportion of alloy-trailers in 6 of 9 strata with the motivation that lighter alloys enable higher payloads while offering the same reliability as a standard steel construction.

Keywords: *tare weight, principal component analysis, typical component composition*

POTENTIAL COST SAVINGS WITH LARGER TRUCKS IN TRANSPORTATION OF FOREST CHIPS IN FINLAND

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Background

From the beginning of October 2013 heavier and higher vehicles have been allowed on Finnish roads. Before, the maximum mass of trucks was 60 tonnes and the maximum height 4.2 metres. Now trucks up to 76 tonnes and 4.4 metres are allowed. The changes in legislation have been motivated by reductions in logistical costs and greenhouse gas emissions.

According to a novel enquiry, functionality of the road network is the by far the most important development area in wood procurement in Finland. The need for development is even higher now with introduction of the bigger trucks. Due to increased masses and heights; the Finnish Transport Agency (FTA), which is responsible of maintaining and developing the public road network, has set new restrictions on bridges and underpasses. In March 2014, new restrictions had been set on more than 500 bridges on the roads maintained by FTA. This is a considerable increase to the number of some 100 bridges that previously had a mass restriction. In addition, there are 28 ferries that cannot bear the new maximum masses and at least 80-120 bridges that are maintained by municipalities or private road maintenance associations that will have a mass restriction.

For a transport company the actual cost savings by using bigger trucks depend very much on the restrictions of the road network in its operation region. Should there be a mass restriction on a bridge on the operator's main transport route, either a truck cannot carry full load or a detour must be found. Either one of the alternatives reduces the cost savings of the entrepreneur.

The objectives of the study are 1) to evaluate the actual cost savings of larger trucks in transportation of forest chips, 2) to identify possible bottlenecks and suitable routes of the road network for the bigger trucks, and 3) to test TCS Opti software in modelling and analyzing supply chains of forest chips. This will be accomplished in a case study, where different supply chains and transport restrictions for a delivery company located in Eastern Finland are compared.

Material and Methods

In the case study the actual cost savings, bottlenecks and suitable routes will be evaluated by comparing different transport scenarios (table 1) of one, hypothetical transport company. The company delivers logging residue chips to a combined heat and power plant in North Karelia, Eastern Finland. The company has a register of roadside storages which is utilized in transport planning. When a storage is chosen to be delivered, the residues are chipped to a chip truck and transported to a selected plant (fig. 1). The plant has a certain monthly demand that the company must meet.

Table 1. The transport scenarios.

Scenario	Truck mass, tonnes	Road network restrictions
60old	60	As before 1 Oct 2013
68old	68	As before 1 Oct 2013
68new	68	As after 1 Oct 2013
76old	76	As before 1 Oct 2013
76new	76	As after 1 Oct 2013

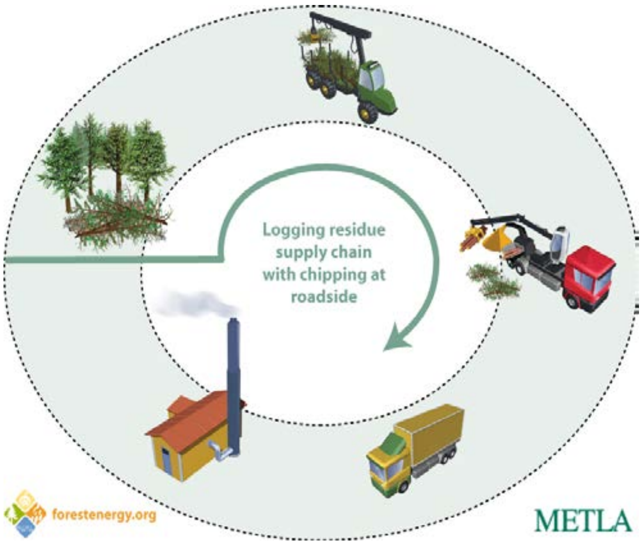

Figure 1. The supply chain.

The transportation costs and used transport routes during one year of operation will be calculated by simulating the operation with TCS Opti software. TCS Opti is a commercial tool for optimizing route logistics. The tool has not been applied in planning of forest chip transport before, but has applications in various other types of logistics such as waste management and security services.

In the simulation the payload of a truck may be constrained either by the maximum mass or the maximum volume, depending on the moisture content of the chips. The moisture content by month is predicted by drying models.

The data on the roadside storages are based on real roundwood storages by Stora Enso. The data on roads and restrictions originate from FTA.

Keywords: *forest chips, simulation, optimization, road transportation, logistics.*

OPTIMIZING FOREST RESIDUE CHIPS FLOWS WITH THE BIOMAX DECISION SUPPORT SYSTEM

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Introduction

Forest residues are an important source of bioenergy in Sweden, but the competition with other energy sources such as waste or recycled building materials is tough. To be competitive, forest fuels need to have an efficient supply chain. Chipping and transportation of forest residues requires capital-intensive machine systems and the delivery of this assortment must meet large seasonal variations in demand. This makes for complex planning and an assortment-specific decision support system (DSS) is needed to both select the right system and plan the transportation. The project was initiated by AB Karl Hedin, a Swedish sawmill company who supply raw materials to a number of energy plants, and saw the need for a DSS to improve their planning of forest residue flows.

BioMax

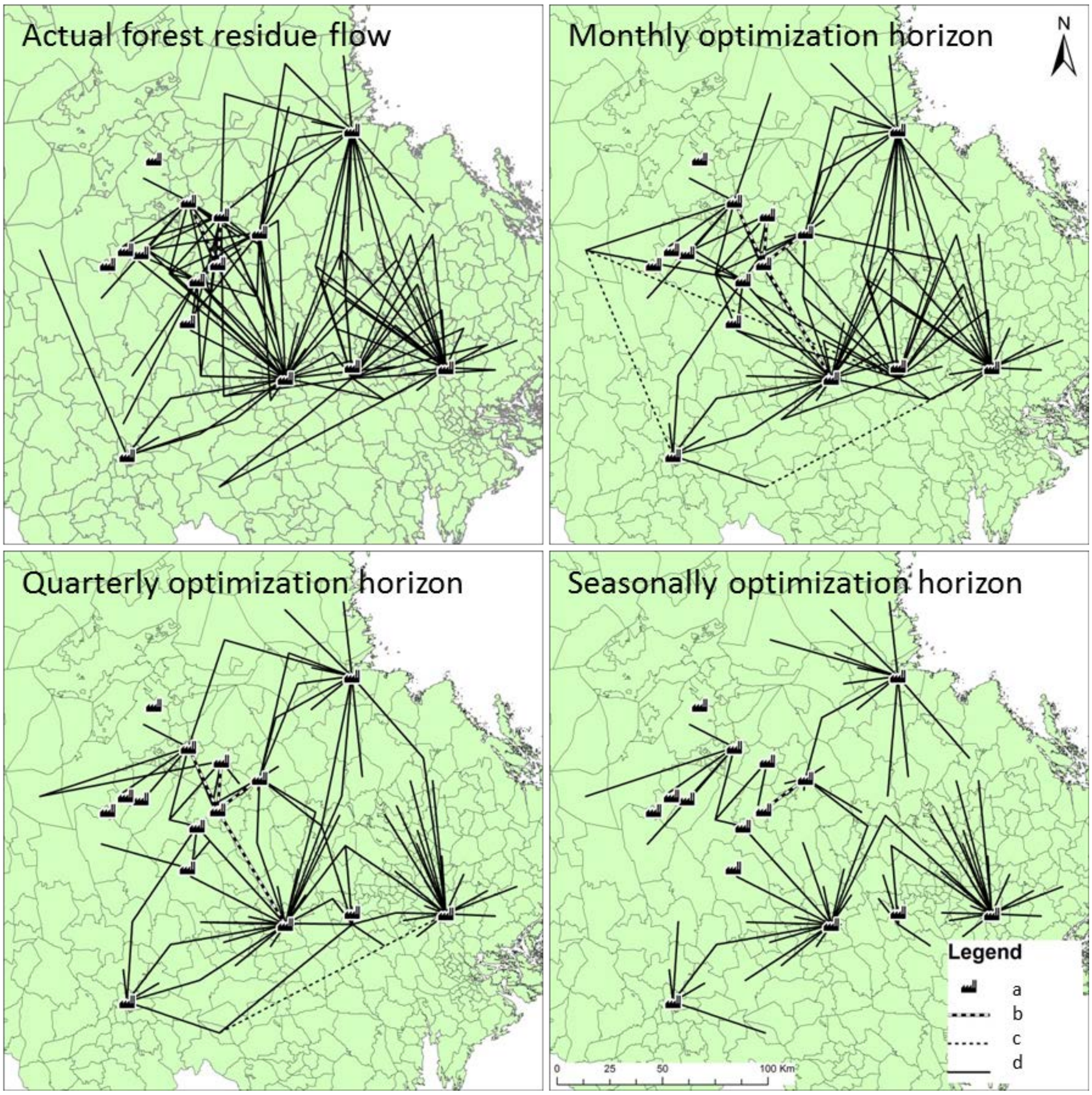
The project's aim was twofold: first to create a user-friendly, single-period DSS for optimizing forest residue chipping and flow planning, and second to quantify the improvement potential enabled by such a system. The objective of the DSS was to maximize the profit of forest residue sales. The result was BioMax; a linear programming-based DSS created mainly in Microsoft Excel and ArcGIS. The development and test of the system was done using nine months of historical data from 2011-2012.

