LATVIJAS VALSTS MEŽZINĀTNES INSTITŪTS "SILAVA"
LATVIAN STATE FOREST RESEARCH INSTITUTE "SILAVA"

MEŽZINĀTNE

Speciālais izdevums
LVMI Silava sadarbībā ar *SNS* un *IUFRO*
organizēto starptautisko konferenču
KOPSAVILKUMU KRĀJUMS

Special issue
ABSTRACTS
for international conferences
organised by LSFRI Silava
in cooperation with SNS and IUFRO

25(58)'2012

SALASPILS, 2012

Zinātnisko rakstu krājuma "Mežzinātne" Nr. 25(58)'2012 **speciālais izdevums** –
LVMI Silava sadarbībā ar Ziemeļvalstu meža pētniecības sadarbības komiteju (*SNS*) un Starptautisko Mežu pētīšanas organizāciju savienību (*IUFRO*) organizēto starptautisko konferenču
KOPSAVILKUMU KRĀJUMS

Special issue *of scientific proceedings "Mežzinātne" No 25(58)'2012*
ABSTRACTS
of international conferences organised by LSFRI Silava
in cooperation with Nordic Forest Research Co-operation Committee (SNS) and
International Union of Forest Research Organisations (IUFRO)

norden
Nordic Forest Research
Co-operation Committee (SNS)

OSCAR un IUFRO (WP 3.05.00)

Ziemeļvalstu un Baltijas valstu mežsaimniecības tehnoloģiju zinātniskā konference OSCAR 2012, 2012. gada 24.–26. oktobris, Rīga, Latvija

The Nordic Baltic conference on forest operations – OSCAR 2012, October 24–26, 2012, Riga, Latvia

AdapCar un IUFRO (WP 2.02.00)

konference "Adaptācijas un pielāgošanās ģenētiskie aspekti meža veselības, koksnes kvalitātes un biomasas ražošanas kontekstā", 2012. gada 3.–5. oktobris, Rīga, Latvija

conference "Genetic aspects of adaptation and mitigation: forest health, wood quality and biomass production", October 3–5, 2012, Riga, Latvia

Tehniskie redaktori / ***Technical editors***
Dagnija Lazdiņa, Āris Jansons, Ilva Konstantinova

ISSN 1407-270X

Krājumā "Mežzinātne" publicēti raksti par jaunākajiem fundamentālajiem un lietišķajiem pētījumiem dažādos mežzinātnes virzienos.

Redakcijas adrese:
Rīgas iela 111, Salaspils, LV-2169, Latvija
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e-pasts: info@silava.lv
"Mežzinātne" internetā: www.silava.lv sadaļā "Publikācijas/Mežzinātne" (raksti lejupielādei, aktualitātes, norādījumi rakstu autoriem).

"Mežzinātne" ir indeksēta datubāzēs CAB Abstracts un AGRIS.

The papers included in the Proceedings "Mežzinātne" (Forest Science) cover the most recent results in the basic and applied forest research.

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Riga str. 111, Salaspils, LV-2169, Latvia
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"Mežzinātne" in the internet: *at www.silava.lv section "Mežzinātne/Forest Science" (papers for downloading, actualities).*

"Mežzinātne" is indexed and abstracted by databases CAB Abstracts and AGRIS.

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Priekšvārds

Meža operacionālo sistēmu pētniecības centrs (OSCAR) ir viens no Ziemeļvalstu mežzinātnes sadarbības komitejas (SNS) pētnieku sadarbības tīkliem, kura mērķis ir veicināt zināšanu un pētniecības kapacitātes koncentrāciju, kā arī iniciēt, sekmēt un attīstīt efektīvu, konkurētspējīgu un videi draudzīgu tehnoloģisku risinājumu ieviešanu meža apsaimniekošanā Ziemeļvalstu un Baltijas reģionā.

OSCAR galvenā darbība joma ir meža darbu operāciju pētniecība. OSCAR darbības formas ir semināri, pieredzes apmaiņas pasākumi, zinātniskā konference, ko rīko reizi 2 gados, rakstu krājumi, ziņojumi SNS, kā arī komunikācija ar OSCAR mājas lapas un preses relīžu starpniecību.

Vairākas meža tehnoloģiju pētījumu jomas ir identificētas kā kopīgas Ziemeļu un Baltijas valstīs, kas darbojas OSCAR tīklā. Kā prioritārās pētījumu jomas noteiktas :

- uzņēmējdarbība meža nozarē, tajā skaitā līgumattiecību veidošana starp meža īpašniekiem un pakalpojumu sniedzējiem, biznesa attīstība, ergonomika un darba ražīgums;
- ietekmes uz vidi mazināšana, tajā skaitā jaunu tehnoloģiju un darba metožu attīstība un mežsaimnieciskās darbības plānošana;
- transporta organizācija, ar īpašu uzsvaru uz modulārām Eiropas mēroga sistēmām;
- meža atjaunošanas un mežkopības darbu mehanizācija.

OSCAR sadarbības tīklu raksturojošo atslēgas vārdu piemēri ir darba ražīgums, rentabilitāte, sertifikācija, energoefektivitāte, standartizācija, informācijas apmaiņa, rezultāti, pētījumu objekti un instrumenti.

OSCAR konference turpina Ziemeļvalstu meža darbu pētniecības padomes (NSR) kopš 2001. gada organizēto meža tehnoloģiju ekspertu sanāksmju tradīcijas. Sekojot NSR labākajai praksei, kā arī 2008. gadā Kopenhāgenā un 2010. gadā Hannu (Norvēģijā) notikušo OSCAR konferenču piemēram, sapulce Rīgā ir vērsta uz informācijas apmaiņu par svaigākajām meža tehnoloģiju pētniecības atziņām starp zinātniekiem un mežsaimniecības praktiķiem,

sadarbības paplašināšanu un sinerģijas meklēšanu ar meža tehnoloģijām saistītajās izpētes un attīstības jomās.

Konferencē nav noteiktas robežas prezentāciju tematikai. Galvenais atlases kritērijs – pētījuma tēmai jāveicina OSCAR mērķu īstenošana. Konferences programmā iekļautas 59 prezentācijas no pētniekiem, kas pārstāv 11 valstis un 18 pētniecības organizācijas un uzņēmumus. Konferences programmā iekļauto prezentāciju tematika saistīta ar:

- meža mašīnu un to sistēmu darba ražības analīzi;
- procesu modelēšanu un vadību;
- koksnes produktu loģistiku un transportu;
- ģeogrāfiskās informācijas sistēmu pielietošanu mežsaimniecisko darbu modelēšanā;
- ergonomiku, darba vidi un darba drošību;
- kokmateriālu un biokurināmā piegāžu ķēžu organizāciju un vadību;
- ietekmi uz vidi, energoefektivitāti un emisijām;
- mežsaimniecības uzņēmējdarbības vides pilnveidošanu;
- mežkopības un meža atjaunošanas darbu mehanizāciju;
- tehnoloģijām plantāciju mežiem un īscirtmeta plantācijām;
- koksnes resursu mobilizāciju.

Mēs vēlamies pateikties SNS par finansiālo atbalstu OSCAR sadarbības tīklam un šai konferencei un IUFRO Meža operāciju pētniecības un vadības divīzijas Meža darbu ekoloģijas (3.05.00) vienībai par atbalstu konferences organizēšanā. Vēlamies izteikt pateicību arī AS "Latvijas valsts meži", Metsa Forest Latvia SIA, Riga rent SIA, GARAISS SIA, Konekesko Latvija SIA un UOT SIA par atbalstu meža tehnikas demonstrējumu organizēšanā.

Salaspils, 01.10.2012
A. Lazdiņš
Latvijas Valsts mežzinātnes institūts "Silava"

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Preface

Operating Systems for Centre of Advanced Research (OSCAR) is one of the SNS (Nordic Forest Research Cooperation Committee) networks targeted on increase of the excellence and critical mass of research and development and on promotion, initiation and development of efficient, competitive and environmentally friendly forest operation systems on a joint Nordic – Baltic basis .

The main interest for OSCAR is forest operations research. OSCAR modes of work are meetings, seminars, a research conference every 2nd year, reporting from common activities through SNS reports and policy briefs, proceedings, as well as communication via web sites and press releases.

Within OSCAR there are a number of focus areas of common interest. The priority focus

areas are:

- *contractor forestry, including forest machine instructors, business development, ergonomics, productivity and tendering;*
- *reducing site impact, including technology, methods, planning etc.;*
- *transports, with special emphasis on the European modular system;*
- *stand establishment and mechanization of silvicultural operations.*

Productivity, profitability, sustainability, certification, energy efficiency, standardization, exchange of information, results, experimental sites, research tools are examples of keywords to be considered within each project area.

The OSCAR conference continues traditions of the the Nordic Council on Forest Operations Research (NSR) conferences organized every 2nd year since 2001. Following in the NSR traditions and the more recent successful meetings in Copenhagen (2008) and Hannu (2010) the conference is targeted on exchange of information about the state of art of the forest technology research between scientists and forestry practitioners, initiation of networking activities and identifying synergies in relevant research and development areas.

There are no strict borders for topics applicable to the conference as far as they are contributing to the common targets of the OSCAR network. Fifty nine contributions were made by participants from 11 countries and 18 different research institutes and companies. The following topics are covered:

- *machine and machine – systems performance analysis;*
- *process modelling and control;*
- *transport and materials handling;*
- *geographical information – modelling and interpretation;*
- *ergonomics, the work environment and safety;*
- *supply chain management and associated methods & technologies;*
- *environmental impacts and emissions;*
- *business process engineering and quality assurances;*
- *mechanisation of silvicultural operations;*
- *plantation forests and short rotation woody crops;*
- *mobilisation of wood resources.*

We would like to thank the SNS for the financial support of the OSCAR network and this conference and IUFRO Division 3 "Forest Operations Engineering and Management" Unit 3.05.00 – "Forest Operations Ecology" for the contribution. We would also like to extend our appreciation to the Latvijas valsts meži JSC (Latvia state forests), Metsa Forest Latvia SIA, Riga rent SIA, GARAISS SIA, Konekesko Latvija SIA and UOT SIA who supported us in organization of the field demonstrations.

Salaspils, 01.10.2012
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FOREST BIOMASS SUPPLY FOR ENERGY IN FINLAND AND SWEDEN – DEVELOPMENT PATHS AND TRANSFER OF TECHNOLOGY TO OTHER COUNTRIES

Antti Asikainen[1], Johanna Routa[1], Rolf Björheden[2] , Juha Laitila[1] and Dominik Röser[1]*

The EU aims to produce 20 % of its energy from renewable sources by 2020. Each member state has their own target, for example Finland should produce 38 % and Sweden 49 % of their energy from renewable sources by 2020. In this context, the development of forest energy utilization and more effective and economic supply systems plays an important role in both countries. This paper provides an overview of the driving forces behind the current technical solutions of forest energy procurement systems in Finland and Sweden and perspectives on future developments and transfer of experiences to other countries. Focus is in the primary forest residues for energy production including logging residues, stump and root wood, small diameter wood and other wood not in demand by the traditional forest industries. Finland consumed 6.9 mill. m^3 forest chips in 2010 and Sweden 8.4 mill m^3.

The nature of forest energy operations is challenging: The available primary forest fuel feedstock combines difficult properties such as and great diversity in shape, bulkiness, small piece size and scattered occurrence with low relative value, heterogeneity and, often, contaminations increasing ash content, tear, wear and damage to equipment and machines. The demand for forest fuel varies throughout the year, while supply is generally stable. Consequently, it is necessary to store the biomass over a certain time. Further, the operations must be performed without harmful impacts on soil, water and remaining growing forest stand. Majority of forest energy biomass is supplied by using systems based on the chipping at the roadside landing. Crushing at the end use facility and terminals dominates only in stumpwood supply.

Finnish and Swedish experiences show that in the market penetration phase the biomass supply can be subsidized. Differences in subsidy policy in Finland and Sweden has had a great impact in the supply volumes of energy biomass from young stands: Due to production subsidies in Finland chips made of small diameter trees has become the largest forest fuel assortment (3.2 mill. m^3/a small trees, residues 2.2 mill. m^3/a) whereas in Sweden logging residues dominated (4.3 mill. m^3/a logging residues, 1.3 mill. m^3/a small trees). To achieve an economically sustainable long term supply, large investments are needed in the development of technology for forest fuel procurement. Finland has invested longer time for

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the stump wood harvest resulting in 1.0 mill. m^3 annual harvest, whereas in Sweden use of stumps for energy has commenced later being now (0.3 mill. m^3/a).

Investments and strong commitment of research organizations as well as forest and energy industries are necessary for successful operations. The end users also need to modify the raw material reception, handling and combustion technologies in order to be able to use forest fuel more efficiently. Involvement of forest owners and development of forest energy trade and measurement practices are prerequisites for the market entrance of forest energy. Forest fuel supply has to be integrated with industrial wood harvesting, because both industrial roundwood and residual forest biomass for energy are often extracted from the same stands. Using the same base machinery as in the roundwood harvesting is a reasonable strategy to start the operations. As the business grows, the capacity for investments in purpose built machinery and equipment will increase. The experience in Finland and Sweden has also shown the importance of relying on proven and established technology and integration of operations to establish systems based on forest biomass for energy. According to many feasibility studies, the Nordic energy wood technology can be applied in Baltics and in Central Europe with minor modifications.

Foresight studies show that in the developed biomass markets such as Finland and Sweden and partially Central Europe, the growth of biomass demand will be from the large combined heat and power (CHP) plants and from possibly emerging large biorefineries. This calls for the development of supply chains that are cost-efficient and sustainable also when supply stretches over very long distances. The manpower requirements are estimated at over 40 000 machine operators in the EU by 2030. Labour input can be reduced by developing partial automation and systems that guide the operators towards efficient work methods.

Keywords: *bioenergy, forest energy, wood harvesting, transport*

SIMULATIONS OF MECHANIZED PLANTING – MODELLING TERRAIN AND CRANE-MOUNTED PLANTING DEVICES

Back Tomas Ersson[1], Linus Jundén[2], Urban Bergsten[3] and Martin Servin[2]*

When reforesting clearcuts in southern Sweden, the Bracke Planter has shown to plant seedlings with better planting quality than operational manual tree planting (Ersson and Petersson 2011). Consequently, there is an increasing demand for intermittently advancing tree planting machines with crane-mounted planting devices in southern Sweden.

Nevertheless, regardless of using one- (Bracke Planter) or two-headed planting devices (M-Planter), today's average planting machine productivity is still too low (Rantala and Laine 2010, Ersson *et al.* 2011) for planting machines to cost-wise compete with manual tree planting in southern Sweden (Ersson 2010). There is, therefore, a need to develop new planting machines concepts that are significantly more productive on Nordic terrain, i.e. clearcuts on moraine soils with varying prevalences of stones and stumps where the slash has been harvested for bioenergy.

For over 40 years, simulation studies have proven useful for testing prospective forest machine concepts (e.g. Sjunnesson 1970), including different types of planting heads (Andersson *et al.* 1977). In particular, simulations studies can nowadays help to cost-efficiently evaluate new ideas before real world implementation (Jundén 2011). However, previous forest machine simulations simplified terrain characteristics like stumps, roots and stones to the extent that these models are too simplistic for meaningful planting machine simulations. For this reason, we have built several terrain, base machine and planting device models for use in discrete-event simulations to test potential solutions that realistically might increase Nordic planting machine productivity. These simulations were performed using a simulator programmed in Python on top of the SimPy discrete-event library (Jundén 2011).

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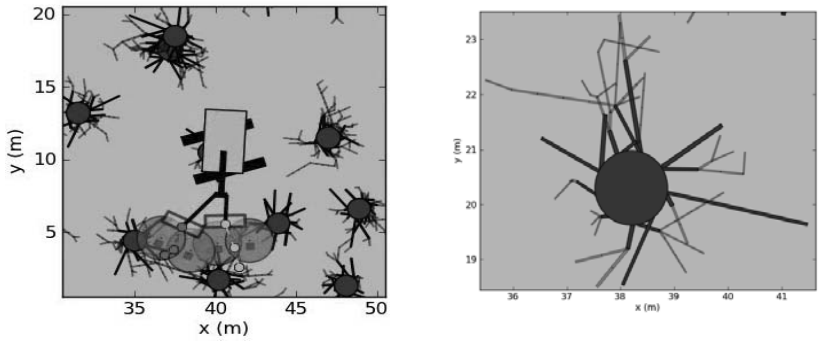

Figure 1. Visualization feature of the planting machine simulator (left) with a close-up view of a modelled stump comprising the root plate and roots over two cm in diameter (right).

TERRAIN MODELS

Presently, our terrain models encompass stumps, roots and underground stones. To delineate the clearcuts, we used Herlitz's (1975) type stands for clearcutting. These type stands also provided the input data necessary for sizing and spatially allocating the stumps. To all stumps, we attached a root plate according to the deterministic data from Björkhem *et al.* (1975) and a stochastic root architecture inspired by Kalliokoski *et al.'s* (2010) root models.