To quantify the improvement potential enabled by the system, the historical data divided into monthly, quarterly and seasonal (9 months) planning horizons and optimized according to two scenarios:

> Scenario 1. Optimization was performed using the identical supply and demand as for the test period. In this scenario, the DSS was only allowed to influence the choice of machine system and destination of the transportation flows.
>
> Scenario 2. Optimization was performed with identical supply as the test period. In this scenario, the delivery to each customer was allowed to deviate up to 10 % from the historical delivery, with a greater possibility for re-allocation between customers.

Table 1 Comparison of average transportation distance (km) between Scenario 1 and 2

Scenario	*Historical average (2011/2012)*	*Optimized average (for respective time horizon)*			*Overall average for optimization*	*Overall reduction for optimization*
		Month	Quarter	Season		
1	52,3	44,2	39,7	38,0	40,6	11,7
2	52,3	43,2	38,7	37,9	39,9	12,4



BioMax output maps comparing actual and optimized flows for different optimization horizons (Scenario 1). The legend indicates the chosen receivers and machine system (a. forest residue receiver, b. wood chip truck, c. forwarder-mounted chipper combined with switch-body container truck, d. truck-mounted chipper). Note that for the actual flows there is no distinction shown between forwarder-mounted chipper/switch-body container truck flows and the truck-mounted chipper flows.

Conclusions

The results showed that longer optimization horizons generated a higher theoretical potential to increase profit. A permitted deviation of deliveries up to 10 % (scenario 2) also generated a higher potential. The higher potential for scenario 2 was linked more to transport cost than customer price because transport distance varied more between potential customers than price did.

The results showed that the potential increase in profit varied between 4,9 and 9,2 % depending on the scenario and optimization horizons. The average reduction of transport distance for all the optimizations was 12 km (approx. 23 % of the historical average of 52 km). Both scenarios resulted in truck-mounted chippers being more frequently chosen than tractor-mounted chippers.

Keywords: *Forest fuel, flow optimization, supply chain, decision support system*

IMPROVING THE USABILITY OF QUALITY KNOWLEDGE - QUALITY GUIDE FOR PRACTICAL ENERGY WOOD OPERATORS

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Increasing demand of forest biomass for energy production causes pressure to improve the quality of the supply chain and the raw material. Quality factors have a direct effect on costs in the supply and energy production. By enhancing the quality on each level of the supply chain it is possible to improve the cost efficiency of energy wood supply and the profitability of companies involved in energy wood operations.

The definition of good quality forest chips is based on quality standards and there is a wide unanimity about the most important quality features of forest chips. However, the knowledge and literature on good quality forest fuel is mainly divided on the basis of different quality factors, e.g. moisture content or particle size, whereas the overall impression of the quality in the recent guides and studies stays unclear. In addition to the dispersion of the information, quality knowledge is often in scientific form in a foreign language and thus it is not available or understandable for practical energy wood operators.

The aims of this study are to:

- describe the quality views of practical energy wood operators
- improve the quality knowledge of practical operators in energy wood supply chain by producing easily accessible and understandable guide material.

This study is a part of “Metsähakkeen tuotannon laadunhallinta” (quality management in forest bioenergy production) -project. The data collection was implemented by literature survey and by interviewing 33 persons working at different phases of the energy wood supply chain in Eastern Finland by using semi-structured interview method. In the analysis of the interviews, both qualitative and quantitative methods were applied; not only to collect information, but also to understand the attitudes and opinions influencing on the background. As a result of this study, a weather-proof, pocket-sized quality guide for practical energy wood operators (Fig. 1) was prepared.

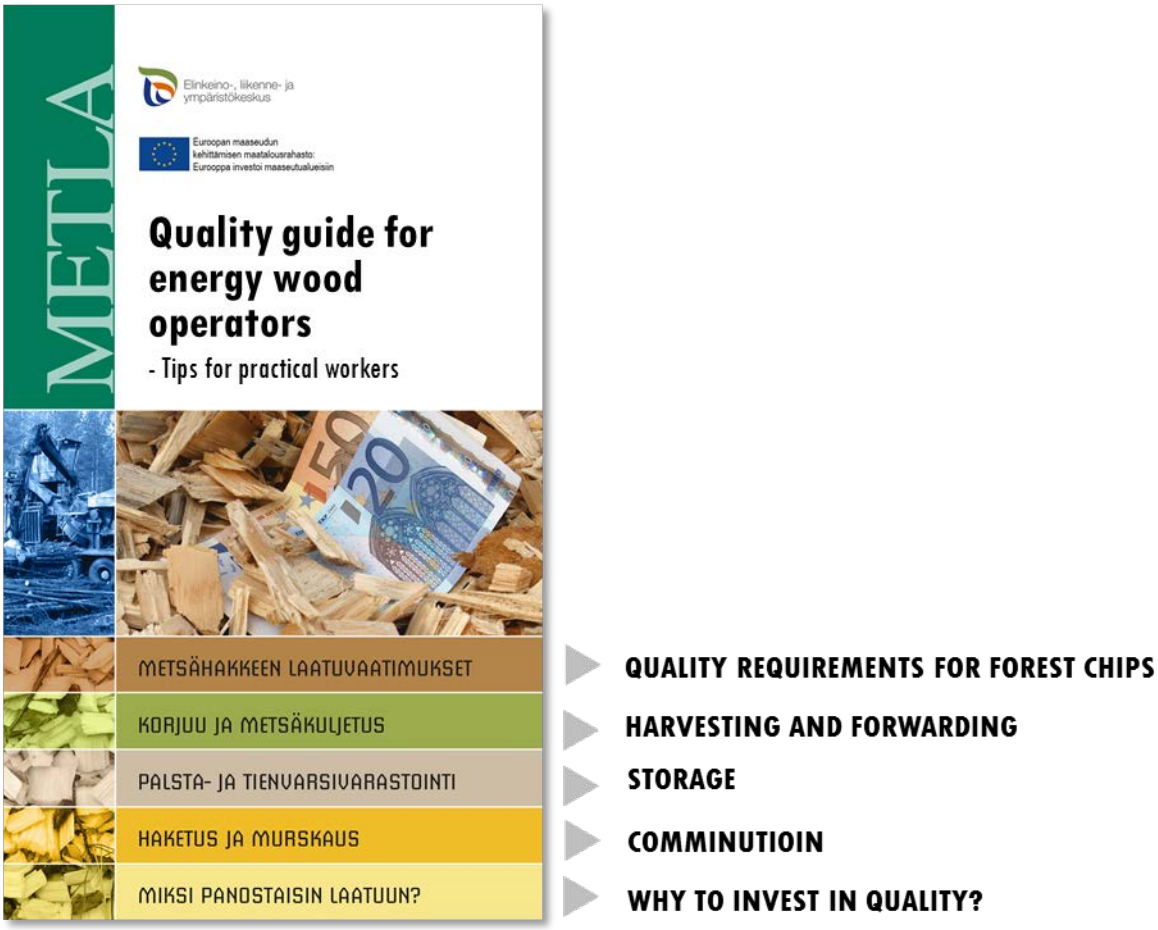

Figure 1. Quality guide for energy wood operators – Tips for practical workers.

Keywords: *quality, energy wood*

BISCUIT- BIOENERGY SUPPLY CHAIN UNIQUE INTEGRATED – TOOL

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When bioenergy supply chains are underdeveloped, both fuel suppliers and energy users face significant challenges in developing cost-effective and sustainable ways to allow them to make the best use of their biomass resources.

The idea of the tool (BISCUIT) is to highlight the key steps in the supply chain for each conversion technology and allow users to understand the requirements of an efficient, functional supply chain. The tool includes three different fuel sources: Woody Biomass, Energy Crops and other Biomass and three different conversion types: Combustion, Combined Heat and Power (CHP) and Anaerobic Digestion (AD). Through BISCUIT various reports may be generate, depending on interest.

The tool has been developed in BioPAD project funded by Northern Periphery Programme (NPP) which is part of European Regional Development program.

Keywords: *Bioenergy, Supply Chain, Wood Biomass, Energy Crops, Combustion*

VARIATION IN MOISTURE CONTENT OF CHIPPED FOREST MATERIAL DELIVERED UNDER WINTER CONDITIONS

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Introduction

Fuel energy content is often used as payment for comminuted forest biofuel, and is estimated by sampling the deliveries' moisture content (MC). Most deliveries of comminuted forest biofuels are conducted with lorries and all lorries are usually sampled. Today there is no legislation in Sweden concerning the measurements forest biofuels as there is for roundwood. But there is an ongoing process concerning new legislation that will require a certain precision for the measurement of forest biofuels. The required precision levels are not finalized but will probably be 9% for deliveries ≤ 50 oven dry tons (ODT) and 6 % for deliveries >50 ODT [1]. Thus, deliveries with one or two lorries will probably have required precision level of 9 %, larger deliveries will have 6 %. To reach these precision levels, the MC and its variation has to be known.

The aim of this study was to: 1) measure the variation in MC for commuted forest biofuels in winter conditions in northern Sweden, and 2) estimate how many lorries are needed per delivery with the current measurement procedures to fulfil the required precision level.

Material and Methods

The study was conducted at Skellefteå Kraft AB power plant, in Skellefteå January 21-February 2013. In total, 18 lorries were sampled; 13 lorries with comminuted logging residues; four with stemwood; and one with a mixture of stemwood and logging residue chips. Each lorry delivered 19.5-39.7 tonnes fresh weight of fuel. The current measurement procedures is that four samples are taken manually per lorry, and these samples are combined into a general sample from which one sample is taken for MC analysis. This study's sampling and sample preparation was made according to Swedish standard SS-EN 14780:2011 [2], SS-EN 14778:2011 [3], and SS-EN 14774-2:2009 [4]. From each lorry 30 samples each of 5 L were taken. The samples were taken after the chips were tipped from the lorry. The wood chip piles were divided in to three layers, where the number of samples corresponded to the volume of each layer. The top layer was assumed to consist of 20 % of the total volume, the middle layer of 30 %, and the bottom layer of 50 %. Samples were taken at predetermined points evenly distributed around the pile. The sample preparation was made by quartering on a stainless steel surface, SS-EN 14780:2011 was diverged from because samples were divided to <1 kg. The surface and tools were cleaned between every sample. In total, 50 samples per lorry were analysed for MC from an original sample of 30 taken from the lorry (i.e. 20 of the samples were split into 40). SS-EN 14780:2011 was diverged from as the samples were placed in paper bags that had with known weight and then dried in 105 °C for 48 h.

The precision level for the measurements consists of two components according to SS-EN 14778:2011. The first component is the variation inside one sample (V_{PT}) and the second component is the variation between samples (V_I). The precision level of the sampling can be calculated from V_{PT}, V_I, number of samples, and lorries. It is also possible to calculate the amount of samples needed in a lorry to achieve a desired precision. The equations in SS-EN 14778:2011 calculate the absolute precision and has to be adjusted to give the relative precision. The average V_{PT} and V_I plus 1.96 times the standard deviation was used in the calculations, and were calculated for all lorries, lorries with logging residues chips and lorries with stemwood chips. Calculations were made for the number of lorries required in a delivery to fulfil the coming requirements under the current sampling procedure.

Results

The MC in Chips from logging residues was clearly higher than in stemwood chips (Table 1). Stem wood chips fulfil the requirements for deliveries with seven or more lorries with the current measurement. Logging residue chips deliveries fulfil the requirements for deliveries with 17 or more lorries.

Table 1. Moisture content (MC), variation in a sample (V_{PT}), variation between samples (V_I), and number of sampled lorries (No.) per group

	All	residues	stem
No.	18	13	4
MC	46.93	49.97	37.00
V_{PT}	9.851993587	10.54863546	3.585247366
V_I	99.26159322	108.9313484	18.52061086

Discussion

The current sampling procedures do not have enough samples to reach the required precision level for small deliveries. Which mean that more samples have to be taken. In manual sampling it is important to consider the strain of more samples on the employees. The number of samples could perhaps be doubled or tripled, meaning eight or twelve samples per lorry. An increase to eight samples would fulfil the requirements for stemwood chips deliveries of five or more lorries, while an increase to twelve would also fulfil the requirement for deliveries with two lorries but not for deliveries with three or four. For logging residue chips, an increase to eight samples would fulfil the requirements for deliveries with eleven or more lorries and an increase to twelve samples would fulfil the requirements for nine or more lorries. If we were to take more than twelve samples, I believe the sampling has to be automated.

All combinations of delivery sizes and required precision is not even theoretical possible regardless of number of samples. Stemwood chips deliveries of two lorries would require ten samples, but deliveries with three lorries would require 166 samples as the required precision is increased. However, deliveries with one lorry can not be measured with the required precision levels. Logging residue chips deliveries with five lorries could be measured but would require 158 samples while smaller deliveries can not be measured with the required precision level at all.

Since the MC variation is lower in chips from stemwood then in those from logging residues, fewer samples are required from stemwood deliveries. However, mistakes might arise if the required number of samples varies too much.

References

[1] Björklund J & Eriksson U. (2013) Torrhalts-bestämning på sönderdelat trädbränsle [Dry matter content measurements on commuted wood fuel]. SDC report.

[2]Fasta biobränslen - Provberedning [Solid biofuels - Sample preparation]. (2011). Swedish standards institute. SS-EN 14780:2011

[3]Fasta biobränslen - Provtagning [Solid biofuels, sampling] (2011) Swedish standards institute. SS-EN 14778:2011.

[4]Fasta biobränslen - Bestämning av fukthalt - Torkning i ugn - Del 2: Total fukthalt - Förenklad metod [Solid biofuels - Determination of moisture content - Oven dry method - Part 2: Total moisture - Simplified method] (2009) Swedish standards institute. SS-EN 14774-2:2009.

Keywords: *bioenergy, biofuels, heating value, logging residues*

DISCRETE-EVENT SIMULATION OF TRUCK QUEUING FOR ALTERNATIVE UNLOADING SOLUTIONS AT A SWEDISH COMBINED PULP- AND SAWMILL

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Introduction

Structural development in the forest products sector has led to a concentration of processing capacity to fewer and larger mills. At the same time, demands for shorter lead times and reduced bound capital in the woodyard stocks requires better coordination between wood supply and mill consumption. With the resulting increased frequency of logging truck arrivals, limited unloading capacity risks increased queuing and reduced truck production. A number of solutions have been examined to enable a more even daily distribution of truck arrivals, ranging from centralized scheduling systems to decentralized ETA functions. Regardless of these, the question of adequate unloading capacity remains. Given the various resources for unloading and handling between sorting, storage and consumption, the distribution of capacity within the woodyard has consequences for truck queuing times and loader utilization. *The aim of this study* was to create a simple discrete-event model for simulating different unloading solutions at a combined pulp- and sawmill, and quantifying the effect of the different solutions on truck queuing times.

Methods

Roundwood handling was modelled in ExtendSimLT and included both pulp- and sawmill flows. In practice, roundwood deliveries arrive via three modes (truck, rail, ship). The model focused on truck deliveries, simplified rail deliveries and excluded ship deliveries. Typically, a pulpmill consumes more roundwood than a sawmill while a sawmill requires more handling per unit (for sorting into length and diameter classes). The mill modelled in this paper had therefore two high-capacity loaders for unloading the pulpwood flows and one high-capacity loader for unloading the sawlog flows. The sawlog flow also had two low-capacity loaders for handling before and after sorting.

The model used historic data from one of Holmen Skog's combined mills in Sweden. The primary data consisted of the daily distribution of truck arrival times during midwinter (Figure 1). Capacities for the different types of loaders were based on the maximum volume handled per effective hour (m3f/G_0 hr) known from practice. Three alternative unloading solutions were modelled: 1) the base case as described above with no sharing of loader capacity between pulp- and sawlog flows, 2) reduced high-capacity loaders for the pulpwood flow, but with a possibility to share the low-capacity loaders between from sawlog and pulpwood flows and 3) reduced high-capacity loaders for the pulpwood flow, but with without sharing of capacity between sawlog and pulpwood flows. Five simulations were made of each alternative loader solution.

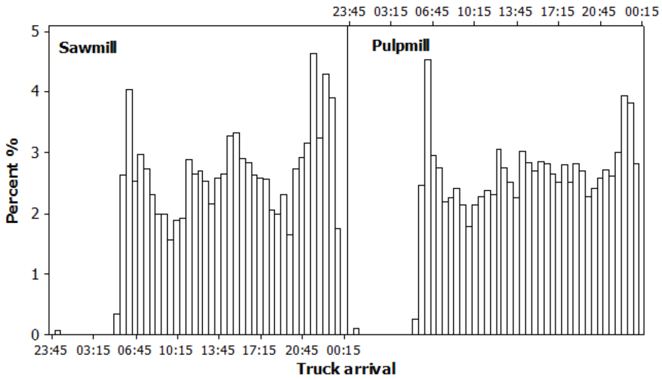

Figure 1. A typical distribution of truck arrival times (percent) for sawlog (sawmill) and pulpwood (pulpmill) flows at the combined mill.

Results

The median queuing times initially modelled for the alternative 1 (base case) were underestimated when compared to times observed in practice (Figure 2, left). Time consumptions for unloading were therefore increased proportionally until the modelled median corresponded to practice. After this, the distribution of truck queuing times and average loader capacity utilization were modelled again for the alternative loading solutions (Figure 2, right).