As concluded already during the 1960s, it is the presence of non-visible, underground stones and boulders which makes mechanized reforestation on moraine soils so difficult (Bäckström 1978). To model this difficulty, we used parameter values from Andersson *et al.* (1977) to define incidences of stones and boulders (i.e. boulder quota or stoniness) and mean stone sizes. Then, we chose an exponential distribution to link stone frequency to stone diameter. In accordance with Eriksson and Holmgren (1996), our modelled stones are spherical in shape and are spatially allocated in a random manner.

BASE MACHINE MODELS

Today's planting machines use excavators as base machines. If using standard components, it might be techno-economically feasible to add another arm to the excavator; thereby creating two- (Fig. 2) or four-headed planting machines where planting head interdependence is minimized. We hypothesized that the productivity of two-armed planting machines, compared to normal one-armed machines, might especially be higher on obstacle-rich terrain since one arm could be free to move while the other arm is busy working. Moreover, two-armed machines might particularly benefit from additional task automation. Preliminary results, however, show that this productivity increase might not be high enough to warrant further development of our two-armed planting machine concept.

Figure 2. The two-armed excavator base machine model.

PLANTING DEVICE MODELS

We modelled today's two most common crane-mounted planting devices, the one-headed Bracke Planter and the two-headed M-Planter. During simulation, the planting machine operator searches sequentially for microsites free from visible obstacles (stumps and main lateral roots). However, both devices can be impeded by underground roots or stones during mounding, and by stones during the planting phase. Striking obstacles with the M-Planter can result in delays for one or both heads.

FURTHER DEVELOPMENT

We are currently expanding the terrain models to include humus layers and surface boulders, on which new multi-headed planting device concepts (with two to four planting heads) with obstacle-avoiding capabilities are being tested. Those simulation results will provide guidance as to how future crane-mounted planting devices should behave and be designed in order to increase planting machine productivity.

Keywords: *terrain model, tree planting machine, boom-tip planting head, Discrete-event simulation, mounding, root architecture, SimPy*

REFERENCES

Andersson, P.-O., Berglund, H. & Bäckström, P.-O. 1977. Simulering av maskinella planteringsorgans arbete [Simulating the operation of mechanized planting units]. Forskningsstiftelsen Skogsarbeten. Redogörelse nr 7.

Björkhem, U., Lundeberg, G. & Scholander, J. 1975. Root distribution and compressive strength in forest soils. Root mapping and plate loading tests in thinning-stage stands of Norway spruce. Institutionen för växtekologi och marklära. Skogshögskolan. Rapporter

och Uppsatser nr 22.

Bäckström, P.O. 1978. Mechanized planting - basic conditions, techniques, productivity and costs. Forskningstiftelsen Skogsarbeten. Meddelande: 74.

Eriksson, C.P. & Holmgren, P. 1996. Estimating stone and boulder content in forest soils - Evaluating the potential of surface penetration methods. Catena 28 (1-2): 121-134.

Ersson, B.T. 2010. Possible Concepts for Mechanized Tree Planting in Southern Sweden - An Introductory Essay on Forest Technology. Department of Forest Resource Management. SLU. Arbetsrapport 269. ISSN 1401-1204. ISRN SLU-SRG-AR-269-SE.

Ersson, B.T., Bergsten, U. & Lindroos, O. 2011. The cost-efficiency of seedling packaging specifically designed for tree planting machines. Silva Fennica 45 (3): 379-394.

Ersson, B.T. & Petersson, M. 2011. Uppföljning av planteringsmaskinen 2011 - färska planteringar [Follow-up of the planting machine year 2011- freshly planted seedlings]. Skogsavdelningen. Södra Skog. Rapport S042.

Herlitz, A. 1975. Typbestånd i slutavverkning [Typestands for clear cutting]. Institutionen för skogsteknik. Skogshögskolan. Rapport Nr 81.

Jundén, L. 2011. Discrete Event Simulations in Forest Technology. Department of Physics/ UMIT Research Lab, Umeå University. Master's Thesis.

Kalliokoski, T., Sievanen, R. & Nygren, P. 2010. Tree roots as self-similar branching structures: axis differentiation and segment tapering in coarse roots of three boreal forest tree species. Trees (Berlin) 24 (2): 219-236.

Rantala, J. & Laine, T. 2010. Productivity of the M-Planter Tree-Planting Device in Practice. Silva Fennica 44 (5): 859-869.

Sjunnesson, S. 1970. Simulation as a tool for analysis of man/machine systems for thinning. Skogshögskolan, Institutionen för skogsteknik. Rapporter och Uppsatser 42.

FUTURE OF FOREST ENERGY IN EUROPE IN 2030 – RESULTS FROM AN INTERNATIONAL DELPHI STUDY

Maria Riala[1] and Antti Asikainen[1]*

The need to increase the use of forest energy is connected to the EU goals for use of renewable energy, which require considerable increase of use by 2020. If the targets are to be reached, forest energy should play a role. The share of forest energy out of all renewable energy will vary between countries. Its share will probably be particularly significant in countries such as Sweden, Estonia, Lithuania, Poland, and Finland, where wood already has quite a large share out of all renewable energy. This study looked beyond the year 2020 to 2030 to chart some possible courses for the future of forest energy in Europe in 2030. The method chosen was a two-round dissensus-based Delphi, which has been used quite often in futures studies. The respondents consisted of members of the COST action FP 0902 and in the second round also of members of the Rok-For programme. Most of the respondents were experts in the field of forestry, and represented more than 20 countries.

The first section of the survey addressed the issue of trends and operational environment. The respondents assessed the likelihood and desirability of several trends happening by 2030. They also, for example, estimated the increase in use of forest energy and the importance of limits to its use. There seemed to be strong trust in technological development and beneficial policy interventions, but the respondents also recognised the problematic competitive situation in relation to other forms of energy. The estimates for increase in use of forest energy fell somewhat short of those in other projections and those required by the EU targets.

In terms of technological development, the experts thought the main challenge to address was transport and logistics. This included a wide range of different issues, for example the handling of bulky, low-value product in an efficient way. The experts saw greatest development potential in improving energy density before transport, and multi-tree handling. Driver-assisting systems would be particularly useful in helping with the planning of felling, e.g. in the case of placing of tracks.

Labour availability is also a pertinent issue. The respondents gave many suggestions on ways to attract new workers to forestry, for example by increasing the pay to the level of pay in manufacturing industry, and by promoting forestry as an environmentally friendly and technologically advanced employer. Education in forestry was also thought to require some improvements.

In general, the expert panel had a strong belief in technological development, which would facilitate increases in use of forest energy. This was evidenced, for example, by their

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opinion that technology producing forest energy would be much more efficient in 2030 than at present. Interestingly, they also recognised the importance of environmental issues, such as the ambiguous role of forest certification organisations. Environmental friendliness could provide one marketing advantage over other energy sources. The relatively low estimates for increases in use and harvesting would not be sufficient for meeting the EU targets. However, the experts also offered interesting solutions to overcoming obstacles, and these might contribute to reaching the targets.

Overall, this study uncovered some alternative future prospects, which could be achieved by particular actions. The future is always uncertain and full of possibilities, and thus these results are only some of the possible futures that might occur. Hopefully the results provide insights for researchers and policy-makers and offer suggestions on increasing the use of forest energy in Europe to the level stipulated in the targets.

Keywords: *futures studies, forest energy, operational environment, technology, labour*

EVALUATION OF NAVIGATION SATELLITE SYSTEMS FOR FORESTRY AND ITS PRECISION IN A FOREST ENVIRONMENT

Karin Westlund[1], Sten Bergstand[2], Petrus Jönsson[1] and Sima Mohtashami[1]*

The Swedish forestry industry is dependent of good positioning in the forest since much of the information in the supply chain depends on positioning. Correct coordinates are needed for the survey of the site, information of the harvesting and forwarding progress as well as positioning of road side inventory. The position data should also be able to save e.g. for planning purposes to be used throughout the forest production life-cycle.

One way of providing position data is through the use of Global Navigation Satellite Systems (GNSS) where the most accurate equipment and strategies provide positions of order 1 cm accuracy in fair conditions. The GNSS equipment currently being used on the machines in the forest is however often more basic equipment that may provide accuracies of order 10 m under the same conditions. In addition to the antenna, receiver and other technical equipment many factors affect the positioning quality; the forest environment itself causes uncertainty in the positioning due to tree trunk blockage of signal paths, reflections from trees, etc.

Currently there are two operating GNSS systems: the American GPS and the Russian Glonass systems. Today only GPS is being used, but with more systems emerging in the near future (e.g. the European Galileo system) the availability of satellite signals for positioning will increase significantly in the forest environment.

The aim of the project is to evaluate the current accuracy of the positioning as well as compare stand-alone GPS with multiple GNSS system solutions in the forest environment. The project will also suggest techniques for improving the accuracy and robustness of the positioning suitable for the forestry field of application.

The project will contribute with improvements of information flows through the whole value chain, making use of correct positioning data. It will also provide input for ICT based systems to increase logging efficiency and minimize ground and soil impacts. Additionally, costs through misleading positioning in timber transport will be reduced and the traceability of timber and forest products will improve. The project will be on going during spring and finalized during the summer 2012.

Keywords: *GNSS, machine guidance, positioning in forest*

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MEASUREMENT OF TREE POPULATION WITH NEW SENSOR TECHNOLOGY ON FOREST HARVESTER

Andreas Barth[1], Håkan Larsson[2], Philip Engström[2], Johan Sonesson[1] and Magnus Thor[1]*

The development of new sensor technology gives forestry new opportunities to measure the standing trees around a harvester in a harvest operation. Typically, these new sensor technologies are based on laser imaging technologies, already available on the market today. Integrated in a system these technologies have the potential to provide forestry with accurate data on stem diameter and tree position. Furthermore, these data can be used to estimate valuable information such as stand density, stem diameter distributions and width of strip roads. The sensor can be used on mobile platforms such as harvesters and the cost of such as system can be less than 10 000 €. Collecting forest stand data using mobile sensors on a thinning harvester can meet many benefits in forestry. Such a system can provide valuable information for updating of forest stand register, monitoring thinning operations, assessment of reference data for remote sensing applications as well as a decision support system for the harvester operator.

Recently, Skogforsk, together with partners from the Swedish Defence Research Agency (FOI) and the Swedish University of Agricultural Sciences (SLU), completed a projected investigating the potentials of using new sensor technologies on harvesters. The aim of the project was to: i) quantify the potential in Swedish forestry as a thought system can give rise to, ii) identify and evaluate available technology for measurement of trees from a harvester, and iii) perform initial tests of a number of sensors on a moving vehicle in a forest environment.

The total economic potential in the Swedish forestry identified in the study was on 40 million €. The greatest economic potential is to develop system for monitoring thinning and decision support to optimize the thinning grade. Today inventory data for monitoring the thinning operation is often assessed by the harvest operator himself and is normally used to evaluate their own work effort. An independent monitoring of the thinning results would be of great value for the forest company and the forest owner as well. A decision support system to optimize the thinning grade would be a quality assurance of the thinning operation. In addition to increased wood production other benefits would be more secure and efficient operators. Data from mobile sensors can also be used to update the forest stand register after treatment. However, recent studies have shown that much of the benefit can be achieved

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already based on available information from the harvester production file.

Four sensors, i) short range flash, ii) pulsed line scanner, iii) distributed light, and iv) passive stereovision were tested in initial field tests. Each sensor was representing different types of technologies. The sensors were tested on a moving vehicle (Volvo V70) in two forest stands outside Linköping in the southern part of Sweden. First stand was a spruce forest with a sparse vegetation of shrubs and grass, while the other stand was a birch forest with a rich vegetation of shrubs and grass. In mainly two systems that would be of interest in a future system, the short range flash is a promising technology but are still too sensitive for the use in different light conditions. The best performing sensor in the test was the pulsed line scanner. In a test of measuring the diameter on total 18 trees it proved to work well for measuring the diameter of up to 12 meter away. All diameter measurements were within 24 mm and 15 of the trees were within 13 mm. However, it is required that it is possible to obtain high accuracy to estimate position and direction of the moving platform.

There are available technologies to accurate measure position and to estimate stem diameter from a moving harvester. With focus on developing systems for monitoring the thinning operation and optimizing the thinning it should also be an economic potential to implement such a system in Swedish forestry.

Keywords: *laser imaging, thinning, harvester, sensor technology, GIS, forest data*

POSSIBILITIES TO REDUCE DAMAGE IN THINNING OF NORWAY SPRUCE DURING UNFROZEN SOIL

Matti Sirén[1], Jari Ala-Ilomäki[1], Harri Mäkinen[1] and Sami Lamminen[1]*

In Finland, about 60 % of the cuttings are carried between October and March, and amount of harvesting machinery must be set according to this demand. However, only 60 % of the machinery is in use in spring and summer. A more stable utilisation of the machinery is needed to lower the costs and to ensure the availability of skilled operators.

Norway spruce stands have mostly been thinned in winter during frozen soil and snow cover to avoid soil and tree damage. The mild winters during the recent years have raised a question, whether a dry and warm autumn would be a better season for Norway spruce thinnings than a mild, wet winter. Furthermore, possibilities to reduce damage are explored, for example with new harvester working methods or forwarder equipments.

Two harvester working methods, as well as forwarder equipment (tracks/chains), were compared in respect to harvester productivity, logging residue on strip roads, rut formation, and logging damage in thinning of two Norway spruce stands in Southern Finland. The stands were at the first commercial thinning stage. Stand 1 was on a coarse moraine soil, stand 2 on a clay soil. Stand 1 was harvested in 2009 in two occasions, in late August with high risk of root rot infection, and in mid October with low infection risk. Stand 2 was harvested in one occasion in September 2010. A total of 24 permanent sample plots (50 m × 20 m or 40 m × 20 m) were established in the stands for comparing the consequences of treatments. Before harvesting, center lines of strip roads were marked every 20 m. On the strip roads, points for measuring soil properties and logging residue were marked every five m. Later during the cutting and forwarding, rut formation was measured on these points after every machine pass.

In the normal harvester working method, trees removed further away from the strip roads were processed outside the strip roads. In the protective method, the harvester operator processed as many trees as possible on the strip road and laid part of the tree tops parallel to the strip road. The protective harvester working method increased the harvester time consumption about 5 %, but a higher proportion (86 %–92 %) of the total logging residue potential was brought to the strip roads. Logging residue mass received to cover the strip roads was around 14–19 kg m^{-2}.

In Finland, the proportion of damaged trees and ruts deeper than 10 cm should not exceed 4 %. In our study, the proportion of damaged trees clearly exceeded the limit. After 2–4 forwarder passes, the percentage of deep ruts mainly remained below that threshold. The average rut depths by passed total mass (machine + load) in the harvester working methods

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and forwarder equipment (tracks on, without tracks) are presented in Fig. 1.

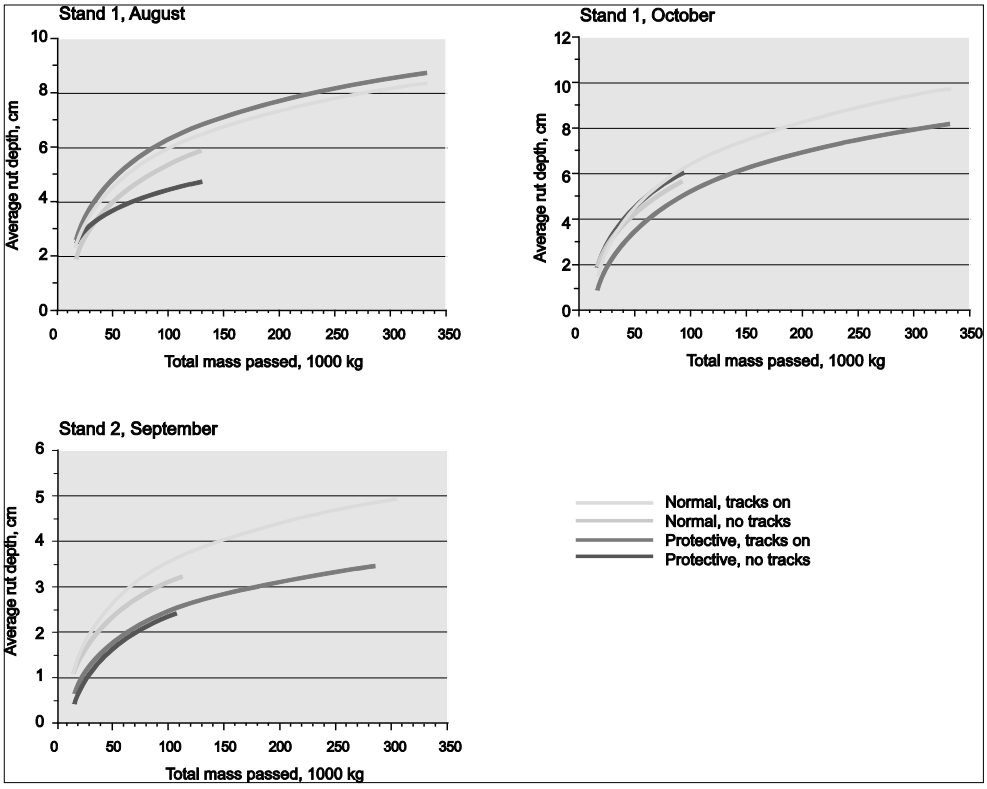

Figure 1. The average rut depths by passed total mass.