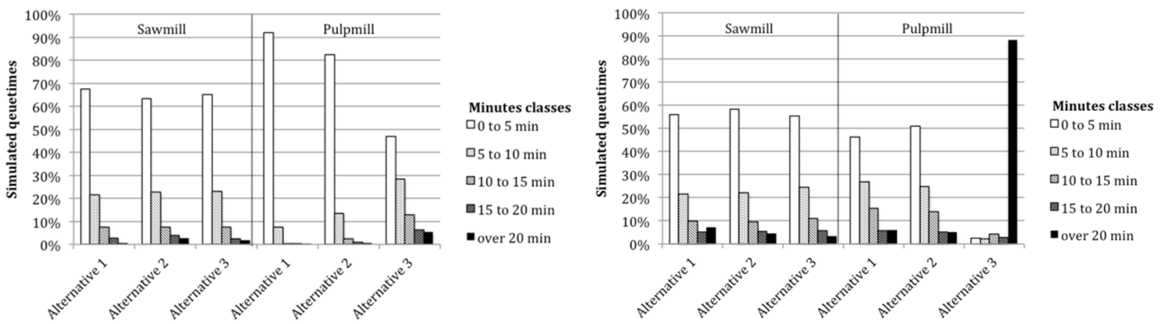

Figure 2. Distribution (percent, %) of truck queuing times (5 min classes) for alternative loader solutions (alternatives 1:base case, alternative 2: reduced resources with sharing, alternative 3; reduced resources without sharing) for the initial model (left) and calibrated model (right).

For sawlog arrivals, loader solution 2 (reduced resources with sharing) had a marginal effect on truck queuing. However for pulpwood arrivals, loader solution 2 resulted in an increased proportion of trucks waiting longer than 5 minutes for the initial model while the calibrated model showed marginal effects. Loader solution 3 (reduced resources without sharing) was associated with an increased proportion of extreme waiting times (greater than 20 minutes) for pulpwood arrivals.

Conclusions

As for earlier studies, this study showed that discrete-event simulation is well suited for modelling the effects of alternative woodyard solutions. In this particular case, the model should be supplemented with more detailed loader capacity utilization schedules and a higher resolution of rail and ship arrivals before making recommendations.

Keywords: woodyard operations, discrete-even simulation, queuing times, loader capacity

COMPARISON OF BRACKE C16.B WORK METHODS IN NATURALLY REGENERATED GREY ALDER STANDS

Jānis Liepiņš[1], Andis Lazdiņš[2], Uldis Prindulis[1] & Agris Zimelis[1]*

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The scope of the study is to compare 3 harvesting methods in pre-commercial thinning of naturally regenerated grey alder stands using Bracke C16.b felling head on a John Deere 1070 wheeled harvester, including extraction and forwarding of trees. The applied methods are:

1. Traditional thinning targeted to a single tree. Operator cuts two strips in both sides of corridor to free space for extracted trees, then removes remaining extractable trees and bushes in the stand. Distance between strips – 5 m (depends from density of a stand), distance between corridors – 20 m. All trees and bushes are extracted in the initial strips, only trees with diameter ($D_{1.3}$) above 4 cm are extracted in remaining part of stand;

2. Simple symmetrical method. Distance between the strips is reduced to 2-3 m depending from a stand density. The remaining stand apart of cleaned strips stays untouched, except clumps of hazel and grey alder;

3. Complex symmetrical method. Distance between the strips is increased to 3-5 m and 4 additional strips are extracted from the same place in a certain angle. The material is piled in central or additional strips (Fig. 1).

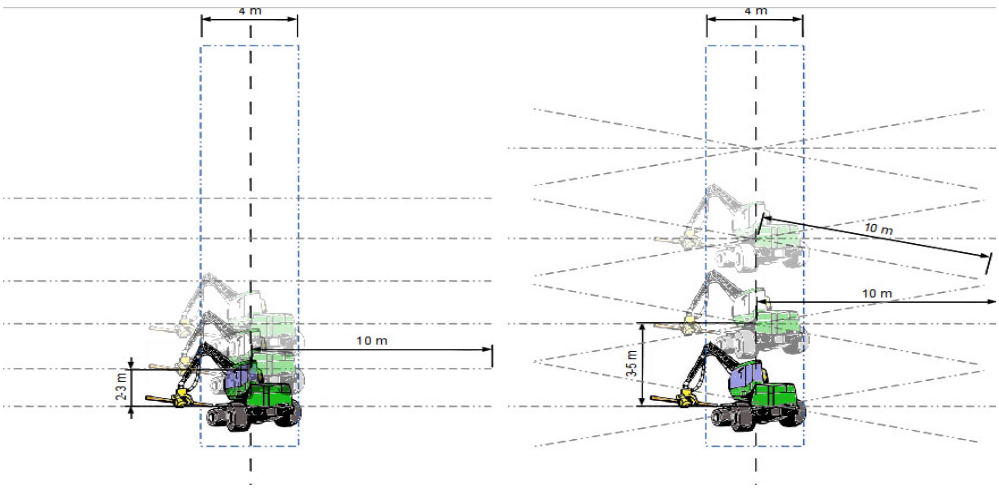

Figure 1: Second and third working method.

Diameter ($D_{1.3}$) of average trees before thinning is 6 cm, height – 10 m, growing stock – 125 m^3, number of trees 7 000 per ha except undergrowth (33 000 per ha), total area of the experiment – 8 ha.

According to the study results the most beneficial is 2nd working method; especially, if dimensions of extractable trees are increasing (Fig. 2). Average productivity using 1st method is 18.3 min. of direct work time (crane cycles utilized to produce biomass) per 1 LV m^3 (LV – loose volume), using 2nd and 3rd method, respectively 16.1 and 19.9 min. per 1 LV m^3.

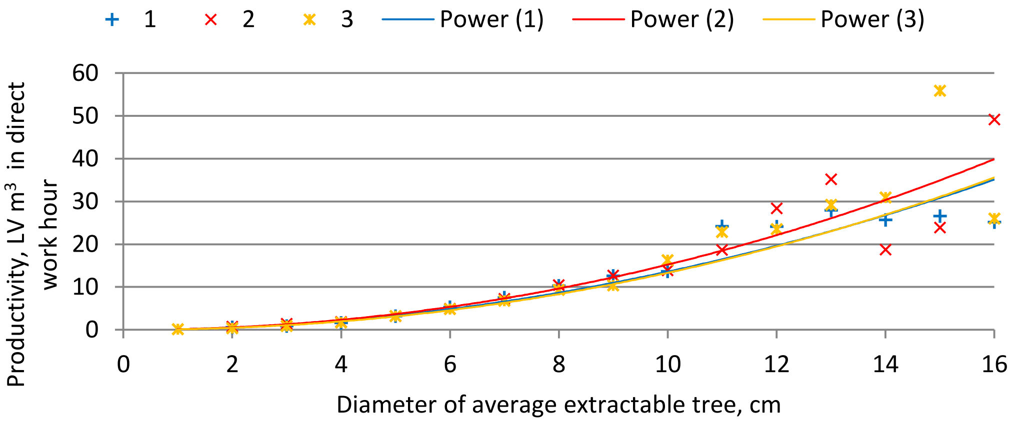

Figure 2: Productivity of extraction depending from diameter of extractable trees.

Number of trees extracted per direct work hour is 214 in 1st method and, respectively 199 and 198 using 2nd and 3rd method. Direct work time is 97 % of productive time and 87 % of engine-on time. Total produced biomass equals to 798 LV m^3, (100 LV m^3 ha^{-1}), volume of average extracted tree is 0.02 m^3. Extraction cost in the specified experimental conditions ranges from 12.3 to 13.3 EUR LV m^3. The extraction cost decreases twice, if $D_{1.3}$ of average extractable tree increases to 8 cm, respectively 6.3, 6.2 and 7.0 in 1st, 2nd and 3rd method. If $D_{1.3}$ of average extractable is 12 cm, cost of extraction reduces, respectively to 2.7, 2.3 and 2.8 EUR LV m^3. Choosing simple symmetric method instead of the traditional method leads to reduction of extraction cost by 1.3 EUR LV m^3 in the study conditions and by 0.8 and 0.4 EUR LV m^3, respectively, if $D_{1.3}$ of average extractable tree is 8 cm and 12 cm.

Selection of work method has impact on productivity of forwarding; if the first method is selected, loading takes 13.0 min. per load, if 2nd or 3rd methods, respectively 12.2 and 12.4 min. per load. Increase in productivity is associated with more regular location of piles of extracted trees, when 2nd or 3rd method is applied. However, the higher productivity per load in 2nd and 3rd method is compensated by smaller loads due to smaller dimensions of average extracted tree – average load in 1st method is 2.7 tons, in 2nd methods – 2.3 tons and in 3rd method – 2.4 tons. Loads are relatively small in the experiment because of low soil bearing capacity during the trials. Use of tracks made problematic weighing of loads by platform scales; therefore, the results are based on measurements made during harvester time studies and will be updated during chipping.