In our study, there were only minor differences when driving forwarder tracks on and without tracks. This was due to high soil bearing capacity. Stand 2 was on clay soil, but the treatments were carried out after a very dry summer. After wet summer, the result could have been different. Many studies show, that in low bearing conditions the use of tracks in a must.

Prerequisites for a successful thinning operation during unfrozen soil are favourable weather, soil and stand conditions. When harvesting Norway spruce stands during unfrozen soil, precise planning and ability to react to weather changes is needed. On dry soils with high carrying capacity, ruts remain shallow and proportion of deep ruts is low. Furthermore, high amount of logging residue decreases rut formation. The amount of residues can be affected with the harvester working method. Protective working method can be recommended in the places with low bearing capacity.

Keywords: *mechanized harvesting, Norway spruce, soil damage, tree damage*

FIND THE SMARTEST ROADS IN THE TERRAIN DURING FOREST OPERATIONS USING GIS

Johan Sonesson[1], Isabelle Bergkvist[1] and Sima Mohtashami[1]

During the last 10–15 years the annual cutting volume in Swedish forestry has increased from ~60 million m^3 solid to ~70 million m^3 solid. Within a few years the annual volume is expected to increase to more than 100 million m^3 solid. One consequence of the increased intensity in the forestry is that more of the logging operations have to be done during bad weather and thereby poor ground conditions. There is thus a great challenge to reach almost twice the volume of wood without serious damage to the environment, particularly soil and water. The key to manage this challenge is improved planning and spread of information. This is possible through smart application of Geographic Information System, GIS.

One ongoing project at Skogforsk is to create a decision tool for digital planning of forestry. In the project we use a high resolution Digital Terrain Model (DTM), produced by laserscanning technique, to find the best harvesting roads in the forest. The DTM is used to extract and built different digital map layer:

–Elevation above sea level, slope and aspect.

Soil type is another complementary map used in the model to find and validate sensitive regions in the logging site.

Each factor is graded from one (best) to five (worst) according to how much it influences the conditions for transport in the logging operation. In addition we use information of nature conservation and cultural heritage from for example the Swedish forest agency and forest companies internal registers. All this digital information is used to create ONE cost index surface layer with "no go areas". That is to say the summarized cost index in each 4 × 4 m pixel and expected areas where no driving should be performed. The cost surface is used to find the best main roads in the logging site concerning both ecological and economic consequences

We believe that the decision can contribute to:

- Less damage to ground and water
- Shorter transport in the logging site
- Increased productivity
- Decreased fuel consumption
- Decreased emissions from the forestry

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Presently we develop the tool further by:

- Evaluation in operational forestry to find improvements and maximize the possible use in practice
- Applying additional important data layers, for example a “Depth to Water index” in cooperation with the University of New Brunswick
- Creating a user friendly interface
- In the future we see a great potential to optimize logging and silviculture concerning site conditions, decide about new roads and dishes as well as perform valuable and cost-effective natural conservation in the forestry.

Keywords: *GIS, Digital Terrain Model, decision tool*

CHIPPING PRODUCTIVITY AND PERFORMANCE IN FINLAND AND AUSTRIA

Robert Prinz[1], Dominik Röser[1], Blas Mola-Yudego[2], Beatrice Emer[3] and Lauri Sikanen[2]*

The aim of this research was to examine the differences in productivity and the overall performance of the chipping of bioenergy at the roadside. The productivity and performance of energy wood chipping operations was investigated at several sites in Finland and Austria. The study quantifies the effects of different variables such as forest energy assortments, tree species, sieve size and machines on the overall productivity of chipping. The results revealed that the characteristics of the raw material also seem to have an effect on productivity. Furthermore, there are significant differences in the chipping productivity in Finland and Austria which are largely based on the use of different sieve sizes.

The close interlinkage between the chipper, crane and grapple was also investigated and the results revealed that investments costs can be optimized and operational costs and stress on the machines reduced if more consideration is given to this relationship in the future. All relevant stakeholders should work together jointly to find solutions that will allow a greater variation of chip size in order to improve the chipping productivity in different conditions.

Keywords: *wood-fuel logistics, forest machinery, bioenergy supply*

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EVALUATION OF TWO STUMP-LIFTING HEADS IN NORWAY SPRUCE STANDS

Kalle Kärhä[1]

The use of stump and root wood chips has increased very rapidly in the 21st century in Finland: in the year 2000, the total consumption of stump wood chips for energy generation was 10 GWh, while in 2010 it was approximately 2 TWh. Metsäteho Oy and TTS Research evaluated two stump-lifting devices (a Väkevä Stump Processor and a Järvinen stump-lifting head) for the lifting of Norway spruce (*Picea abies*) stumps. The productivity and costs of stump lifting were determined.

The Väkevä Stump Processor is currently the most popular stump-lifting heads in Finland. So far, the Väkevä Stump Processor lifting head has been supplied for more than 150 stump-lifting machines in Finland and abroad. The Järvinen stump-lifting head was still in a prototype stage in the study. In the time study, both stump-lifting heads were fitted on a Hitachi EX 225 USR (engine power: 122 kW) tracked excavator that weighed 24 tonnes. The final study material for stump processing time modelling was 749 spruce stumps.

When lifting stumps with a diameter of 30 cm, the effective hour productivity of stump lifting was 11.2 m^3 sob/E_0 (4.8 t_D/E_0) without site preparation using a Väkevä Stump Processor, and when lifting spruce stumps with a diameter of 40 cm, the productivity was 14.9 m^3 sob/E_0 (6.5 t_D/E_0) (Figure 1). When the site preparation (mounding) was integrated into lifting work, the stump-lifting productivity decreased 21–27%. The stump-lifting productivity of the other lifting head (Järvinen) was lower than that of the Väkevä Stump Processor. Some development suggestions for the Järvinen lifting head were presented and discussed.

The cost calculations showed that stump-lifting costs are extremely high when stump diameter is less than 20 cm (Figure 2). Therefore, the study recommended a change in the current stump-harvesting guidelines of Finland: The study suggested that all the stumps with a diameter less than 20 cm should be left on the harvesting site.

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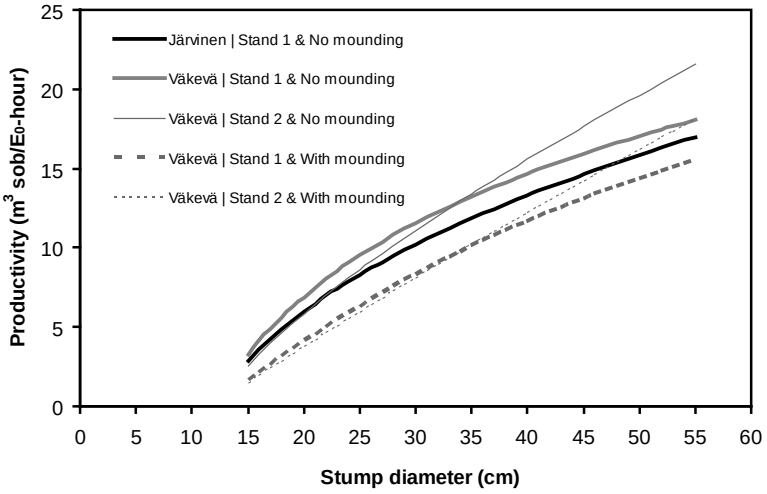

Figure 1. Effective hour productivity of Norway spruce stump lifting applying the Järvinen stump-lifting head and the Väkevä Stump Processor with and without mounding work in stand 1 and 2. The density of stump removal was 500 stumps removed per hectare.

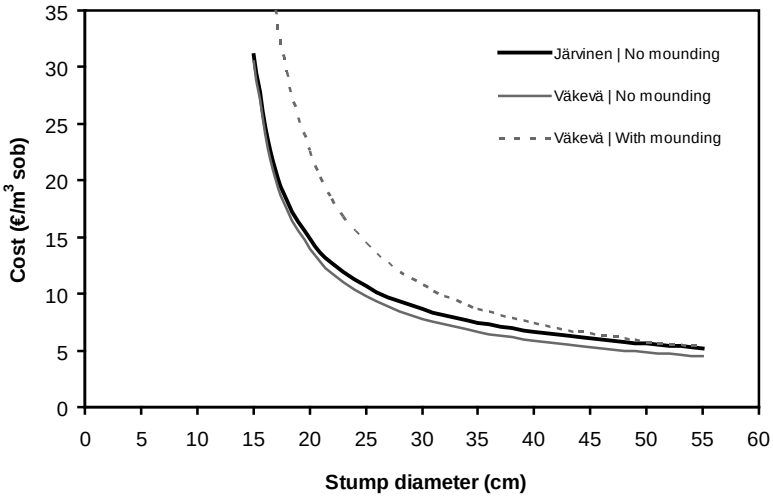

Figure 2. Costs of Norway spruce stump lifting using the Järvinen stump-lifting head and the Väkevä Stump Processor with and without mounding work. The density of stump removal was 500 stumps/ha.

Keywords: *costs, productivity, stump and root wood*

GROUND DISTURBANCE AND PRODUCTIVITY OF BIOREX30

Simon Berg[1]

There is today an increased interest for stump as fuel as the demand for bioenergy is increasing. Stumps contain high quality fuel wood when they have been cleaned from soil and stones. In Sweden there are concerns about unintended negative impacts of stump harvesting and the harvest is therefore only conducted on trial basis. These impacts are manly caused by the ground disturbance associated with the uprooting of stumps. Large ground disturbance can lead to decrease in the soil carbon poll, leakage of nutrients, leakage of heavy metals and erosion. It is therefore important to reduce the ground disturbance caused by stump harvest so stumps can be used as a sustainable source of fuel in the future. There is today no detailed studies about how large the ground disturbance is when harvesting stumps. It is therefore important to investigate the ground disturbance of heads using different uprooting principles to determine if some method causes lower ground disturbance. It is also important that the method used by the head produce stump fuel wood at a competitive price. If a method gives a too high production cost, it does not matter how small ground disturbance it causes, it will not be used. It is therefore also important to study the productivity of harvesting heads that use different uprooting principles. Thus, the best method must be both cost-efficient and give low impact on the environment.

In the summer 2012 a field study took take place in Östersunds municipality in Sweden that evaluated the productivity and ground disturbance when harvesting stumps with the Biorex30 harvesting heads. The experiment had one-way layout and effects of treatments was by ANOVA, with clear cut age as treatment. The ground disturbance and the stump harvesters work time was recorded at stump level so regression functions for the productivity and ground disturbance depending on stump size was made.

The Biorex30 head which is a "fork like head" with a splitting knife (Figure 1). Previous studies indicate that "fork heads" (without knife) are more productive on small stumps than the e.g. the Pallari principle heads, which has two breaking teeth and a splitting knife, and the opposite relation seems to apply to larger stumps. A "fork head" equipped with a knife has not been studied before and no previous studies have been done about the ground disturbance in this matter. It is therefore highly interesting to develop scientific knowledge in this area. The aim is to present preliminary results from the study at the OSCAR conference.

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Figure 1. Stump harvesting head with a "fork" design (Biorex30) equipped with a splitting knife.

Keywords: *bioenergy, efficiency, stump lifting*

The study was financed by:

ESS 2

Jämtkraft

Swedish Energy Agency

SKELLEFTEÅ kraft

Svensk Fjärrvärme

SLU Sveriges lantbruksuniversitet Swedish University of Agricultural Sciences

Swedish University of Agricultural Sciences
Dept of Forest resource Management

FIRST

FORECASTING MOISTURE CHANGES OF ENERGY WOOD AS A PART OF LOGISTIC MANAGEMENT

Routa J. [1], Kolström M.[2] Ruotsalainen J.[3] and Sikanen L.[2]

The quality of wood chips is one of the most important factors for a rapidly growing bioenergy sector. Moisture content of wood is considered to be an important quality parameter regarding wood based fuels (Röser *et al.* 2011). Most of the modern medium and small scale heating and power plants have limitations as to how moist fuel they can handle. Dryer fuel can improve plant efficiency and lower emissions. Lowering moisture content from the green state of 55% to 30% would increase the energy yield in a conventional combustion unit by as much as 10% (Nurmi & Hillebrand 2007). Forecasting moisture changes of energy wood is important tool for companies to handle the quality of biomass storages. In logistic management the moisture content is one of the most important factor; wet fuel is expensive to transport and CO_2 emissions increase due the increased transportation. In combustion of energy biomass the emissions of N and small particles increase if the fuel is wet.

Wood is hygroscopic matter, which can adsorb moisture to itself from the atmosphere if it is dry and correspondingly yield moisture to the atmosphere when wet (Kärkkäinen 2007). Moisture content is defined as the ratio of the mass of water contained in the wood to the mass of the same sample of dry wood. Just logged wood moisture contents are varying between 40–60% and it varies strongly even between same species (Kärkkäinen 2003).

After cutting, wood moisture starts to react with surrounding microclimate. In Scandinavian conditions, the moisture content of wood drops rapidly in springs. Usually in late August and September transpiration decreases and the moisture content increases, in some cases even over the "green" moisture after cutting. Maximizing the natural drying and minimizing the re-moistening are key elements in the quality assessment of energy wood.

Storing of energy wood (especially logging residues and small diameter whole trees) in stands before forwarding can lower significantly the moisture content of energy wood. Forwarding from stand to storage place on the roadside has to be made before fall to avoid the moistening again. During storage the moisture content can decrease 20-30 % (Ranta 2003). Covering the piles may give up to 6–15% lower moisture content in comparison with non-covered piles (Nurmi & Hillebrand 2007, Hillebrand 2009).

The objective of our work is study the drying processes of whole trees, small diameter

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stem wood and logging residues in stand and in the roadside storages. We are connecting changes of moisture content to weather conditions and microclimate. We aim to develop different calculating models to forecast the energy wood moisture content.

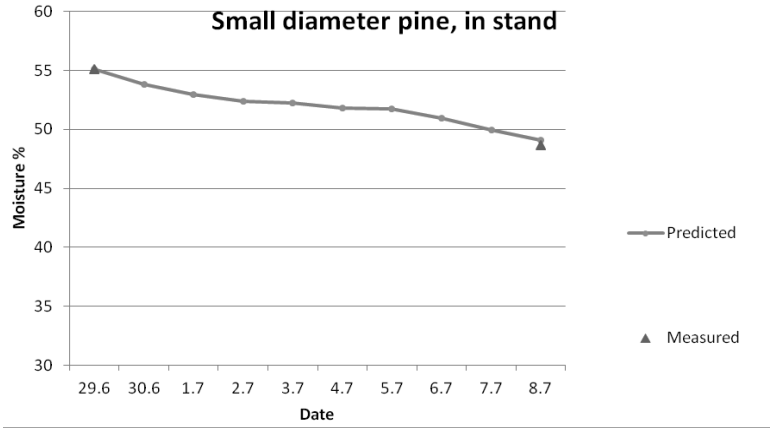
At the Mekrijärvi Research Station (University of Eastern Finland) has been built drying racks with continuous measuring systems. Determination of the moisture content is based on weight changes in the energy wood storage pile. With those racks we can have extremely valuable information about drying processes. The drying process of energy wood can be linked to the weather phenomenon, because there is a meteorological station at the Research Station. The first measurements have been started in October 2011. We have also had some field results and measurements from different locations in southern Finland as a study material.

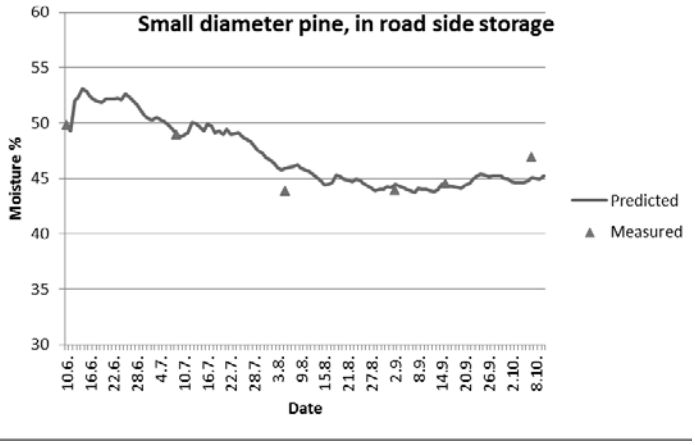
The very first results have shown that net evaporation, the difference between evaporation and precipitation, seems to be good determining variable to energy wood drying (see figures). Basic model is very simple:

DMC = a*net evaporation+b , where

DMC is daily moisture change in energy wood and a and b: variables are varying with different species and different energy wood fractions.

Prediction models will be developed and improved with data from racks and meteorological data from Finnish Meteorological Institute.





REFERENCES

Kärkkäinen, Matti. 2003. Puutieteen perusteet (Basics of wood sciences.) Metsä Kustannus Oy. (in Finnish).

Kärkkäinen, Matti. 2007. Puun rakenne ja ominaisuudet.(The structure and properties od wood) Hämeenlinna: Metsä Kustannus Oy. (in Finnish).

Ranta, Tapio 2003. Suurimittaisen metsähakkeen tuotanto. (Large scale production of forest chips.)Teoksessa Knuuttila, Kirsi (toim.) Puuenergia, Jyväskylä: Gummerus Kirjapaino Oy. (in Finnish).

Hillebrand, Kari 2009. Energiapuun kuivaus javarastointi. (Drying and stocking of energy wood.) VTT Research reports. (in Finnish).

Nurmi, J. & Hillebrand, K. 2007. The characteristics of whole-tree fuel stocks from silvicultural cleanings and thinnings. Biomass & Bioenergy 31(6): 381-392.

Röser, D., Mola-Yudego, B., Sikanen, L., Prinz, R., Gritten, D., Emer, B., Väätäinen, K. & Erkkilä, A. 2011. Natural drying treatments during seasonal storage of wood for bioenergy in different European locations. Biomass & Bioenergy 35(10): 4238-4247.

FORWARDING OF FRESH AND DRIED LOGGING RESIDUES USING A FORWARDER WITH A DEDICATED RESIDUE LOAD AREA

Eliasson Lars[1], Brunberg Torbjörn[1] and Lundström Hagos[1]*

In Sweden, logging residues are commonly left on the logging site to dry during a summer before they are forwarded to the landing. Recently the interest for forwarding of logging residues directly after the harvesting operation has increased. It is perceived to have a number of advantages, e.g. the same forwarder that was used to forward sawlogs and pulpwood can be used, more of the material is recovered, increased forwarder productivity and the site can be replanted during the first summer after the cut. In order to confirm earlier results a field study was made to examine if drying of residues prior to forwarding affected forwarder productivity.

Figure 1. The forwarder had dedicated residue load area.

Forwarding of fresh and dried residues was studied on one cutting site each. The same forwarder equipped with a Breson residue load carrier (figure 1) was used on both sites. Forwarding of dried residues was studied in June and forwarding of fresh residues was studied in October.

The forwarder loaded on average 7.8 oven dry tons (odt) in both treatments. The

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forwarder travelled with a speed of 62.7 m per minute when traveling empty and a speed of 48.4 m per minute when loaded. There were no statistically significant differences in travel speeds between treatments, although there was a tendency for higher speeds with load when forwarding fresh residues. The time for *Loading & unloading* (T) is highly dependent on the residue concentration per 100 m of strip road (odt_{100}) and number of stops per 100 m ($stop_{100}$) but not affected by residue freshness, and can be modelled as

$$T = 87{,}1 + \frac{524{,}1}{odt_{100}} + 21{,}05 Stop_{100}$$

Results show that there were no significant differences in time consumption per odt between forwarding of freshly cut residues and dried residues given the same concentration of residues per ha. This confirm the results from last year's study and the presented time consumption models compare well with the earlier model and with Finnish models.

A common theory to why the productivity should be higher when forwarding fresh residues is that the biomass recovery is higher thus increasing the forwarded amount of residues per meter of strip road. Such an effect would not be detectable as residue concentration per meter of strip road was used as a covariate in our models. An 10 % increase in residue recovery rate would lower the time consumption for *"Loading and unloading*" 3 % when forwarding fresh. However, given the fact that there is a strong trend that *"Loading and unloading*" is faster when handling dried residues and that there is a significant difference in unloading time this calculated decrease in time consumption should not be seen as any large advantage for forwarding of fresh residues.

There are more important arguments for why residues should be extracted fresh than a small increase in forwarder productivity. When forwarding fresh residues forwarding is done close to the harvest and likely in the right time for travelling in the stand which should reduce soil damage. Furthermore the cut can be scarified and replanted faster than if we have residues lying on it to dry for a summer. Proponents for forwarding of dried residues argues that residues dries better in small piles on the cut than in large piles at the landing and that less nutrients are extracted from the cut area.

Keywords: *forest fuel, time consumption model, load utilisation*

PROCESS MODELLING FOR STREAMLINED FUEL SUPPLY

Johannes Windisch[1] and Dominik Röser[1]*

The fact of the economic feasibility of forest biomass procurement being on a knife-edge in many cases represents a commonly recognized issue in this field of research. In Finland these issues have been studied extensively. Recent studies demonstrated how even little changes in the procurement costs can significantly affect the available potential of logging residues.

A crucial factor influencing the economy of forest biomass procurement operations was identified recently: In medium scaled forest fuel supply chains organisation and management of the supply chain constitute a significant cost factor and differences in the work time expenditure between different supply chains indicate a considerable potential for cost savings through increasing the efficiency of the business logistics.

The present study investigated the cost structure of an integrated roundwood/biomass supply chain in Germany regarding the management and organisation of operations and the related costs. Business process reengineering techniques were applied then to lower those costs by creating a leaner and more efficient business process. The cost saving potential was determined using discrete-event simulation.

Real staff costs incl. mileages and commissions provided by the actors in the supply chain was used to calculate the costs per m^3, except for the contractors. As contractor are not able to run their machines while carrying out tasks related to organisation and management, opportunity costs apply. The contractors' opportunity costs were calculated based on exemplary machine cost calculations.

The reengineering approach used best practice guidelines from literature as well as best practices applied in other supply chains. Main focus of the reengineering approach was put on data collection and exchange. The time consumption of the reengineered processes was simulated using the SigmaFlow Workbench software. Based on the simulation results and the staff and opportunity costs, the costs per m^3 for organisational and managerial tasks was determined for all actors in the supply chain and compared to the currently applied process.

With the reengineering three different new business processes were developed. The first one improves the current practice of integrated roundwood/biomass harvesting from commercial thinnings and final fellings (To-be process). As there is going to be need to exploit new sources of forest biomass in the future, two business processes were developed for biomass procurement from precommercial thinnings (Biomass process and Biomass FA process). The cost calculation based on discrete-event simulations shows that the contractors bear the largest share of the management costs in the current process which is demonstrated

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in Figure 1. Additionally, Figure 1 shows the considerable cost saving potential provided by the modelled business processes.

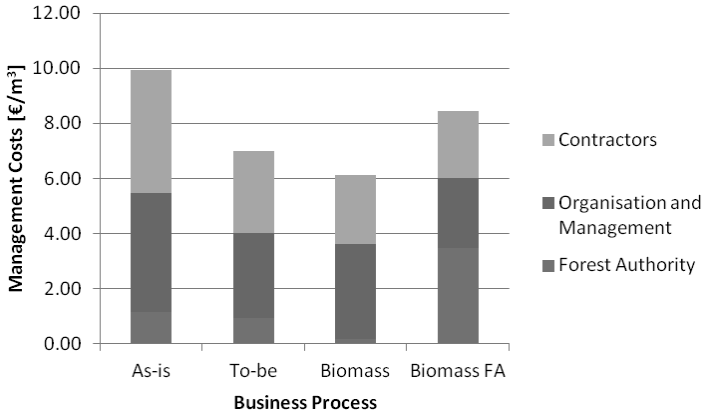

Figure 1. Costs related to organisational and managerial tasks for the currently applied and modelled business processes.

Keywords: *business process modelling, supply chain management, process simulation*

STUMPS LIFTING IN ESTONIA – A CASE STUDY IN SPRUCE STANDS

Vahur Kurvits[1], Allar Padari[1], Veiko Uri[1] and Peeter Muiste[1]*

The general goal of the promotion of bioenergy in Estonia is – by 2020 the use of renewable energy should increase by 7% up to 25% of the final consumption of energy. The biggest portion of the target will be reached by forest fuels.

The available quantity of woody biomass for energy is dependent on the permitted level of use of forest resources. The Forestry Development Programme 2001–2010 established a level of 13.1 Mm^3 and only half of the potential harvesting volume was used in recent years. The similar level has been prescribed for the period up to year 2020 and it is sufficient to supply both wood processing industry and energy sector. The consumption of traditional firewood has remained at the same level for several years, as the main consumer is the residential sector. This assortment has been used also in wood processing industry as a raw material for production of particle boards, mechanical pulp or technological pellets. Larger boilers are the main consumers of wood waste and chips, which form about half of the total production of wood fuel.

But the forecast for wood fuel supply over the next 30 years indicates that the available quantities of traditional firewood will decrease if private forest owners start to harvest grey alder stands and reforest them with other tree species. And the need for additional sources of wood fuel will become urgent if combined heat and power production from woody biomass commences. Today big (25 MW_{el} and 50 MW_{th}) biofuel-fired combined heat and power plants are operating in Tallinn, Tartu, Pärnu and several will be built during the coming years. The conclusion can be drawn that in order to supply the consumers of wood fuels in the coming decades the main focus of the attention should be on the use of harvesting residues, but also collection of stumps is promising. Supported by a Grant of the *State Forest Management Centre* a study of technologies of stump lifting of spruce stumps was carried out in November 2011.

The general aim of the study was to investigate the environmental impacts of spruce (*Picea abies*) stump lifting in Estonian conditions, but a sub-topic had the aim to study the technologies. In co-operation with State Forest Management Centre 4 sample plots were selected to carry out the study. The plots were located in *Hepatica*, *Oxalis* and *Myrtillus* site types and one plot in a forest hevily damaged by the root rot (*Heterobasidion*). For lifting of stumps a stump harvester Pallari KH-160 mounted on a hydraulic excavator New Holland Kobelco E235 was used. During the stump lifting the whole process was recorded by a video camera and later analysed on cycle and elemental level in a computer. The time

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study was carried out to characterize the productivity, energy consumption, quality of the raw material etc.

The processing of data is not finalized yet, but for the conference the extended abstract and the presentation will be prepared.

Keywords: *stump lifting, spruce stands, wood fuel*

PRODUCTIVITY OF STUMP LIFTING HEAD MCR-500

Andis Lazdiņš[1] and Agris Zimelis[1]*

The first studies on stump extraction for bioenergy in Latvia are dated with second half of 19th century. During independence (20ths and 30ths of 20th) century stump extraction was identified as one of the most prospective and challenging tasks of forest sector to secure sustainable deliveries of solid biofuel for households and industry. In that time stump extraction using explosives was considered to be a conventional forestry technology. Now we are facing the same challenges and tasks, the only real difference is more advanced and powerful technologies.

MCR-500 is the first prototype of combined stump extraction and mounding head for caterpillar excavator produced in Latvia by the LSFRI Silava and engineering company Orvi SIA. The device is supposed to be used for extraction of stumps with diameter up to 50 cm in coniferous and deciduous tree stands (Figure 1). The main benefit of the device is ability to prepare soil by making mounds for the following forest regeneration.

Figure 1. Stump lifting head MCR-500.

The MCR-500 head was tested in autumn (2011) in clear-felling sites on fertile mineral soils nearby Riga city. It was mounted on New Holland 215B excavator and operated by professional instructor of forest machines with limited experience on excavators. All extracted sites were regenerated with Norway spruce during next spring. The reference method of soil scarification was disc-trenching completed few weeks after stump extraction. In total 3.5 ha were extracted during the studies. Harvested amount of stumps was estimated using biomass equations; therefore, might be corrected after estimation of the actual biomass weight during comminution studies. Preliminary data from forwarding studies confirms concerns proposed

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in earlier trials, that biomass equations borrowed from Nordic countries considerably underestimates below-ground biomass of stumps.

The figures of productivity were recorded using Allegro field computer with SDI program. Time consumption was accounted separately for a single stump. The height, diameter and specie of all stumps with diameter above 20 cm was determined before the time studies. The working time was split into: (1) turning of tower; (2) driving in stand; (3) reaching a stump; (4) catching; (5) lifting; (6) splitting; (7) shaking and (8) dropping to get rid of soil; (9) scarification – site preparation; (10) other unexpected operations and (11) non-working time elements.

Average calculated stock of extractable biomass (stumps and coarse roots) in the experimental sites was 28 tons ha^{-1} (7.6 % of extracted roundwood expressed in m^3); average extractable biomass of stumps was 73 kg, average diameter – 32 cm. Share of extractable biomass of harvested stumps was 62 % of the biomass of all stumps with diameter above 20 cm.

Productivity of stump extraction was 2.4...3.4 tons per efficient hour (2.5 tons in case of good quality of soil preparation). Productivity of soil scarification was 3.4...4.3 hours per ha. The figures of time consumption for stump extraction per area unit are comparable with others obtained in Latvia; however, calculated output of biomass is considerably smaller. Scarification of soil with stump lifting head consumes twice more time than conventional trenching; however on wet soils productivity figures come closer making excavator competitive.

Average number of prepared mounds was 571 per ha^{-1} (315...1496), total efficient time – 9.5 hours ha^{-1} including 7.6 hours for stump extraction and 1.9 hours for mounding. Productivity was considerably affected by lack of experience of the operator – in the last stand (104-9) scarification took by 73 % more time than at the beginning, but number of produced mounds increased by 162 %. Similarly, productivity of stump extraction in the last stand increased by 20 % in compare to the first stand (Table 1). The quality of scarification increase as well with every stand. If not accounting operations relevant to stump extraction, average time for soil scarification would be 3.4 hours ha^{-1}.

Table 1. Productivity figures recalculated to area units

Object code	Number of extracted stumps, per ha	Extractable biomass, kg ha^{-1}		Number of prepared mounds per ha	Efficient time, hours per ha			
		extracted stumps	all stumps		total	for stump processing	for mounding	for soil preparation
176-18	377	22907	31774	315	9.4	8.3	1.0	3.0
98-4	324	31828	48511	355	10.4	8.5	1.9	3.4
104-9	384	24970	47242	1496	9.8	6.6	3.3	4.3

According to the study time consumption for stump extraction depends from species and diameter of the stump (Figure 2). For birch productivity continuously to grow until stumps reach diameter of approximately 45 cm; then productivity remains relatively constant. For pine the productivity slightly increases until stumps reach approximately 40 cm in diameter. For spruce slight increase in productivity continues even if stumps are more than 60 cm in diameter.

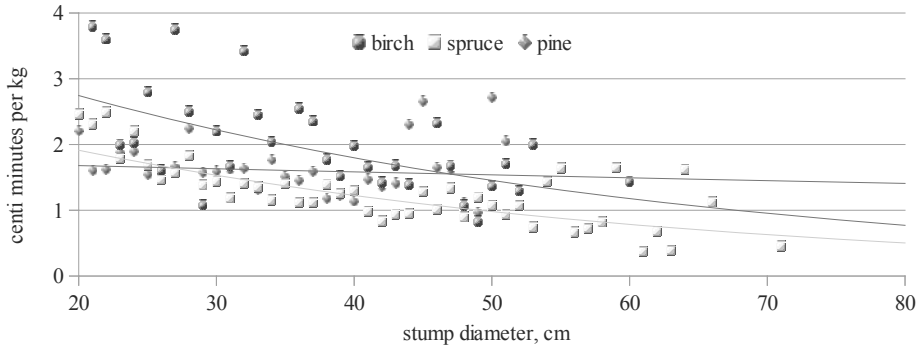

Figure 2. Productivity depending from diameter and species of trees.

Keywords: *stump extraction, mounding, forest regeneration*

ECONOMIC AND TECHNICAL IMPORTANCE OF CRANE SCALE ACCURACY: A CASE STUDY ON TIMBER TRUCK CRANE SCALE MEASUREMENT

Aaron Petty[1] and Timo Melkas[1]

Crane scale measurement having increased in use has become a commonly accepted means of measurement throughout the procurement process within the forest industries. Assortments from energy wood to logwood may be measured systematically, producing critical information for stakeholders not limited to wood procurement in the buying and selling process e.g. kg, m^3, MWh. Accuracy and reliability of the measurement process is of critical importance throughout the supply chain. Established guidelines provide standards for calibration and acceptable variances within the measurement process.

Due to the importance of accuracy in the procurement process, we conducted a study analyzing the importance and effect of the time of year (based on quarters), timber assortments, scale models, and measuring principle (strain gauge or hydraulic pressure gauge) on the accuracy of a timber truck crane scale when applicable. To perform an assessment of the accuracy of crane scale measurement, information was collected through Metsäteho shareholders, belonging to the Finnish Forest Industries Federation. Data was collected throughout a 12 month period in 2011 providing approximately 65,000 measurement observations, which primarily included truck, trailer, and combined truck and trailer loader scale and weigh bridge data, percent differences, assortments, time, scale model type, and measuring principle. Further data filtering was needed to expunge outliers, normalize data, and to obtain consistency in reported data. The accuracy calculation was determined with measured mass values (kg) from both the loader scale and weigh bridge, as represented in eq. (1).

$$P_d = (L_s - W_b)/W_b * 100 \quad (1)$$

where, P_d – Percent difference

L_s – Loader scale weight (kg)

W_b – Weigh bridge weight (kg)

An analysis of the differences between average accuracy and the differences between standard deviations of average accuracies of the measurement data was performed to assess the accuracies based on the predefined categories. Two-way Anova's were performed utilizing SPSS to determine whether any correlation existed between categories. The analysis elucidates

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an important research field, in crane scale measurement, one that is becoming a technological standard and an important aspect in timber procurement.