The study demonstrated that the most beneficial in pre-commercial thinning of grey alder stands is simple symmetrical method, however it should be adopted to conditions in naturally regenerated stands and instead of regular parallel strips operator has to select the most appropriate direction every time. The minimum average diameter of trees to reach positive cash flow in grey alder stands using Bracke C16.b is 8 cm.

The study is done within the scope of the National forest competence centre project “Methods and technologies to increase forest value” (L-KC-11-0004).

Keywords: *Bracke C16.b, thinning, productivity.*

OPERATIONS PLANNING AND PERFORMANCE OF WINDFALL SALVAGING IN NORWAY

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Introduction

Wind felled timber can be particularly difficult to salvage because of the large concentrated volumes that need to be harvested concurrently, because of the location of this mass in relation to possible markets, and because of the physical conditions in the stand. The trees can be uprooted, which limits machines access, the trees can be broken, which limits the recovery of useful assortments, and the direction and orientation of the stems on the ground can be more or less chaotic, resulting in excessive handling time. These issues are accentuated by conditions in western Norway, where it is difficult to access the stands on steep slopes with their limited infrastructure, and specific planning information can make a significant and critical contribution to the economic feasibility of the operation.

Many sources predict an increased frequency, seasonality and intensity of storms, and as part of this adaptation to climate change, the forest sector needs to both improve resilience through changed forest management practices, and response, as knowledge on how to salvage the timber in a rational and safe way can contribute to alleviating the consequences. In this paper, we describe a method for determining the orientation of the fallen trees from aerial photographs to assist in operations planning, and also present results of productivity studies on salvaging wind felled timber where2 methods (with and without motor-manual assistance in cutting the stumps free) were tested against each other.

Materials and Methods:

All measurements were done on an inland windblown site near Brandbu in Oppland County (N 60.447419, E 10.490828). The stand had been a monoculture of 50 yr old Norway spruce (*Picea abies*) with a high site index (G23) and estimated volume of 400 m^3 ha^{-1}. Practically all trees had been completely blown down with only a few individuals having snapped (fig 1, left). The slope was between 15%-20% and classified as easy terrain for a CTL system. A John Deere 1270E harvester was used in the trial. In the first treatment, the harvesting head was used to cut the stem free of the stump, then process the tree. The second treatment involved cutting the stem free of the stump motor-manually using a chain-saw, then lifting and processing the stem with the harvester. The motor-manual cutting was done by two people working at a safe distance from each other and well ahead of the machine. Costs for the harvester were set at 1060 NOK SMH^{-1} and for the manual forest workers, 250 NOK h^{-1} per person, including all oncosts. Time studies were carried out using Haglöf SDI software running in a Windows CE environment on an Allegro MX™ datalogger, which allows for continuous recording at the centi-minute level. Just over 200 trees were studied for each treatment.

To determine the orientation of the stems, images from aerial photography were processed in Matlab’s image analysis package. Stem edges were detected and delineated using Hough transformation. Orientation was determined by calculating the heading from the xy-coordinates of the vertices at the end of each straight line segment.

Figure 2 (left) view of the storm felled area studied, and (right) results of the automated stem edge recognition

Results

Results of the time study showed that there was a difference of roughly 15% between the motor-manual assisted processing (36 s tree^{-1} s.d. 12.6) and the fully mechanised processing (41 s tree^{-1} s.d. 31.8) although the variation in the latter was much larger, given the higher occurrence of handling problems arising. The motor-manual assisted processing resulted in a productivity rate of just over 30.3 $m^3E_0h^{-1}$ while the fully mechanised system produced 26.7 $m^3E_0h^{-1}$. However, when considering the combination of efficiency and cost, the fully mechanised system was significantly cheaper (40 NOK m^{-3}) than the motor-manual assisted processing (54 NOK m^{-3}).

The stem detection algorithm was effective in identifying edges, with about 90% being detected as compared with a manual identification procedure (fig. 1, right).

Discussion

The productivity levels achieved were unexpectedly high, implying that there is not much difference between harvesting standing or windblown timber if the trees are lying in an orderly fashion. While efficiency was improved by including motor-manual assistance in cutting the stump free, the cost of doing so was not justified, and it was considerably cheaper to run a fully mechanised operation. This is an important result, as motor-manual operations in storm felled timber are highly dangerous, and in this case, any associated risk would be unjustified. It should be noted however that we consider only the effective work time in this paper, delays arising from e.g. frequent saw chain changes are were not included. Further research is required on the digital image analysis and the development of the ‘chaos’ index, which could be extended to making volume estimates at the same time.

Acknowledgements

We would like to thank our colleague Leif Kjøstelsen and Daniel Kindernay (Technical University Zvolen) for assistance with the time studies.

Keywords: *storm damage, utilisation, climate change, forests, planning*

PERFORMANCE AND QUALITY IN SELECTIVE HARVESTING WITH HARVESTER AND FORWARDER

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Abstract

Of the different forest management regimes available, the system usually applied in Swedish forestry includes scarification and planting, pre-commercial thinning, thinning and clearcutting. Selective harvesting is an alternative, leading to a state of continuous forest cover. Selective harvesting can work when the forest is dominated shade tolerant, secondary tree species such as Norway spruce. Further, it requires that the stand is healthy and include trees in diameter classes from plant sizes to full sized trees. The largest trees are periodically harvested in a selective harvesting operation and the remaining trees continue to grow in the created gaps until next operation. The selective logging operation can be done with a harvester and a forwarder.

The performance and silvicultural quality of a medium sized harvester and forwarder in selective harvesting was studied through time studies and field measurements and compared to the performance levels in final felling and in thinning.

Four study objects were chosen from different locations in Sweden. The objects were located from the south to the north of Sweden, close to Vimmerby, Falun, Mora and Örnsköldsvik.

The studied operations included opening of strip roads plus selective harvesting as well as selective harvesting exclusively, which will be a more typical operation after an initial shift-over from clearfelling to selective forest management.

Time consumption were analysed through time study data and matched with data from separate stems for the harvester. The separate stem data were collected from harvester production files. Time consumption for forwarder were analysed through time study data but with analysis on each crane cycle and load, and not for each stem. Variables such as stem per hectare, strip road distance and damages to left trees and the ground were studied in a follow-up after the studies.

Machine operators in Sweden are not used to do such selective harvesting from above as in this study, and removed stem were not marked before the study. The time for the selection were therefor collected when the harvester needed to pause when selecting.

A comparison of raw data from the study, without levelling towards known data, have shown big similarities with time consumption in thinning. The increase of mean stem volume show a little higher impact on the productivity norm than the raw study data, when time consumption is analysed (Figure 1).

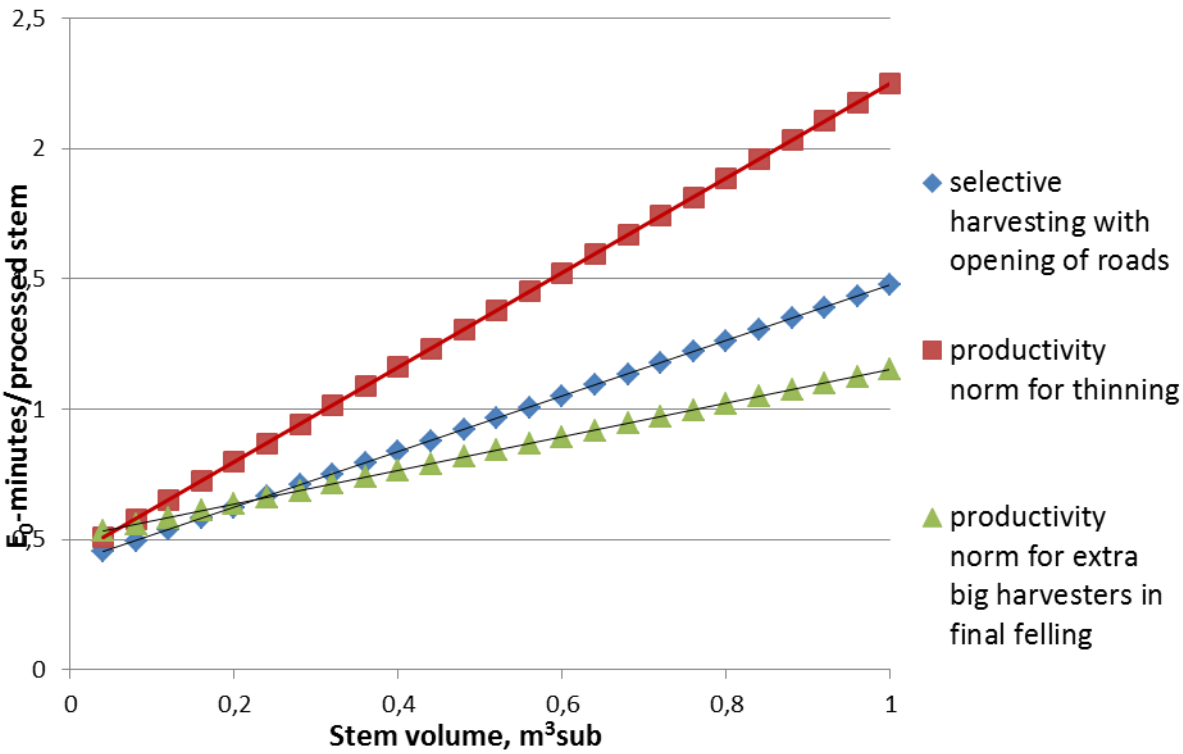

Figure 1. Time consumption over stem volume.