Keywords: *Crane Scale Measuring, Scale Accuracy, Timber Assortments*

HEADLAMPS FOR HARVESTERS

Martin Englund[1] and Petrus Jönsson[1]*

The performance of work lights has improved over the last decades. We have moved from halogen to xenon and now LED is becoming a competitive alternative. However, regardless of the technology used the work lights used on harvesters today often fail to illuminate one of the areas that are most important for operators to see: the area around the base of the tree where the felling cut will be made. That lack of illumination is likely to mean a high risk of hitting rocks or boulders with the chain saw, stumps that are made unnecessarily high or both.

Traditionally the working lights are placed on top of the cabin, on the chassis or on the boom. Even though these lights at times are capable of illuminating the tree the operator is reaching for, the area around its base is obscured by the harvester head when the tree is grabbed.

By placing lights on the harvester head itself these problems can be overcome. The area around the fell cut/stem base will be well lit regardless of the position of the tree relative the machine. This has recently become possible because of the availability of small and robust LED-lights.

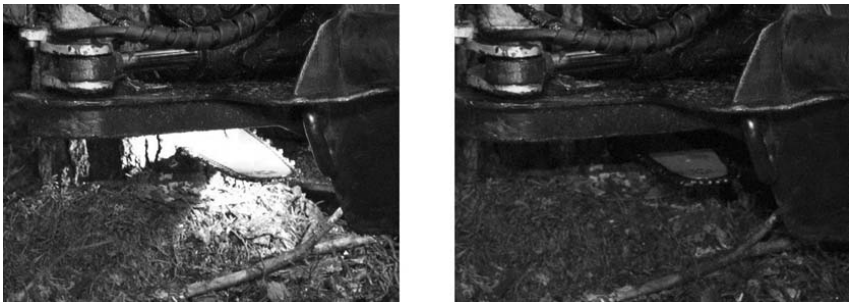

Figure1. The area around the stem base, with and without the additional lights in the harvester head. Pictures from the very first trial.

During the early spring of 2012 a pilot study was carried out to gain impressions from harvester operators and to test the durability of LED lights placed in the harvester head as described above. Because of the positive results an extended study is planned to be initiated in the autumn of 2012.

A report from the pilot study and hopefully preliminary data from the extended study will be presented at the upcoming OSCAR conference.

Keywords: *work lights, visibility, illumination, light, LED*

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WHAT, HOW AND WHEN TO HARVEST IN YOUNG DENSE STANDS

Maria Iwarsson Wide[1]

What assortments should be harvested from young, dense stands, and how should it best be done? That is a more and more common question in today's first thinning, when we don't have the expected 2 000 stems per hectare, but more denser stands with weaker mean stem volumes. Should we harvest only for pulp wood, for energy wood or perhaps make an integrated harvest for the both? Often the answer is quite obvious – when we know the presumptions! But the marginals are small and it is important to be familiar with the determining factors. Most importantly the number of stem per hectare, mean stem volume and distribution of tree species, and of course the price relations between different assortments.

Compared to removal of only pulp wood in dense thinning the harvested volume typically increases with 20-40 % when including also the small stems and tops of pulp wood stems in the harvest, for example as delimbed energy wood. If harvesting for whole trees the harvested volumes will increase with 50-150 % depending of the diameter distribution and mean stem volume within the stand. Another alternative would be to make an integrated harvest, an alternative that has become more and more popular over the last two-three years.

This will raise the incomes – but also the harvesting costs per harvested volume because of the lower mean stem volumes in the removal. Pre-clearing of the weakest stems, typically up till 5 centimeters in diameter breast height, can raise the mean stem volumes and thereby also the productivity in the harvest. But it will probably cost about € 150-200 per hectare, and when it comes to pine and birch, it is sometimes not worth the cost, when looking at it strictly economically.

Multi-tree handling is vital for a profitable harvest and handling of small dimension stems, especially in stands with a low mean stem volume and a big removal per hectare. Productivity can rise with 20-50 % in the dimension typically harvested from these stands, 0,03-0,06 m^3fub per stem. Improved working methods can also help to increase the productivity – mainly by decreasing the crane movements, which also decreases the stress on the driver.

A great challenge and problem for persons that plans these thinning is to estimate the possible volumes to harvest, and thereby estimate revenues and cost in the operation. Today estimates, if any are done, are very rough are often built on experience or guessing. When deciding what assortment to harvest and what technology and method to use we need to look at the whole handling chain, harvesting, storing, transportation and chipping. Also the

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price relations between the different assortments are crucial and decides that should best be harvested.

To be able to calculate and compare different alternatives depending on the stand data, Skogforsk has developed a volume and cost calculation tool. With a tool that can calculate assortment volumes and takes into account different prices on the assortments and also calculate the cost for harvesting and forwarding of the different assortments, using models for time consumption per hectare it becomes easier to compare the outcomes of the different options. A more advanced version will also calculate costs for chipping, storing and transporting the material to the industry.

Software like this leads to increased profitability in early thinning and higher precision in analyses of different systems and their economical outcome in early thinning. The possibility to make a simple calculation to compare the outcome of harvesting pulpwood, forest fuel or a combination harvest in each stand provides a good decision support and increase the possibility to reach a profitable result in the operation.

Keywords: *Biomass and pulp wood harvesting, small dimension stands, calculation, decision making, multi-tree handling*

EFFICIENCY OF MULTIPLE-TREE PROCESSING IN DIFFERENT ENERGY-WOOD STANDS

Teijo Palander[1] and Antti Perho[1]*

In small-diameter stands, there is a great potential to increase the efficiency of multiple-tree processing through rationalizing an energy wood harvesting system. In this study, the potential stand characteristics were rated and further analyzed in order to increase the technological efficiency of multiple-tree processing. Research data were collected in 12 stands during early thinnings in 2009, when an experienced harvester operator carefully selected trees either for multiple-tree processing or single-tree processing.

Figure 1. A harvester is processing small-sized thinning wood.

After energy-wood harvesting, the average share of multiple-tree processing of the stands was 75.0 % with the standard deviation of 21.8 %. The smallest average size of removed trees was 3.7 dm^3 in stand 4, while the share of multiple-tree processing was the largest, 98.8 % (Table 1). Table 1 indicates that the largest share of multiple-tree processing was in stand 7, 99.2 %, and the smallest share of multiple-tree processing was in stand 8, 27.9 %. The most dense stand measured was the stand 4, in which the number of trees before harvesting was 14,781 trees per hectare and the average diameter of trees ($d_{1.3}$) was the smallest, 4.8 cm. The smallest number of trees before harvesting was measured in the stand 8 with 1,800 trees per hectare, in which the average diameter of trees ($d_{1.3}$) was 14.0 cm and the height was 17.0 m.

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Table 1. Removal characteristics in energy-wood harvesting. G1 = Trees before harvesting (trees/ha), G2 = Diameter ($d_{1.3}$) before harvesting (cm), G3 = Height before harvesting (m), G4 = Size of removed trees (dm^3/tree), G5 = Number of trees in harvester head (trees), G6 = Share of multiple-tree processing (%), G7 = Harvesting productivity (m^3/h). The stands were divided into two groups A (bold faced small values) and B using Mann Whitney U test

Stand	G1	G2	G3	G4	G5	G6	G7
1	**3932**	**9.3**	14.0	43.8	**1.1**	**77.5**	5.5
2	4800	**9.1**	14.5	59.4	**1.0**	**70.6**	5.9
3	**2100**	12.4	15.5	89.9	**1.2**	**51.2**	8.6
4	14781	**4.8**	**6.0**	**3.7**	5.1	98.8	**3.1**
5	**2400**	14.9	18.0	109.8	**1.0**	**53.4**	9.2
6	5933	**5.9**	**8.0**	**16.6**	1.6	94.9	**3.9**
7	8360	**6.3**	**9.0**	**9.7**	2.0	99.2	**3.2**
8	**1800**	14.0	17.0	200.2	**1.0**	**27.9**	12.5
9	**2200**	10.6	**14.0**	90.3	**1.0**	**70.8**	8.3
10	**3000**	10.1	**12.0**	**32.8**	1.3	90.3	**4.4**
11	4057	**9.9**	14.5	**26.0**	2.7	86.2	**5.0**
12	4466	10.7	14.0	**27.9**	1.6	78.6	**4.7**

The most important stand and removal characteristics for the selection of multiple-tree processing in Finland are presented in Table 2. In the stands, the average size of removed trees varied from 3.7 to 200.2 dm^3/tree. Further, the volumes of energy wood removal of stands varied largely around the average size of 59.2 dm^3/tree, while the standard deviation was 56.2 dm^3/tree.

Table 2. Statistical values of stand and removal characteristics

	Trees before harvesting (trees/ha)	Diameter ($d_{1.3}$) before harvesting (cm)	Height before harvesting (m)	Size of removed trees (dm^3/tree)	Share of multiple-tree processing (%)
N	12	12	12	12	12
Average	4819	9.8	13.0	59.2	75.0
Lower quartile	2250	7.0	9.8	19.0	57.7
Median	3995	10.0	14.0	38.3	78.1
Upper quartile	5950	12.0	15.3	90.2	93.8
Standard deviation	3656	3.1	3.6	56.2	21.8
Range	12981	10.1	12.0	197.0	71.3
Minimum	1800	4.8	6.0	3.7	27.9
Maximum	14781	14.9	18.0	200.2	99.2

According to our results, the harvester operator selected multiple trees into the harvester head as stand density was more than 2,000 trees/ha, and multiple-tree processing was more efficient method than single-tree processing as stand density was more than 4,000 trees/ha. Furthermore, the harvester operator used the method as the average diameter and tree height was smaller than 10 cm and 15 m, respectively. He also used the method for stands suitable for pulp wood procurement. In addition to consideration of stand characteristics, a grapple scale measuring and undergrowth pre-clearing should be used for the successful harvesting system. Significant findings of this study are that the efficiency of multiple-tree processing can be promoted in early thinnings by careful selection of stands, and, its efficiency can be compared to single-tree wood harvesting technology in energy-wood stands.

Keywords: *Early thinnings, Energy wood, Harvesting technology, Wood procurement*

HIGH CAPACITY TRANSPORT – A THREE YEAR ROUNDWOOD HAULAGE TEST IN SWEDEN

Claes Löfroth[1], Johanna Enström[1] and Niklas Fogdestam[1]

1. INTRODUCTION

Figure 1. The studied vehicle, loaded with 65 tonnes at one of the terminals.

A logging truck, 30 m in length, and with a gross vehicle weight (GVW) of 90 tonnes, has been tested for three years in North of Sweden. On two round trips, the volume of roundwood that this truck can haul is equivalent to that carried by three conventional trucks. The results show reduction of both costs and CO_2 emissions by 20 % compared to regular Swedish roundwood vehicles of 60 tonnes and 24 m length.

After several years of planning and development work, the first ETT roundwood haulage rig started operating in January 2009. After three years in production, the mileage covered by the vehicle is 800 000 km and the total transported volume measures 150 000 m^3. ETT is a Swedish abbreviation for *One stack more*, which is the name of the project initiated by Skogforsk to study the consequences of higher GVW and extended length on roundwood logging trucks. The project is a collaborative venture between Skogforsk, the Swedish Transport Administration, the forestry companies, The Swedish Association of Road Transport Companies, Volvo, the automotive industry and the private road association. The studied vehicle is now operating on a 170-km run from a terminal in the north of the country down to one of SCA's large sawmills in Piteå.

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The aim of the project has primarily been to achieve environmental benefits from reduced fuel consumption and secondarily to raise efficiency and cut costs in the haulage of timber. In the Swedish forestry sector, road haulage accounts for 25 % of the total costs from stump to mill. The aim was also to improve traffic safety by decreasing the number of heavy vehicles needed for the same transportation task. Several research areas, such as environmental, technical, economical and risk analysis, have been included in the project.

The development task for the manufacturers was to construct an efficient timber vehicle from standard components, in this case truck, dolly, link and trailer. Regular Swedish timber trucks are built from a truck and a 4-axel trailer. The rigid truck was manufactured by Volvo, the trailer units by Parator and the truck body by Bergs Fegen. Newly developed high quality steel from SSAB has been used in the construction of the rig to keep the weight as low as possible.

2. RESEARCH METHOD

Before the testing period, a literature study of the difference in accident risk between long and short truck configurations was performed. Mean values of the risk ratios between long and short truck configurations were calculated from more than 20 studies.

During the practical test the vehicles speed, load and fuel consumption have been monitored continuously through the trucks information system, Dynafleet. Skogforsk has been analysing costs, production, fuel consumption, vibration and environmental impact (CO_2, NO_x, etc.) based on the provided data.

The Swedish Transport Administration has been monitoring road wear and the load on bridges. Analyses have been made through the Percostation system – a tool for monitoring bearing capacity in road construction. Sensors, providing real time data of the impact on different road layers, were used.

The manufacturers have been responsible for technical evaluation and development during the project.

A study of traffic safety, have been performed by VTI (The Swedish National Road and Transport Research Institute). The purpose of the study was to investigate if the introduction of extra-long and heavy vehicles has an effect on safety on Swedish roads, especially in terms of overtaking. Four empirical studies are included: a focus group interview study with heavy truck drivers, an interview study with extra-long truck drivers, a simulator study and a field study.

3. RESULTS AND CONCLUSIONS

FUEL CONSUMPTION AND PRODUCTION

The collected data over fuel consumption shows a decrease of 20 % for the ETT- vehicle compared to a reference vehicle of GVW 60 ton when preforming the same transportation task. The consumption of diesel for the ETT-vehicle was 0.016 l/tonkm*, and for the reference

vehicle 0.019 l/tonkm[2]. The payload of the ETT-vehicle is 50 % higher than for a conventional timber truck of 24 m.

Since emission of CO_2 is directly connected to the fuel consumption, the result of 20 % savings also applies to the emissions of CO_2.

ECONOMY

The economic calculation shows that the increased production capacity of 50 % cuts the transportation cost by 20 %. The capacity in the existing road network has been suitable for the ETT-vehicle. The system thereby demonstrates an interesting possibility of increasing the road transport efficiency without investments in infrastructure.

IMPACT ON ROADS

The data collected from the Percostation system does not show any difference in impact in the road body between passing 60-ton trucks and the 90-ton truck. Despite the sensitive equipment, over passings of the 90-ton truck can not be identified in the data since the pressure per axle is the same as for regular trucks. Hence, no increased wear on the roads from higher GVW can be spotted.

TRAFFIC SAFETY

Literature study

The literature study indicates that the overall effect regarding truck size and traffic safety are positive for the larger trucks, nevertheless, there seems to be specific problems which probably put the larger vehicles more at risk in certain environments, like towns.

Focus group and interview study

The focus group interviews reveal many concerns from drivers of regular heavy trucks on how longer and heavier vehicles will comply with other road users. However, the drivers of the ETT-vehicle do not experience the predicted problems. They do point out the importance of planning ahead while driving.

Simulator study and field study

When overtaking of 18.75 m vehicles and 30 m ETT-vehicles were compared, a small but significant difference of the critical timeslot were found. The timeslot is specified as the time from when the overtaking car has passed the front of the truck until the two lanes start merging into one (on a 2+1 lane road). The results could not be confirmed in the practical field study, while comparing 24 m and 30 m logging trucks. The general conclusion from all of the safety studies performed by VTI is that more research is needed. The reduction of number of vehicles due to higher capacity per vehicle is also not to be forgotten.

TECHNICAL DEVELOPMENT

During the project a number of new techniques have been tested. The EBS (Electronic Brake System), which is connected to all the truck units, ensures that all wheels brake simultaneously. This guarantees effective braking, and that the braking distance of the ETT rig

[2] l/tonkm – total fuel consumption, back and forward, divided by the total distance and the loaded weight.

will not be longer than that of a 60-tonne rig. The ETT-vehicle is the first application with a digital communication system between 4 units (truck, dolly, link, trailer).

The steel, Domex 700, has opened the possibility for a lighter construction which enables higher payload. The technique for achieving a light but still strong construction, have also been transferred into development of other vehicles.

A NEW EXTENDED PROJECT IN PROCESS

The overall results from the ETT-project are positive and demonstrate a great potential in high capacity vehicles (HCV). However, they also show that further research is needed in several areas. Overtaking is only one of many aspects on traffic safety that needs further investigation. In order to relate the figures of fuel savings and efficiency of the vehicle, several studies in different geographical areas and on different road conditions are necessary.

A new extended project is therefore established. The aim is to strengthen the research in the field of HCV for transportation of forest products, but also to give public and authorities the opportunity to view HCV in operation, closer to their own region. The new project is called DETT (Demonstration of ETT), and will, if permitted by Swedish Transport Agency, include a number of HCV geographically spread over Sweden.

New focus areas are:

- Logistics including truck and train transport in combination – how does HCV affect the overall logistic chain?
- Transport of forest fuel as chips – demanding a different type of vehicles and a different logistic chain.
- Direct transport from forest landing to industry – how does HCV apply to the public and private forest road network?
- How does HCV effect the traffic situation in densely populated regions and what reactions does general public have associated with HCV?
- Extended study of traffic safety in different traffic environments. More aspects will be included, in addition to the study on overtaking.

Keywords: *HCV (High Capacity Vehicle), HCT (High Capacity Transport), EMS (European Modular System), logging truck, fuel consumption, CO_2 reduction, traffic safety*

HARVESTING COSTS AND TRANSPORTATION LOGISTICS OF WHOLE-TREES AND MULTI-STEM DELIMBED ENERGY WOOD IN FINLAND

Juha Laitila[1] and Kari Väätäinen[1]*

The present study is aimed at evaluating the competitiveness of various supply systems of small-diameter wood harvested from young stands for fuel. Trees were harvested for the cost comparison either as (i) multi-stem delimbed shortwood or (ii) as whole-trees or (iii) the harvesting was based on bundle-harvesting using the newly-developed Fixteri II bundle harvester (Figure 1). The felling of whole-trees and multi stem delimbed shortwood was carried out using a conventional harvester head equipped with multi-tree-handling (MTH) accessories. Forwarding was carried out using a standard medium-sized forwarder. The comparison of procurement costs was done at stand level as a function of breast height diameter (5-13 cm) and on-road transportation distance (5-160 km).

Figure 1. A conventional harvester head equipped with multi-tree-handling accessories (left) and Fixteri II bundle harvester. Chipping of energy wood at a roadside landing or at a terminal using a trailer-mounted drum chipper (right).

Figure 2. A biomass truck equipped with solid side panels and bottom (left), a standard chip truck and a standard timber truck (right).

The harvested wood was chipped either at a roadside landing or at a terminal using a trailer-mounted drum chipper (Figure 1). Multi-stem delimbed shortwood and whole-tree bundles were transported to the terminal using a conventional timber truck and whole-

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trees were transported using a biomass truck equipped with solid side panels and bottom (Figure 2). The chips from the roadside landing and from the terminal were transported using a standard chip truck (Figure 2). The comparison of the supply systems was done using recently published productivity parameters and data obtained from complementary field studies. The strategic goal of the study was to improve the cost efficiency of production of forest chips from wood harvested from young stands especially by testing technologies for chipping and on-road transporting of small-diameter thinning wood. Updated data on costs and productivity are useful when selecting the appropriate supply systems for wood harvested from various young stands.

In the case of whole-tree bundling, savings in transportation and chipping costs did not offset the high felling and compaction costs, and the novel bundling system was the least competitive alternative. The cost of whole-tree and multi-stem delimbed shortwood chips was at the same level when the breast height diameter of the harvested trees was 11 cm (pine) or more. The felling of whole-trees is cheaper, but the cost difference diminished as a function of tree size. The productivity of transportation (Figure 3) and chipping (Figure 4) of multi-stem delimbed shortwood (5 m) was significantly higher compared to the loose whole-trees.

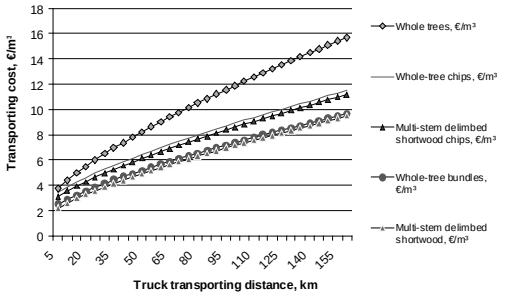

Figure 3. Transporting costs of wood biomass as a function of transporting distance.

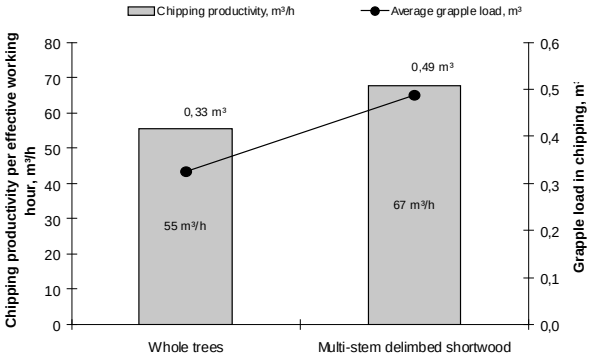

Figure 4. Chipping productivity of whole-trees and multi-stem delimbed energywood, m^3/E_0h.

When applying roadside chipping in Finnish conditions with small and sparsely located forest holdings, acquiring large enough concentrations of wood for profitable production is a great challenge. Machine relocations can be reduced by transporting raw material to terminals or the end-use facility to be chipped. Terminals offer opportunities for buffer storaging and combining various transportation modes. However, the low bulk density of the initial material restricts the operation radius unless the wood biomass is pre-processed. According to the results of our study, harvesting of multi-stem delimbed energy wood is a promising way to simplify operations and to reduce transportation and chipping costs.

Delimbed material produces uniform fuel stock devoid of needles and branches which may be a benefit especially at some power plants with a restricted capability to handle high levels of chlorine and alkali metals contained in the branch material. Sufficient quantities of alkali metals and chlorine causes agglomeration of bed sand as well as corrosion in fluidized and circulating fluidized bed boilers and heat exchangers. Since harvesting undelimbed assortments increases nutrient export from the site, which can affect soil productivity, the whole-tree harvesting alternatives included in the present study cannot be recommended on infertile soil stands.

Keywords: *whole-trees, delimbed energy wood, chipping, transportation, young stands, terminals*

ANALYSES OF BIOMASS SUPPLY CHAIN COST- AND ENERGY EFFICIENCY FOR EARLY THINNINGS IN FENNOSCANDIA

Dan Bergström[1] and Fulvio di Fulvio[1]

Young dense thinning stands in Fennoscandia show a great variety of conditions in terms of e.g. tree density, species composition and tree size distribution. Young un-thinned stands are in general biomass dense, giving a significant annual harvesting potential in Sweden of ca 5 Mm^3solid (~10 TWh). In the harvesting operations thinning harvesters equipped with accumulating felling heads for whole tree or tree section harvest, or harvester heads which can also produce delimbed logs are used. Recent studies on techniques and systems for boom-corridor thinning show that this method increases the productivity on conventional harvesters by up to 40% while the effects of implementing new boom-corridor technology show as much as a 2-fold increase in productivity. Subsequently, the assortments are hauled to roadside by forwarders and the material may be stored for some time before further handling. Recent studies show that if a high share of the extractible trees is under-sized for pulpwood, extraction of whole trees as fuel wood is more efficient. As a third alternative, in certain stand conditions, an integrated harvest of both products (pulpwood and fuel wood) can be made. There are many factors that influence the productivity of forest operations, such as e.g. tree size, assortments and forwarding distance. The selection of the harvesting system which give the highest net income at roadside is however to high degree influenced by the current prize relation between the products, i.e. pulpwood and fuel wood. At roadside the materials can be further upgraded by e.g. fractioning to chips or chunks, or compressed and bundled to high density bundles before transportation to terminal or industry. The effect of producing high density bundles in-stand with cost-efficient technology has shown to give significant logistical advantages. The extracted assortments give also different degrees of possible trucking payloads in the following order: pulpwood, chips/bundles, chunks and tree sections.

In this work, analyses of the effect of stand conditions, harvesting methods and technology, assortments (products and densities), and road transport systems on the supply systems cost- and energy efficiency will be conducted. The effects of introducing cost-efficient technologies for boom-corridor thinning, forwarder and truck load-compression and in-stand bundling (e.g. integrated into the harvester work) will be included in the analysis. The modelling of systems will be based on literature data from previous publications in the Nordic Countries. The work is currently in progress and the intention is to present preliminary results at the OSCAR conference. The presented work is financed by the Swedish R&D program Efficient Forest Fuel Supply Systems (ESS).

Keywords: *fuel wood, bioenergy, operations*

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WORK MODELS FOR THINNING AND FINAL FELLING OPERATIONS

Heikki Ovaskainen[1]

The basis for development of work models for harvester cutting operations has been the aim of creating more systematic and uniform teaching methods. Forest machine education, so far, has been based largely on learning by doing, i.e., when the student has mastered the basic functions of the machine and is able to operate it safely enough, he/she has been allowed to independently practice work planning and implementation. Responsibility of learning the work and achieving a certain level of productivity has largely been the responsibility of the student. This type of training does not usually lead to the best result, due to the possibility of learning inefficient and dangerous work practices. When this occurs, correcting work practices that lead to either inefficiencies or unsafe work practices within cutting operations is known to be difficult.

Another factor challenging learning adequate techniques in schools through work study practice has been the teaching of individual working techniques of the teacher. Teachers have tended to place a strong emphasis on understanding working techniques through their own knowledge of cutting operations. This knowledge is acquired as described above, where in the opinion of the operator or teacher, successful work performances are achieved by references to their own experiences. Performance success guides working techniques to the direction, where an operator achieves their greatest productivity with methods that are easiest for the operator themselves. In these cases, the operator has created their own reasoned approach to work. On the other hand, the lonely nature of forest machine work impedes the feedback and the exchange of ideas of work performance from colleagues. As these persons later position themselves as teachers, common visions of proper working techniques are not present, due to the strong influence of their own operating backgrounds. Therefore, commonly accepted work models have yet to be found in forest machine schools. This has led to conflicting instructions in teaching situations, and perhaps also weakened the learning outcomes.

On the basis of description above, a need to develop commonly agreed upon work models for schools teaching work practices exists. This necessitates clear, simple enough, easy to learn and easy to teach descriptions of ways of working with the forest machine. While working with a certain work model, the operator performs the work within the framework of rules, which offers a systematic, reasoned and controlled process for work. Through the work model the student may attain with greater speed the principal elements of their work, which

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makes the learning process faster and allows the student to more readily meet employment requirements. In addition, a work model increases indirectly well-being and job-satisfaction, as the operator knows that they conduct work following proper guidelines. In this study, the work model is defined as "a description of a systematic way to work, which leads to good result with a reasonable effort".

The aim of this study was to compare three work models in thinning (sector model, applied sector model and sideways felling model) and three work models (furthest tree tactic, nearest tree tactic and forward felling) in a final felling environment. The work models were compared through productivity, fuel consumption and loading of forwarder. Four harvester operators were operating with the models in the study.

The results indicated that the studied work models were very close to each other in productivity. In thinning, the sector model was approximately 2 % more productive compared to the other models. In final felling, the forward felling model was 3 % more productive than the furthest tree tactic and 4 % more productive than the nearest tree tactic. In fuel consumption, joined felling and processing work phase, the sector model consumed 2 % less fuel than the applied sector model and 7 % less fuel than the sideways felling model in thinning. In final felling, the forward felling model consumed 7 % less fuel than the furthest tree tactic and 12 % less fuel than the nearest tree tactic. In thinning, within forwarder loading work, log piles were fastest to load from the piles made by the sideways felling model. The sideways felling model was 8 % faster than the applied sector model and 11 % faster than the sector model. In final felling, the fastest model was the furthest tree tactic. The nearest tree tactic was 10 % and forward felling tactic 16 % less productive. The time differences in loading were calculated for one cubic meter of logs.

TECHNICALLY AVAILABLE BIOMASS IN YOUNG STANDS OF *PINUS CONTROTA* AND *PINUS SYLVESTRIS* IN LATVIA

Āris Jansons[1], Līga Puriņa[1], Oskars Krišāns[1] and Linards Sisenis[2]*

Increasing importance of biomass as a source of renewable energy, both to minimize greenhouse gas emissions and reduce dependence from foreign energy sources, has triggered research into its availability. Sources of biomass in traditional forest management – logging residues – have their limitations mainly due to soil conditions – often they need to be put on skidding roads to avoid soil damages or shall remain in forest to improve nutrient availability. Large areas of abandoned agricultural land are potentially available for establishment of biomass plantations in Latvia. There are numerous alternatives for establishment of plantations (stand) on rich soils, but so far very few on poor, sandy soils. Therefore aim of the study was to estimate available above-ground biomass in young, dense stands of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm) on poor, sandy soil.

Data were collected in 2 experimental trials, located in central part of Latvia in Zvirgzde (56°41'N, 24°28'E). Trials were established using one-year old bare-rooted plants with density 5000 tree ha^{-1}, using seed material from Canada 53°00'–56°58'N, 119°00'–122°45'W. Site conditions: poor sandy forest soil with normal moisture regime – *Vacciniosa* forest type. Latvian Scots pine was used as a control lot, no thinning carried out prior to measurements at the age of 22 years. Above ground biomass was estimated with equations based on measurements of 221 sample trees of *Pinus contorta* from experiment in Latvia (Jansons *et al.*, unpublished).

Results reveal that total absolute dry above ground biomass of the lodgepole pine reached 77.3 t ha^{-1} on average for *Pinus contorta* in contrast to only 26.1 t ha^{-1} for *Pinus sylvestris* (differences statistically significant p=0.001). Productivity in these experiments was slightly higher than in earlier studies at similar sites, where absolute dry above ground biomass of the lodgepole pine was found to be 48±3.6 and 94±9.4 t ha^{-1} at the age of 22 and 25 years respectively (Jansons *et al.*, 2012, submitted). Among-species differences can be partly explained by survival 66% for lodgepole pine (ranging from 49% to 84%) and only 36% for *Pinus sylvestris*. This, in turn, could be partly explained by effect of needle cast on early survival of Scots pine at particular site. Theoretical biomass was modeled, assuming 66% survival for all provenances to obtain only effect from growth on the total biomass. Results reveal, that differences between species still remains significant and large (80.4 vs. 47.8 t ha^{-1} respectively).

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Provenance was a significant (p=0.01) factor affecting the above-ground biomass: it varied more than two-fold from 49.7 to 108.6 t of dry matter ha-1 (corresponding to average productivity of 2.6 to 4.9 t of dry matter ha^{-1} y^{-1}). Provenances with highest productivity were from latitude 53-55°N.

During the thinning process (leaving 700 dominant trees ha^{-1}) most of the biomass (61% on average) can be removed, corresponding to 27.6 to 74.10 t dry matter ha^{-1}. If the appropriate provenances are chosen lodgepole pine is attractive alternative for biomass production on poor sandy soils in Latvia.

Keywords: *productivity, provenance, above-ground biomass*

IMPROVEMENT OF TIMBER HARVESTING SYSTEM: APPLICATION OF DISCRETE-EVENT SIMULATION IN EUCALYPTUS PLANTATIONS

Nopparat Manavakun[1]

Forest plantations have become popular resources for timber production in Thailand, particularly Eucalyptus plantations. Because of their astonishing growth characteristics, climatic adaptabilities and utilization varieties, eucalyptus trees have rapidly expanded and become the most important commercial tree species. In timber harvesting, motor-manual based timber harvesting is the dominant conventional method in developing countries, such as Thailand. This is an ineffective operation that offers a low production rate and high risk. The general purpose of this research was to improve productivity, reduce cost, and enhance work safety. Hence, the specific aims of this study were to (1) investigate the appropriate technology in harvesting operations and (2) measure the potential system balance, production, and cost improvements achievable via the application of simulation-based operation.

The experimental observations were carried out during the final felling of Eucalyptus stands, five years rotation period. The proposed study focused on the work study involved in timber harvesting, time consumption models were developed. The ineffective working elements were examined through sensitivity analysis. Discrete-event simulation models were constructed to facilitate the comparison of alternatives. Simulations in this study were performed using the SIMUL8 simulation package. Several variables had taken into consideration in the simulation, such as log lengths, stem sizes, skidding distances, and winching distances. Currently, all three of the major conventional harvesting systems that are mainly employed are cut to length methods, but differ in the order of the working processes and in equipment use. Workflows of the three conventional harvesting systems are as follows:

System A: felling (brush saws), delimbing (hand tools), bucking (brush saws), stacking (manual) and loading (manual),

System B: felling (brush saws), delimbing (hand tools), bucking (brush saws), stacking (manual) and loading (loader),

System C: felling (brush saws), bucking (brush saws), delimbing and stacking (manual) and loading (loader).

In addition, an alternative system (system D) has been introduced, known as the tree length method, which involves the reorganizing of work processes as follows: felling (brush saws), skidding (farm tractor), delimbing (hand tools), bucking (brush saws), and loading (loader).

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Table 1. The relative productivity results from simulation categorized by bucking lengths and DBH classes

Bucking (m)	DBH classes (cm)	Relative Productivity (%)			
		System A	System B	System C	System D
2	5.01-10.00	100	102	158	246
	10.01-15.00	100	138	205	321
	15.01-20.00	100	140	205	357
	20.01-25.00	100	206	309	603
3	5.01-10.00	100	153	243	347
	10.01-15.00	100	142	213	413
	15.01-20.00	100	189	282	508
	20.01-25.00	100	284	433	656

Preliminary results indicated that bucking was the key element that had a significant impact on operating costs and productivity. In addition, simulation results showed that system D provided the highest productivity as well as the cheapest unit cost among the systems (Table 1). Likewise, harvesting productivity increased with increasing stem size and log length. Nevertheless, cost analysis suggested that the harvesting of small tree size, which dbh less than 10 cm, was not yet competitive in operating costs point of view (Figure 1). Moreover, the correlation test showed that increasing stem sizes and reorganizing work processes strongly improved the productivity. A positive correlation was recorded between stem sizes, working processes, log lengths and productivities. This means that changes in one variable are strongly correlated with changes in the production rate.