Mathematic functions for time consumption were created from statistical analysis of the data material. For the harvester; the functions included operations with both opening of strip road and selective harvesting and only selective harvesting with existing strip roads. Functions have also been created for forwarding.

The functions will be used for simulations enabling e. g. cost comparisons between selective harvesting, final felling.

Keywords: *logging cost, continuous forestry, selective logging, time consumption, time function.*

RESULTS OF EVALUATION OF BRACKE C16.B WORKING METHODS IN CONIFEROUS AND MIXED STANDS

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The scope of the study is to compare 3 working methods in pre-commercial thinning of spruce and mixed stands using Bracke C16.b felling head on a standard John Deere 1070 wheeled harvester. The applied methods are:

1. traditional thinning targeted to a single tree – operator cuts two strips in both sides of corridor to free space for extracted trees, then removes remaining extractable trees in the stand. Distance between strips – 5 m in average (depends from density of a stand), distance between corridors – 20 m. All trees and bushes are extracted in the strips;

2. simple symmetrical method – distance between the strips is reduced to 2-3 m depending from a stand density. The remaining stand apart of cleaned strips stays untouched;

3. complex symmetrical method – distance between the strips is increased to 3-6 m and 4 additional strips are extracted from the same place in a certain angle. The material is piled in central or additional strips (Fig. 1).

The operators were instructed to leave trees and bushes if $D_{1.3}$ < 4 cm, except in those strips, where they are piling material. All participating operators had previous experience with this harvester head.

Diameter ($D_{1.3}$) of average trees before thinning is 9 cm, height – 8 m, growing stock – 69 m^3, number of trees 2000-3000 per ha except undergrowth, total area of the experiment – 15 ha.

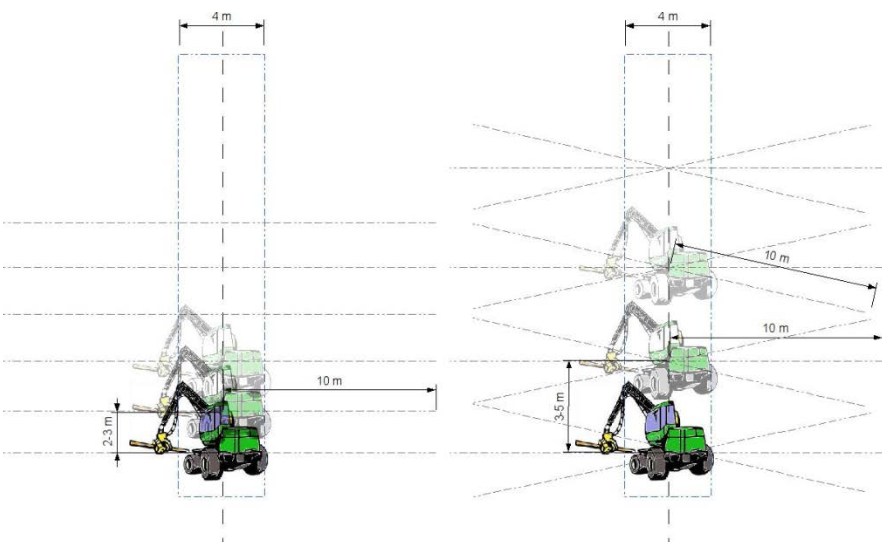

Figure 3: Second and third working method.

According to the study results 3rd method secures the fastest growth of productivity of Bracke C16.b, if $D_{1.3}$ of extracted trees in stand is increasing (Fig. 2). Average productivity of all methods in the studied stands is 14 min. of direct work time (crane cycles utilized to produce biomass) per 1 LV m^3 (LV – loose volume).

Figure 4: Productivity of extraction depending from diameter of extractable trees.

Prime cost of wood chips delivered to 50 km distance in average is 10.0 EUR LV m^{-3} using the 1st method, and 11.8 and 11.9 EUR LV m^{-3} using, respectively, 2nd and 3rd method. Increase of the prime cost in 2nd and 3rd method is caused by smaller average diameter of trees in the same stands. According to the system analysis income from selling biomass exceeds thinning cost if $D_{1.3}$ of average extractable tree is at least 8 cm.

The net income before taxes is 429 EUR ha^{-1} using 1st method, 490 and 480 EUR ha^{-1} using, respectively, 2nd and 3rd method, if $D_{1.3}$ of average extractable tree is 9.5 cm (reduction of thinning cost is considered in calculation). The cost of motor-manual thinning without production biomass in the same conditions would be at least 172 EUR ha^{-1}.

The study demonstrated, that qualification of operators and technical conditions of machines is very important factor affecting cost and benefit ratio much more than average productivity figures. Duration of inefficient (not resulting in piled extracted trees) crane cycles was 16 % of total engine work time. Downtime of the machine due to different technical issues during the studies was nearly 20 %.

The 3rd method can be applied, when number extractable trees is relatively high and dimensions of trees – small; however, the most beneficial this method seems to be in stands with large dimensions of trees ($D_{1.3}$ >12 cm). The 2nd method can be used in less dense stands. Symmetric thinning is not recommended for naturally regenerated stands. Traditional thinning (1st method) can be applied in naturally regenerated deciduous stands, where trees are growing in groups as coppice crops.

The minimum average diameter of trees to reach positive cash flow in thinning using Bracke C16.b is 8-9 cm. Downtime should be reduced by proper and timely maintenance of machines.

The study is done within the scope of the National forest competence centre project “Methods and technologies to increase forest value” (L-KC-11-0004).

Keywords: *Bracke C16.b, thinning, productivity.*

Conference Programme

Nordic Baltic Conference OSCAR14

Solutions for Sustainable Forestry Operations

June 25-27, NOVA Park Conference, Knivsta, Sweden

Sponsors:

MELLANSKOG Skogsägarna OPTEA SCA Care of Life

Wednesday, June 25 2014
Opening

-10.00	Registration, Coffee

Plenary Opening session (Chair Rolf Björheden)		
10.00-10.20	Welcome to OSCAR14!! *Rolf Björheden, Skogforsk*	
10.20-10.40	Keynote: Challenges for Forest Operations, *Magnus Bergman, SCA*	
10.40-11.00	Keynote: Knowledge exchange – a quarter century with IJFE, *Ola Lindroos, SLU & IJFE*	
11.00-11.20	Keynote: Why do we need to reduce site impact?, *Hillevi Eriksson, Swedish Forestry Agency*	
11.20-11.40	Keynote: Contractor forestry – finding new ways, *Eva Skagestad, Skogkurs, Norway*	
11.40- 12.40	Lunch break	
	A1 Site impact (Chair Kjell Suadicani)	**B1 Organisation & Training** (Chair Bruce Talbot)
12.40-12.55	***Högbom, L.*** *Mitigating effects on run-off water quality after final felling using forest buffers*	***Gercāns, J.*** *LVM logging service development strategy and tools*
12.55-13.10	***Lupikis, A.*** *Comparison of soil compaction using tracked and wheeled machines in early thinning*	***Sääf, M.*** *The communication process between contactors and clients*
13.10-13.25	***Mohtashami, S.*** *Avoiding ground damages during logging operations using digital maps*	***Norrby, B.*** *Environmental and quality improvement through self-awareness, communication and feedback*
13.25-13.40	***Hansson, L.*** *Soil physical changes caused by driving with heavy vehicles on boreal regeneration areas*	***Fjeld, D.*** *Developing training for industrial wood supply management*
13.40-13.55	***Friberg, G.*** *Waterproof forwarding with LiDAR-datasets in south Sweden*	***Ottaviani Aalmo, G.*** *Forest workers and steep terrain winching: the impact of environmental and anthropometric parameters on performance.*
13.55-14.10	***Berg, S.*** *Ground disturbance after stump extraction under different conditions*	***Sääf, M.*** *Development work within silviculture contractor firms*
14.10-14.25	***Lazdiņš, A.*** *Case study on wood ash properties in pellet factory*	***Lindroos, O.*** *What affects the machine operator's choice of thinning method?*
14.25-14.55	Coffee break	