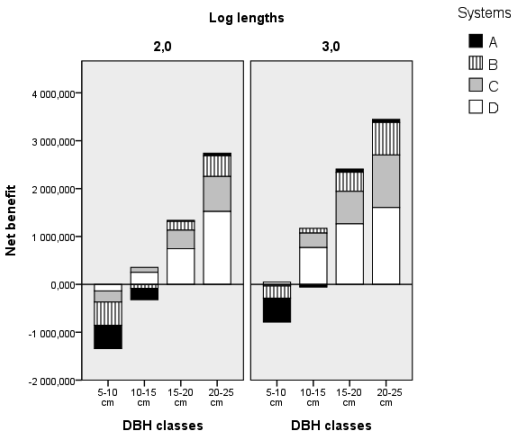

Figure 1. The net revenue of four timber harvesting systems.

To conclude, forest work is considered as a physically demanding and poorly paid job, it is difficult to recruit new workers, and a shortage of labour will become the main future challenge in the forest sector. In the long term, mechanized timber harvesting should be considered to replace labour-intensive operations.

Keywords: *harvesting systems, Eucalyptus, productivity, discrete-event simulation*

SUPPLY CHAIN OF LOGGING RESIDUES FROM *EUCALYPTUS GLOBULUS* STANDS IN ASTURIAS, SPAIN

Sandra Sánchez García[1], Elena Canga Líbano[1] and Dimitris Athanassiadis[2]

The aim of the study was to use two different methods to calculate the distance within which the current demand of a pulp mill for logging residues would be satisfied and to examine the possibility to install a standalone heat generation plant that would utilize the available quantity of logging residues considering the three levels of accessibility to the resource and the distance to the plant.

The asturian territory is divided into 22 classes according to Third National Forest Inventory (DGCN, 2003). The supply of logging residues (t/year) of Eucalyptus globulus stands from the forest area was calculated (classes 14, 15, 16 and 17). Table 1 shows the characteristics which define each classe where eucalyptus is present.

Table 1. Characteristics of the Eucalyptus globulus stands

Classes	Dominant species	Occupation	Characteristic stands	Canopy cover (%)	Area (ha)	Nº plots
14	*Eucalyptus globulus*	>=70	High forest Pole stage	70 - 100	36268.15	69
15	*Eucalyptus globulus*	>=70	High forest Pole stage	20 - 69	16026.86	47
16	*Eucalyptus globulus* with *Castanea sativa* or with *Pinus pinaster* or with *Pinus radiata*	30<=Esp.<70	High forest Pole stage	20 - 100	21545.47	67
17	*Eucalyptus globulus, Pinus pinaster* and *Pinus radiata*	>=70; 30<=Esp.<70	Ticket stage Sapling	5 - 100	12893.75	98

Different restrictions of accessibility (Table 2) were applied on the logging residue supply and total direct supply (level1), physically accessible supply (level2) and physically and legally accessible supply (level3) were calculated. Also the industrial demand of logging residues (171,486 t/year) of the ENCE pulp mill in Navia (Asturias) was taking into account, the road network was created from the National Cartographic Database (BCN200, 2010) E: 1:200.000 and the eucalyptus plots (279) were georeferenced.

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Table 2. Logging residues

Restrictions	Total logging residues (t/year)	*Eucaliptus globulus* logging residues (t/year)	% *Ecualiptus globulus* respect to total logging residues
Level 1	806706	324857	40.26
Level 2	612874	239156	39.02
Level 3	569993	234737	41.18

To work with the results of biomass per plot or classes indiscriminately, it was considered that the total biomass existing in a class was uniformly distributed between all the plots that belong to that class, i.e. for a class with N plots logging residues of each plot were equal to the logging residues of that class divided by N. Considering the council such as the smallest administrative area, it was decided to take the value of residual biomass for each level of restriction by council and divide by the number of plots belonging by the council. In this way were assigned values of logging residues (t/year) to each plot and for each level of restriction.

Two different methods were carried out to calculate the distances (best route) between the plots and the pulp mill. With method A was created a network dataset from the road network, using the NETWORK ANALYST (Closest facility) ArcGis 10.0 to find the shorter routes of supply from industrial site. With method B we proceeded in the same manner as in previous works (Athanassiadis *et al.*, 2011). Geodesic distances were calculated between each plot and the industry through the ArcToolBox tool (Near) ArcGis 10.0. To correct this distances taking into account the road network, it was identified the shortest route from a number of plots taken as a sample (10% of all plots for each council) to industry. The correction factor to estimate the real distance from each plot to the industry was 1.4.

Table 3 shows the distance (km) within which the industry satisfies its annual demand for logging residues (t/year) by method (A) and (B).

Table 3. Distances by method (A) and (B)

	(A) km	(B) km	ENCE anual demand (t/year)	Remaining logging residues (t/year)
Level 1	79	84	170279.77	149345.42
Level 2	102	102	170928.82	64791.62
Level 3	108	115	171442.10	59950.08

The distance calculated by method (B) is greater than with method (A) for 241 routes (87% of routes). That is, the method 2 overestimates the distance calculated by the road network (method1) with a mean of 11.43 meters.

After discounting the plots where biomass go entirely to industry, the possibility to install a biomass boiler or a plant in a particular place would be evaluated from three perspectives: amount of biomass available considering the three levels of accessibility, the

best routes of transport and the costs involved in forest operating system (bundle, forwarder and truck for transport to industry).

REFERENCES

Athanassiadis, D., Lundstronm, A., Nordfjell, T. 2011. A Regional GIS-Based Evaluation of the potencial and Supply Costs of forest biomass in Sweden. Dempartment of Forest Resource Management, Swedish University of Agricultural Sciences. Austro2011/FORMEC´11 Graz, (Austria), Octubre 2011.

BCN200, 2010. National Cartographic Database. "©Instituto goegráfico nacional de España".

DGCN 2003. Tercer Inventario Forestal Nacional (1997-2006). Asturias. Ministerio de Medio Ambiente,. Madrid. 439 p.

DETERMINING THE EFFECT OF TREE SIZE, BARK-WOOD BOND STRENGTH AND TREE FORM ON THE PRODUCTIVITY OF AN EXCAVATOR-BASED HARVESTER IN ACACIA MEARNSII IN THE KWAZULU-NATAL FORESTRY REGION OF SOUTH AFRICA

Muedanyi Ramantswana[1], Andrew McEwan[1] and Jeanette Pauw[1]*

The Acacia mearnsii (Black wattle) species covers 8.2% of the total plantation area in South Africa (Forestry South Africa, 2010). *A. mearnsii* is economically favourable as a plantation species as both the timber and the bark can be utilised. Traditionally in South Africa, the harvesting of A. mearnsii has been done using motor-manual systems in combination with manual systems, whereby chainsaws are used to fell and crosscut and manual labour is used to debark and debranch the trees. However, mechanization is becoming more attractive because of labour scarcity, increasing labour wages and declining productivity of manual operations because of HIV and AIDS. The aim of this study was to determine the effect of tree size, bark-wood bond strength and tree form on the productivity of cut-to-length harvesting of *Acacia mearnsii* using an excavator-based harvester in the KwaZulu-Natal forestry region of South Africa.

Tree diameter and height measurements were used to determine individual tree volumes, after which the trees were classified into different tree volume, bark-wood bond strength and tree form classes. Time studies were carried out to determine harvester productivity. Descriptive statistics and regression analysis were used to evaluate the influence of tree volume, bark-wood bond strength and form on the productivity of the harvester.

The results showed that tree volume plays a crucial role in the productivity of the harvester, but bark-wood bond strength and tree form also influenced productivity. The harvester productivity varied from 5.5 m^3 per productive machine hour (PMH) with 0.05 m^3 trees to 16.9 m^3 per PMH for 0.25 m^3 trees. The bark-wood bond strength did not influence harvester productivity when handling small trees of less than 0.1 m^3. In small trees, the productivity of the harvester was also not affected by different form classes, but as tree size increased, there was greater productivity variation between the different form classes. The results suggest that single-grip harvester cut-to-length harvesting system can be a viable option to effectively meet the labour challenges in South Africa.

Keywords: *harvester, productivity, tree volume, bark-wood bond strength, tree form*

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LOG LENGTH MEASUREMENT ACCURACY OF HARVESTER AND PROCESSOR HEADS: ANALYSIS OF SAWMILL MEASUREMENT DATA AND THE EFFECT OF AN INTERVENTION EXPERIMENT

Thomas Leitner[1] and Lukas Maier[1]*

Harvesters or processors become more and more important for log production in Austria. According to the Austrian Timber-Trade usages, a minimum over length (for this study 400 cm nominal length + 6 cm over length) has to be added at the bucking process. As there is some uncertainty of log measurement length are often intentionally exceeded to avoid a discount by not fulfilling the contract at sawmill. On the other side too long assortments cause losses and problems along the whole wood supply chain.

The main objective of this study is to sensitize the participants within this supply chain among harvester and processor length measurements. Besides certain literature studies, parameters that affect this process should be detected. Additionally, economic effects of over-length were evaluated. The aim of the intervention experiment is to observe the accuracy of the defined heads and impacts of calibration respectively maintenance to the measurement process.

For this project sawmill measurement data were statistically analyzed. The data were separated by harvesting systems (highly mechanized cable yarding; fully mechanized harvesting) and by season. At the intervention experiment the produced assortments from the heads (Woody H60, Komatsu 350.1) were measured and compared with the results of the machine's computer. Afterwards a certified engineer calibrated and serviced the heads and the comparative measurement was repeated.

The analyses showed that 47 % of the observed assortments were longer than 415 cm which means an over-length of 9 cm minimum. An essential influence among length measurement is the harvesting season (summer versus winter). The harvesting system for itself had no influence. Due to the produced over-length a loss between 0.93 € and 1.90 € per sold m^3 was calculated. The intervention experiment indicated that both heads measure accurately and through calibration and maintenance the difference (control measurement versus machine measurement) decreased from 1.09 cm to 0.66 cm (Woody H60) and from 0.76 cm to 0.21 cm (Komatsu 350.1).

Keywords: *length measurement, accuracy of harvester head, accuracy of processor head, intervention experiment*

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ANALYSES OF A MULTIFUNCTIONAL ONE-MACHINE HARVESTING SYSTEM IN EARLY THINNINGS FOR PULPWOOD AND ENERGY-WOOD

Fulvio Di Fulvio[1] and Dan Bergström[1]

Previous studies show that a multi-purpose forest machine with the capacity to change its configuration so that it can work as a harvester, forwarder or a harwarder can be a cost-efficient option compared to a two-machine system (harvester and forwarder) on sites from which the removal per hectare is less than 100 m^3; when the total removal volume per site is less than ca 250 m^3; when machine relocations tend to be frequent or over long distances; or when the annual harvested volumes per machine are below 20 000 m^3. This situation is typical for early thinning stands under private ownership in the north of Sweden.

According to these premises, a field study of a Ponsse Dual machine system with three types of heads (feller-buncher head, harvester head and a slash grapple) was carried out in order to measure the work time consumption in early thinnings. The study included harvesting and forwarding of pulpwood (felling and processing pulpwood), energy-wood (felling and bunching whole trees) and integrated harvesting, i.e. harvesting the two products at the same time (felling and processing pulpwood in one pile and bunching under-sized whole trees and tree tops in another pile). The aim of the study was to analyze the productivity, costs and profitability for the different machine's configurations/treatments in different stand conditions, when including harvesting costs from stump to the roadside.

The biomass removal per ha increased in the following order: pulpwood, integrated and energy-wood. The harvester work time consumption per tree did not differ significantly between treatments, while the productivity (m^3 PW-hour-1) was ca. 35% higher for the energy-wood treatment compared to the pulpwood and integrated treatment.

The forwarding efficiency was highly correlated to the biomass concentration (removal per ha) and forwarding distance; the forwarders' work time consumption per m^3 during loading work was for the energy-wood treatment 25% lower compared to the pulpwood and integrated treatments. Even though hauling of energy-wood (tree sections) give lower payloads than pulpwood, the forwarder productivity of energy-wood was the highest for all treatments over short distances (up to ca. 380 m).

The economic analyses showed that the Ponsse Dual harvesting system achieved the highest cost-efficiency during an exclusive energy-wood removal. Conversely, with current market prices, the pulpwood treatment gave the highest net income per ha, but it was still

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economically unprofitable in the studied conditions. In conclusion, the Ponsse Dual system achieved similar productivities found in literature on specialized harvesters and forwarders performing thinning work, but its operational cost per hour is much higher. Thus, if a single-machine system shall be economical competitive with a two-machine system in early thinning, its operational costs must be ca. 20-30% lower than for the studied Ponsse Dual system.

Keywords: *fuel wood, pulpwood, integrated thinning, harwarder, efficiency*

UTILIZATION OF MULTI-TREE HANDLING IN CUTTING OF THINNING WOOD

Kalle Kärhä[1], Antti Perho[1], Teuvo Kumpare[2], Sirkka Keskinen[3], Juha-Antti Sorsa[3], Asko Poikela[3] and Teijo Palander[4]*

The studies carried out by Stora Enso Wood Supply Finland, Metsähallitus, Metsäteho Oy, and the University of Eastern Finland determined the time consumption and productivity in cutting work when using the multi-tree handling (MTH) in thinning stand. The main aim of study was to clarify how large-sized thinning trees can be multi-tree processed cost-efficiently with adequate harvesting machinery.

The tested cutting methods within the studies were: 1) Separate cutting of pulpwood with single-tree handling (STH); fractions separated into separate piles (species) (Separate Pulpwood & STH). 2) Separate cutting of pulpwood with MTH; fractions separated into separate piles (species) (Separate Pulpwood & MTH). 3) Integrated cutting of pulpwood and delimbed energy wood with MTH; only butt log for pulpwood pile and the rest of stem for delimbed energy wood pile (Intergated Two Pile). 4) Separate cutting of delimbed stemwood with MTH; all fractions combined within same pile (Separate Delimbed Stemwood).

The working method comparisons were conducted with three harvesters: 1) the Ponsse Ergo 8w & Ponsse H7, 2) the Ponsse Ergo 6w & Ponsse H6, and 3) the Ponsse Fox & Ponsse H5 (Figure 1). Multi-tree handling in all harvester heads tested was conducted by software. Time studies were carried out in one first-thinning Scots pine (*Pinus sylvestris* L.) dominated stand in Vieremä (63°54'N, 26°55'E), in Central Finland in August 2012. There was one harvester operator in the time studies. The operator had over 10 years of experience with harvesting work in thinning operations and approximately five years of experience in multi-tree handling of pulpwood before the studies.

A total of 4,519 trees were cut in the time studies. All the trees felled during the time studies were hauled to the roadside landing and weighed with a crane scale. Ponsse LoadOptimizer crane scale was used for weighing. A total of 299 green tonnes were produced.

In the cutting methods 2–4, more than half (53% to 86% by time study plot) of the cut trees were multiple-tree processed. The diameter at breast height of the biggest trees that were multi-tree processed in the time studies was 15 to 18 cm. The studies indicated that relatively

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large-dimensioned ($d_{1.3}$≈15–18 cm) pulpwood trees can be multi-tree processed technically and cost-efficiently if we have a heavy enough cutting machinery (the operating weight of harvester is around 20 tonnes and harvester head >1 tonne), as well as a skilful harvester operator (Figure 2). Consequently, the results stated that MTH can be utilized also in dense later thinnings and small-dimensioned final cuttings.

Furthermore, the cost-effectiveness of thinning wood can be improved when delimbed stemwood fraction in addition to pulpwood is recovered from harvesting site. Besides, the study results displayed that the fewer timber assortments are harvested, the higher is the productivity of cutting work.

Figure 1. Multi-tree handling of pulpwood-dimensioned stems with the Ponsse Ergo 8w/H7 in the time study. Photo: Antti Perho.

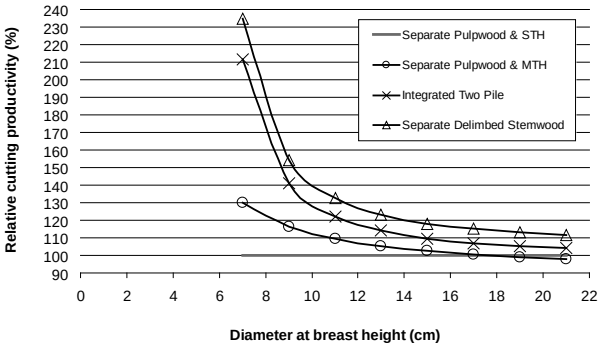

Figure 2. Relative productivity of the cutting methods as a function of stem size processed in the time studies.
Productivity 100 = Cutting productivity in the method of Separate Pulpwood & STH.

Keywords: *cutting, multi-tree handling (MTH), productivity*

THE IMPACT OF ROAD CHARACTERISTICS ON FUEL CONSUMPTION FOR TIMBER TRUCKS

Gunnar Svenson[1]

Fuel costs account for more than 35% of the transport cost in Swedish forestry. In order to lower these costs it is important to understand the impact on fuel consumption of a number of factors. In this study the impact of gradient, curvature and road surface roughness has been studied, as well as their correlation to functional road class.