	A2 Silviculture & Reforestation (Chair Andis Lazdiņš)	B2 Wood value and logistics (Chair Lars Wilhelmsson)
14.55-15.10	***Laine, T.*** *Automatic feeding system for mechanized planting; an evaluation of the Risutec Automatic Plant Container (APC)*	***Nordström, M.*** *Towards capturing the full value of the tree through improved harvester measurements*
15.10-15.25	***Ersson, T.*** *The feasibility of crane-mounted tree planting devices with more than two heads*	***Grīnvalds, A.*** *Calibration of forest inventory data by precise pre-harvest measurements*
15.25-15.40	***Kärhä, K.*** *Mechanized tree planting in Finland*	***Suadicani, K.*** *Decision support in harvesting of Norway spruce*
15.40-15.55	***Grönlund, Ö.*** *Harvesting of a birch shelterwood*	***Enström, J.*** *Success factors for larger forest fuel terminals*
15.55-16.10	***Makovskis, K.*** *Environmental impacts of mounding method in forest site preparation*	***Kons, K.*** *Characteristics of Swedish forest biomass terminals*
16.10-16.25	***Wallgren, M.*** *Management strategies for reducing browsing damage by moose*	***Sikanen, L.*** *Importance of dry matter losses and capital costs in energy wood supply chain*

16.30-18.30	Work group meetings etc. as planned by WG

19.30-	Dinner

Thursday, June 26 2014

	A3 Systems Evaluation (Chair Antti Asikainen)	B3 Bioenergy (Chair Maria Iwarsson Wide)
08.00-08.15	***Eriksson, M.*** *The effect of machine factors on harvester productivity in thinning and final felling*	***Routa, J.*** *Precision measurement of forest biomass moisture change and dry matter losses by constant weight monitoring*
08.15-8.30	***Björheden, R.*** *Size matters! Improving operations by analysing effects of machine size.*	***Pajuoja, H.*** *Determining of the moisture content of energy wood during forest forwarding and storing*
08.30-08.45	***Jonsson, R.*** *Simulation of thinning with zero, one or two intermediate passages between the striproads and comparison of logging costs*	***Laitila, J.*** *Productivity of multi-tree cutting in thinnings and clear cuttings of downy birch (Betula pubescens) in the integrated harvesting of pulpwood and energy wood*
08.45-09.00	***Kalēja, S.*** *Evaluation of impact on assortments' structure on productivity of Timbear harvester in early thinning*	***Belbo, H.*** *A Chip-Truck Trojan Chipper – a sound solution for small scale fuel-chip supply?*

09.00-09.15	Plenary: Information about Excursion

Excursion
09.30 – 22.30 Excursion by bus

09.15-09.30 Boarding bus

10.00-11.30 Technical demonstrations at Jälla Forestry school

- Head-Up Display OPTEA
- Vibration test course
- XT28 Novel forestry machine

12.00-13.00 Field lunch

14.00-16.00 Heby (host Mellanskog)

- Use of DTW maps
- Quality assured wood measurement
- Mellanskog and its' contractors

} Coffee served

16.30 Sala historical silver mine

- History of the site
- Mine tour

19.00- Heart-warming Conference dinner

21.00 Return by bus to Nova Park, Knivsta

Friday,	June 27 2014	
	A4 Research tools & methods (Chair Lars Eliasson)	**B4 Transports** (Chair Dag Fjeld)
08.00-08.15	***Eliasson, L.*** *Time and performance concepts in chipping studies*	***Andersson, E.*** *Tare weight variations for conventional self-loading logging trucks in Sweden*
08.15-08.30	***Søvde, N. E.*** *A parameter estimation approach for forwarder productivity*	***Anttila, P.*** *Potential of cost savings with larger trucks in transportation of forest chips in Finland*
08.30-08.45	***Iwarsson Wide, M.*** *Effective estimate of biomass in young stands and on roadsides using laser data*	***Narfström, K.*** *Optimizing forest residue chips flows with the BioMax decision support system*
08.45-09.00	***Lindroos, O.*** *Reaching for the future - by estimating the harvester head's position*	***Jahkonen, M.*** *Improving the usability of quality knowledge - Quality guide for practical energy wood operators*
09.00-09.15	***Pierzchala, M.*** *Deriving the position and motion parameters of a forest machine using monocular vision.*	***Nivala, M.*** *BISCUIT- Bioenergy Supply Chain Unique Integrated –Tool*
09.15-09.30	***Asikainen, A.*** *Arising radical and incremental innovations for supply chains of residual forest biomass*	***Berg, S.*** *Variation in moisture content of chipped forest material delivered under winter conditions*
09.30-09.45	***Bhuiyan, N.*** *Standardized harvester data as a base for planning of forest operations and feedback to planning system*	***Wahlström Bergstedt, S.*** *Discrete-event simulation of truck queuing for alternative unloading solutions at a Swedish combined pulp- and sawmill*
09.45-10.15	Coffee break	
	A4 Research Methods, cont.	**B5 Systems Evaluation** (Chair Magnus Thor)
10-15-10.30	***Ortiz Morales, D.*** *Analysis of human generated crane motion patterns – towards the automation of forestry manipulators*	***Liepiņs, J.*** *Comparison of Bracke C16.b work methods in naturally regenerated grey alder stands*
10.30-10.45	***Rabie, J.*** *Analysis of a mechanised cut to length harvesting operation through use of discrete event simulation*	***Talbot, B.*** *Operations planning and performance of windfall salvaging in Norway*
10.45-11.00	***Väätäinen, K.*** *The impact of the forwarding technique on forwarding output*	***Jonsson, R.*** *Efficiency and quality in selective harvesting with harvester and forwarder*
11.00-11.15	***Wilhelmsson, L.*** *Increasing the value of forest products by increasing efficiency of harvesting operations*	***Lazdiņš, A.*** *Evaluation of Bracke C16.b working methods in coniferous and mixed stands*

11.15-12.00 Plenary Round-Table Closing session (Chair Rolf Björheden)

	New restrictions – New opportunities? Effect on Forest Operations? *Magnus Thor*
	Summing up and looking forward. Continuation of OSCAR *Rolf Björheden*
	Plenary discussion
	Closing remarks *Rolf Björheden*
12.00—13.00	Lunch
	Departure to OSCAR 2016
13.00-16.00	Meeting rooms available for **Technical meetings until 16.00**

Arbetsrapporter från Skogforsk fr.o.m. 2013

2013

Nr 786 Grönlund, Ö. & Eliasson. L. 2013. Knivslitage vid flisning av grot. Effects of knife wear on per formance and fuel consumption for a small drum chipper. 11 s.

Nr 787 Sonesson, J. & von Hofsten, H. 2013. Effektivare fältarbete med nya datakällor för skogsbruksplanering. – Greater efficiency in field work using new data sources for forestry planning. Final report to Stiftelsen Skogsällskapet, Project no. 0910-66/143-10 LOMOL. 19 s..

Nr 788 Bhuiyan, N., Arlinger, J. & Möller, J.J. 2013. Kvalitetssäkring av beräkningsresultat från hprCM och konvertering av pri- till hpr-filer. – Quality assurance of calculation results from hprCM and conversion of prifiles to hpr files. 24 s.

Nr 789 Brunberg, t. 2013. Bränsleförbrukningen hos skördare och skotare 2012. – Fuel consumption in forest machines 2012. 12 s.

Nr 790 Eliasson, L. & Lundström, H. 2013. Skotning av hyggestorkad grot. – Skotare med Hultdins biokassett. – Forwarding of dried logging residue: study of Hultdins Biokassett 10 s.

Nr 791 Andersson, g. & Frisk, M. 2013. Skogsbrukets transporter 2010. – Forestry transports in 2010. 91 s.

Nr 792 Nordström, M. & Möller, J.J. 2013. Kalibrering av skördarens mätsystem. – En kartläggning av nuläge och utvecklingsbehov. A review of current status and development needs. 15 s.

Nr 793 Lombardini, C., Granlund, P. & Eliasson, L. 2013. Bruks 806 STC. 0150 – Prestation och bränsleförbrukning. – Performance and fuel consumption of the Bruks 806 STC chipper. 9 s.

Nr 794 Fridh, L. 2013. Kvalitetssäkrad partsmätning av bränsleved vid terminal. – Quality-assured measurement of energy wood at terminals. 32 s.

Nr 795 Hofsten von, H. & Brantholm, M.-Å. 2013. Kostnader och produktivitet i stubbskörd – En fallstudie. Productivity and costs in stump harvest systems-A case study 9 s.

Nr 796 Brunberg, T. & Iwarsson Wide, M. 2013. Underlag för prestationshöjning vid flerträd shantering i gallring. – Productivity increase after multi-tree handling during thinning. 6 s.

Nr 797 Jacobson, S. & Filipsson, J. 2013. Spatial distribution of logging residues after final felling. – Comparison between forest fuel adapted final felling and conventional final felling methods. Trädresternas rumsliga fördelning efter slutavverkning – Jämförelse mellan bränsleanpassad och konventionell avverknignsmetod. 19 s.

Nr 798 Möller, J. J., Arlinger, J. & Nordström, M. 2013. Test av StanForD 2010 implementation i skördare.

Nr 799 Björheden, R. 2013. Är det lönsamt att täcka groten? Effekten av täckpappens bredd på skogsbränslets kvalitet. – Does it pay to cover forest residue piles? Effect of tarpaulin width on the quality of forest chips. 16 s.

Nr 800 Almqvist, C. 2013. Metoder för tidig blomning hos tall och gran. – Slutrapport av projekt 40:4 finansierat av Föreningen skogsträdsförädling. – Early strobili induction in cots pine and Norway spruce. – Final report of Project no. 40:4, funded by the Swedish Tree Breeding Association. 26 s.

Nr 801 Brunberg, T. & Mohtashami, S. 2013. Datoriserad beräkning av terrängtransport-avståndet. – Computerised calculation of terrain transport distance. 8 s.

Nr 802 Johan Sonesson, Lars Eliasson, Staffan Jacobson, Lars Wilhelmsson &, John Arlinger. Analy ses of forest management systems for increased harvest of small trees for energy purposes in Sweden. – Analys av skogsskötselsystem för ökat uttag av klenträd som bränslesortiment 32 s..

Nr 803 Edlund, J., Jonsson, R. & Asmoarp, V. 2013. Fokusveckor 2013 – Bränsleuppföljning för två fordon inom ETTdemo-projektet, ST-kran och ST-grupp. – Monitoring fuel consumption of two rigs in the ETTdemo project, ST-crane and ST-group. 22 s.

Nr 804 Iwarsson-Wide, M., Olofsson, K., Wallerman, J., Sjödin, M., Torstensson, P. O., Aasland, T., Barth, A. & Larsson, M. 2013. Effektiv volymuppskattning av bio massa i vägkanter och ungskogar med laserdata. – Effective estimate of biomass volume on roadsides and in young forests using laser data 40 s.

Nr 805 Iwarsson-Wide, M., L., Bäfver, Renström, C. & SwedPower, P. 2013. Fraktions-fördelning som kvalitetsparameter för skogsbränsle – Kraft- och värmeverkens perspektiv. 38 s.

Nr 806 Englund, M. & Jönsson, P. 2013. LED-lampor i såglådan – En pilot¬studie. – LED lamps in the saw box – A pilot study. 8 s.

Nr 807 Nordlund, A., Ring, E., Högbom, L. & Bergkvist, I. 2013. Beliefs among Formal Ac tors in the Swedish Forestry Related to Rutting Caused by Logging Operations. – Attityder och åsikter med koppling till körskador inom olika yrkesgrupper i skogsbruket 18 s.

Nr 808 Arlinger, J. & Jönsson, P. 2013. Automatiska tidsstudier i skogsmaskinsimulator. – Driftuppföljning och produktionsdata enligt StanFord 2010. Automatic time-studies in forest machine simulators – Operational monitoring and production data according to StanForD 2010. 10 s.

Nr 809 Englund, M., Mörk, A. & Jönsson, P. 2013. Skotartävling på Elmia – Kran- och motor-inställningars påverkan på bränsleförbrukning och tidsåtgång. Forwarder contest at Elmia. – Effect of crane and engine settings on fuel consumption and speed of work. 9 s.

Nr 810 Eliasson, L., Lombardini, C., Lundstruöm, H. & Granlund, O. 2013. Eschlböck Biber flishugg – Prestation och bränsleförbrukning – Rangering av fliscontainrar med en John Deere 1410 containerskyttel.

Nr 811 Eliasson, L. 2013. En simulering av en integrerad skördare för förpackad flies vid ener giuttag i gallring. – Simulation of an integrated harvester for pre-packaged chips during energy harvest in early thinning. 16 s.

Nr 812 Englund, M. 2013. Test av stolar och tillbehör med avseende på helkroppsvibrationer. Test of seats and associated equipment in terms of whole-body vibrations. 32 s.

Nr 813 Enström, J., Athenasiadis, D., Grönlund, Ö. & Öhman, M. 2013. Framgångsfaktorer för större skogs bränsleterminaler. – Success factors for larger energy wood terminals. 37 s.

Nr 814 Wennström, U. 2013. Holmens fröbehov, produktion och genetisk kvalitet 2012-2060. – Holmen's seed requirements: production and genetic quality 2012–2060. 50 s.

Nr 815 Hannrup, B., Andersson, M., Larsson, J., Sjöberg, J. & Johansson, A. 2013. Slutrapport för projekt "Beröringsfri diametermätning i skördare – Utveckling av skräpreducerande skydd". Final report of the project 'Hands-free measurement of stem diameter in harvesters. – Development of waste-reducing protection'. 71 s.

Nr 816 Eriksson, E. & Täljeblad, M. 2013. Prekal – Självföryngring före slutavverkning. – Slutrapport Försök 1–6. Prekal. – Natural regeneration before final felling. Final report, Experiments 1–6. 28 s.

2014

Nr 817 John Arlinger, Torbjörn Brunberg, Hagos Lundström och Johan Möller. Jämförelse av JD1170E och JD1470E i slutavverkning hos SCA Skog AB hösten 2013. Comparison of JD1170E and JD1470E in final felling at SCA Skog AB, autumn 2013. 29 s.

Nr 818 Bergkvist, I., Friberg, G., Mohtashami, S. & Sonesson, J. 2014. STIG-projektet 2010–2014. The STIG Project, 2010-2014. 19 s.

Nr 819 Björheden, R. 2014. Studie av Fixteri FX15a klenträdsbuntare. Study of Fixteri FX15a small-tree bundling unit.

Nr 820 Löfroth, C. & Brunberg, T. 2014. Bränsleförbrukningen hos rundvirkesfordon 2008 och 2013. Fuel consumption of roundwood vehicles in 2008 and 2013. 12 s.

Nr 821 Jönsson, P., Hannrup, B., Gelin, O. & Löfgren, B. 2014. Utvärdering av sågenheten R5500 med avseende på kaptid och energiåtgång. Evaluation of the R5500 sawing unit in terms of bucking time and fuel consumption. 24 s.

Nr 822 Eliasson, L. & Johannesson, T. 2014. Effekten av olika bottensåll på prestation, bränsleförbrukning och flisens fraktionsfördelning för flishuggarna Kesla 645 och Eschlböck Biber-92. – Effects of sieve size on chipper productivity, fuel consumption and chip size distribution for the chippers Kesla 845 and Eschlböck Biber-92. 18 s.

Nr 823 Eliasson, L., Lombardini, C., Granlund, P., Magagnotti, N. & Spinelli, R. 2014. Prestation och bränsleförbrukning för en lastbilsmonterad Pezzolato PTH 1200/820 flishugg. – Performance and fuel consumption of a truck-mounted Pezzolato PTH 00/820 chipper. 12 s.

Nr 824 Iwarsson- Wide, M. Grönlund, Ö. 2014. Lastindikatorer och lastbärarvågar. 15 s.

Nr 825 Sikström, U. 2014. Föryngring av gran under högskärm: Försöksverksamhet vid Bergvik Skog – Uppföljning 2013.

Nr 826 Englund, M. 2014. Mätning av mental arbetsbelastning – En metodstudie. 27.

Nr 827 Jönsson, P., Björheden, R. & Eliasson, L. 2014. Destinering och lägesbyten för att effektivisera transporterna av skogsflis.

Nr 828 Barth, A., Holmgren, J., Wilhelmsson, L. & Nordström, M. 2014. Evaluation of single tree based estimates with terrestrial laser scanning in Sweden.

Nr 829 Jacobson, S. Asktillförsel och dess påverkan på trädens tillväxt och näringsstatus – Revision av sex fältförsök. 32 s.

Nr 830 Björheden, R. 2014. Proceedings of the Nordic Baltic Conference OSCAR14 Solutions for Sustainable Forestry Operations, June 25-27, NOVA Park Conference, Knivsta, Sweden. – Proceedings från den Nordiska Baltiska konferensen OSCAR14 Solutions for Sustainable Forestry Operations, June 25–27, 2014, NOVA Park Conference, Knivsta, Sverige. 114 s.

SKOGFORSK

– Stiftelsen skogsbrukets forskningsinstitut

arbetar för ett lönsamt, uthålligt mångbruk av skogen. Bakom Skogforsk står skogsföretagen, skogsägareföreningarna, stiften, gods, skogsmaskinföretagare, allmänningar m.fl. som betalar årliga intressentbidrag. Hela skogsbruket bidrar dessutom till finansieringen genom en avgift på virke som avverkas i Sverige. Verksamheten finansieras vidare av staten enligt särskilt avtal och av fonder som ger projektbundet stöd.

FORSKNING OCH UTVECKLING

Två forskningsområden:

- Skogsproduktion
- Virkesförsörjning

UPPDRAG

Vi utför i stor omfattning uppdrag åt skogsföretag, maskintillverkare och myndigheter. Det kan gälla utredningar eller anpassning av utarbetade metoder och rutiner.

KUNSKAPSFÖRMEDLING

För en effektiv spridning av resultaten används flera olika kanaler: personliga kontakter, webb och interaktiva verktyg, konferenser, media samt egen förlagsverksamhet med produktion av trycksaker och filmer.

Arbetsrapport

Från Skogforsk nr. 830–2014

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