The study was done with a 60 ton logging truck in an area which captured high variation in the studied variables. Topography and road surface roughness was measured with a profilograph.

The results showed a high correlation between fuel consumption and gradient, curvature, road surface roughness and functional road class. Functional road class was also found to be correlated to both curvature and road surface roughness.

A function describing the impact of gradient and road surface roughness on fuel consumption was established and it shows that 77% of the variation in fuel consumption could be explained by these two variables.

Keywords: *Logging truck, fuel consumption, gradient, curvature, road surface roughness, functional road class*

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CO_2 EMISSIONS OF FOREST CHIPS SUPPLY CHAINS

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CO_2 emissions of forest chip production are originating from fuel consumption of forest machines in raw material production and trucks in transportation of biomass and machinery. The main factors influencing the total emission per energy content of produced forest chips are machines' productivities and transportation distance to the power plant. This paper presents the CO_2 emission comparison of 12 forest chips production supply chains, which include logging residues and stumps from final fellings and small diameter trees from thinnings as raw materials. The supply chain operations taken into consideration were raw material production (felling and/or bunching, bundling or stump lifting), forwarding, chipping or crushing, transportation, loading and unloading of trucks and forwarders, and transportation of machinery. The productivities and fuel consumptions (diesel oil) used in this calculation are based on several studies concerning the productivity of forest machines, chippers and crushers in Finland. The fuel consumption of transportation trucks is based on the LIPASTO calculation system for traffic exhaust emissions and energy consumption in Finland.

The results show that the total emissions of supply chains per produced MWh of forest chips are directly related to the supply chains structure. If more processing, loading or transportation operations are involved, also more CO_2 emissions are produced during the supply respectively. However, the transportation distance to the heating plant has an influence on total CO_2 emission levels between different supply chains. At 45 km transportation distance, supply chains utilising logging residues from final fellings, chipping the raw material at the road side storage and transporting chips directly to the end use facility are producing the least amount of CO_2 emissions (Figure 1). At shorter distances loose raw material transportation and less processing at early stages of supply chain leads to lower emission levels per delivered MWh of forest chips despite the lower energy content of the truck load.

The most emissions are produced in stump supply chains with terminal crushing of biomass. Compared to other raw materials, the lifting of stumps is an additional work phase which requires the transportation of an excavator to the regeneration site. In addition, terminal chipping or crushing of biomass is increasing the emissions due the extra loading and unloading operations and the transportation of forest chips from the terminal to the power plant after processing.

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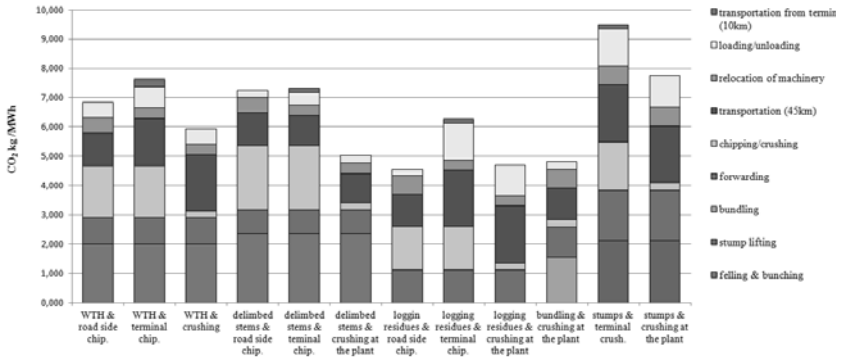

Figure 1. CO_2 emissions of supply chains by operation types.

When the transportation distance is increasing above 45 km, chipping of raw material at the road side gets beneficial, not only from economical, but also from energy efficiency and total emissions point of view (Figure 2). Also, the transportation of more solid raw material such as delimbed stems or residue bundles is more efficient with long distances. Terminal processing tends to increase the total emissions compared to other chains at all distances. An exception is the delimbed stems chain, where the transportation of solid wood keeps the total emissions closer to the levels of road side chipping options.

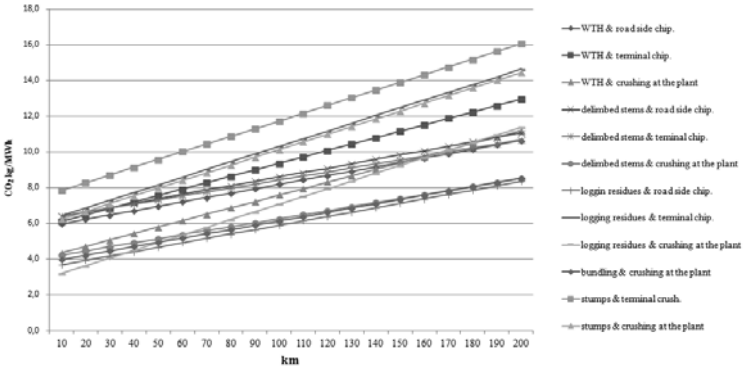

Figure 2. CO_2 emissions of supply chains by transportation distance.

In order to put the above figures into perspective, it is important to compare how much energy is used in the supply chains compared to the energy content of delivered raw material at the power plant. In this study the $MWh_{diesel}/MWh_{forestchips}$ ratio of supply chains varied between 1,7–3,6 %.

Keywords: *CO_2 emission, forest chips, supply chain*

CONTRIBUTION OF HARVESTED WOOD PRODUCTS TO GREENHOUSE GAS EMISSIONS DUE TO FOREST MANAGEMENT IN LATVIA

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The term "reference level" was introduced into the greenhouse gas (GHG) inventories of forest sector during negotiations about the second commitment period (2013 2020) of the Kyoto protocol (KP). The reference level (RL) has to characterize GHG emissions from forest sector under a "business as usual" conditions considering legal situation before 2009. The countries participating in KP are obligated to report their RL according to the Decision 2/CMP.6. Initial calculation of the RL for Latvia was done by the Joint Research Centre (JRC) in 2011; however, the results proposed incredibly high removals of CO2 in forest sector – 16 mill. tons of CO_2, including harvested wood products (HWP). The main reason for high rates of the future removals was underestimation of harvesting; during 2010 and 2011 the prognosis was about 20 % below the actual harvested volume.

The national projection of future harvests for a 100 years period was based on assumption that all forest owners have rights to extract timber, if there are no environmental or other restrictions. The software tool "Meža eksperts" was used to calculate harvest rate. The distribution of harvest stock was optimized to secure formation of even aged stand structure. The National forest inventory plots (about 9500 records) were used as input data considering every plot as a single forest compartment.

According to the study future harvesting rate will be 15.2 mill. m^3 annually (Figure 1). The most of increase of harvesting rate is associated with deciduous trees. Notably that theoretical potential of annual harvesting in the next decade is 40 mill. m3, because nearly half of forests in Latvia already reached age or dimensions, at which final felling is allowed.

The CO_2 removals in HWP was calculated using the model, which estimates delayed emissions on the basis of the annual stock change of semi-finished wood products (only primary processing and board production is considered). The estimation uses the product categories, half lives and methodologies as suggested in para 27, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4. The activity data for Latvia (production and trade of sawnwood, wood based panels and paper and paperboard) is derived from the TIMBER database (time series 1964–2009).The HWP numbers have been calculated applying the sub-categories of sawnwood, wood based panels and paper and paperboard as well as conversion factors as specified in Table 1. As suggested by the FCCC/KP/AWG/2010/CRP.4/Rev.4 emissions are

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calculated from locally originated wood using the first order decay function as outlined in the 2006 IPCC Guidelines.

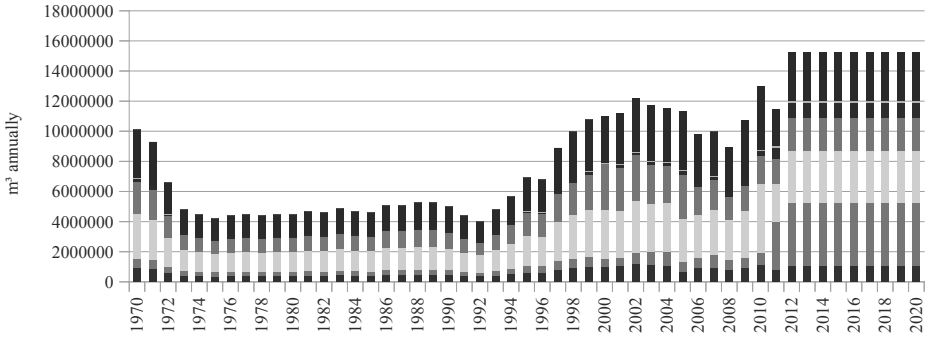

Figure 1. Historical and projected harvesting rates in Latvia.

Table 1. Recalculation coefficients for density and carbon stock

Classification		Type of HWP	Relative wood density, g cm^{-3}	Gg C 1000 m^{-3}
FAO	UNECE			
1866	1.2.C	Industrial rdw - coniferous	0.45	0.23
1867	1.2.NC	Industrial rdw non-coniferous	0.67	0.34
1632	5.C	Sawnwood -coniferous	0.45	0.23
1633	5.NC	Sawnwood - non-coniferous	0.67	0.34
1634	6 1	Veneer sheets	0.59	0.30
1640	6 2	Plywood	0.48	0.24
1646	6 3	Particle board (including OSB)	0.63	0.29
1647	6.4.1	Hardboard	0.85	0.42
1648	6.4.2	MDF (medium density)	0.73	0.32
1649	6.4.x	Fibreboard compressed	0.79	0.34
1630	6.4.3	Insulating board	0.27	0.11
1876	10	Paper and paperboard	0.90	0.45

The carbon removals in HWP are shown in Figure 2. Considering that the methodology developed by the JRC proposes static share of different HWP and export rate, production of all HWPs increases equally to growth of harvesting rate.

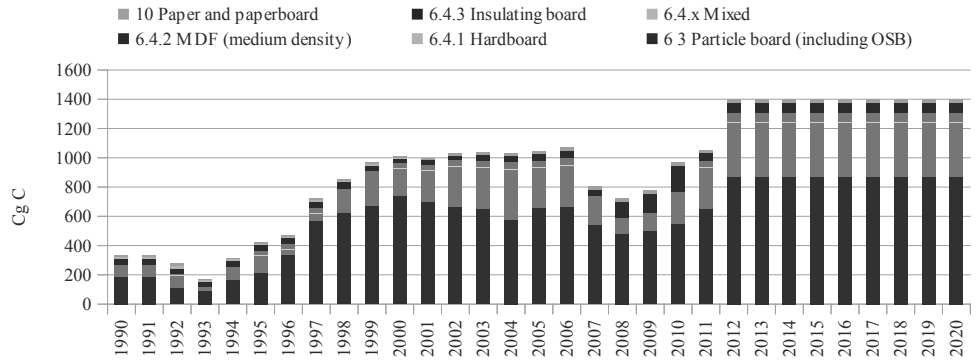

Figure 2. Annual removals of carbon in locally originated HWP.

Average net emissions from HWP pool in 2013–2020 according to the calculation would be -3101 Gg CO_2 (Figure 3). The share of HWP in the reference level than would be 37 %.

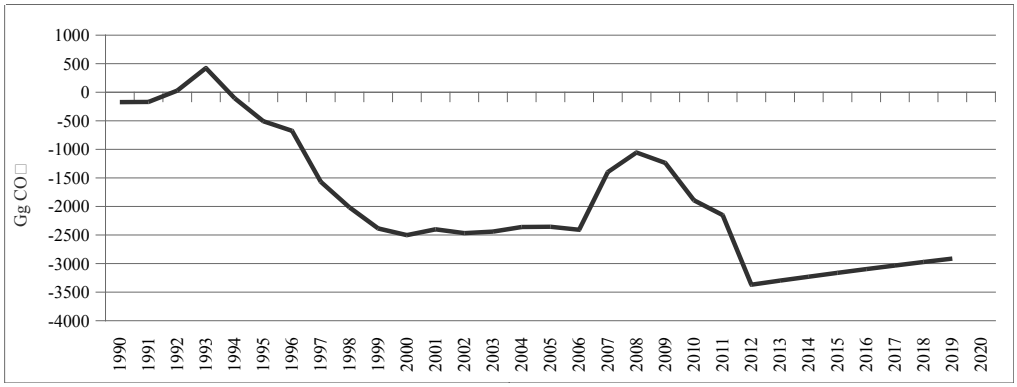

Figure 3. Net carbon stock changes in HWP.

Keywords: *harvested wood products, greenhouse gases, Kyoto protocol*

USING FUNCTION MODELLING TO DESCRIBE OPERATIONS MANAGEMENT – EXPERIENCES FROM A SWEDISH CASE STUDY

Emanuel Erlandsson[1]

In order for the Nordic forest industry to stay competitive, efficiency in the wood supply chain is crucial. Harvesting costs constitute the greatest share of the total production cost and management of harvesting operations is therefore a natural focus area for development. Improving operations management is important to increase machine utilization and work quality in harvesting operations. In order to find possibilities for improvement one must first understand existing work methods and constraints. This is commonly done by process modeling and there are numerous standards and techniques to apply for this, depending on the purpose.

The purpose of this paper is to communicate some experiences of applying function modeling to describe operations management. These experiences are based on a recent case study (Erlandsson, unpubl.) where the aim was to map the main business activities within two forest owners associations (FOAs) in order to identify the impact of organizational context on procurement, management and development of harvesting services. The study applied the IDEF0 (Integrated Definition for Function Modeling 0) standard for function modeling.

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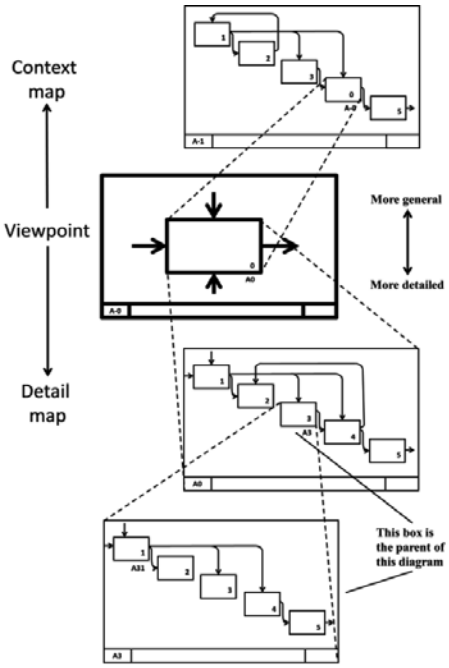

Figure 1. An illustration of levels and detailing in IDEF0 modeling (National Institute of Standards and Technology, 1993). Observe the hierarchical structure, illustrating the dependency between concurrently occurring activities.

IDEF0 is a standard for function modeling available at the US National Institute of Standards and Technology (1993). The standard is designed to consistently model functions with their hierarchy and interactions. When modeling with IDEF0 no organizational aspects are included, only the functions and their conducted activities. This makes the standard useful to compare activities between firms with similar functions but different organizational structures. The standard has been used in forest industry-related studies before (cf Cascini et. al 2008), and is also used in the wood supply education at SLU in Sweden.

When conducting the study, qualitative data was gathered through 16 interviews at two FOAs: one FOA without own mills and one FOA with own mills. By the rules of IDEF0, the harvesting function was defined as the viewpoint for the modeling. With this viewpoint, both a context and a detail modeling of functions and interactions were done. In the context modeling, all constraints for the harvesting function were modeled and tracked to their origin within the respective organizations. All main business activities were modeled in order to understand the dependency of the harvesting function on business functions. In the detail modeling, all activities within the harvesting function were modeled with increasing levels of resolution.

The final models visualized the impact of varying organizational context on operations management. The consistent syntax of IDEF0 made models easy to compare between two cases and differences could be easily identified, e.g. the greater number of activities and more frequent coordination for the FOA with own mills. This particular difference was interpreted as a result of the need for continuous adaptions of harvesting operations to own mill demand. The differences in the dynamics of the respective production systems also framed the conditions for procurement of harvesting services. The modeling of harvesting service procurement showed differences between the two cases. The FOA without own mills had certain harvesting capacity needs for the coming six month period (of contracted delivery volumes) but uncertain needs between six month periods. In comparison, the FOA with own mills had to continuously handle short term variation in mill consumption but had less uncertainty in the long term capacity needs.

Function modeling with IDEF0 proved to be a suitable tool for describing and comparing activities in operations management. The technique realistically captured coordination and feedback between and within functions, which are key elements in a dynamic production environment.

REFERENCES

Cascini, G., Rissone, P., Rotini, F. 2008. Business re-engineering through integration of methods and tools for process innovation. Proc. Inst. Mech. Eng. Part B-J. Eng. Manuf. (2008) 222:1715-1728.

National Institute of Standards and Technology. 1993. Integration Definition for Function Modeling (IDEF0). USA. Federal Information Processing Standards Publication 183.

USING HARVESTER CAN-BUS DATA FOR MOBILITY MAPPING

Jari Ala-Ilomäki[1], Sami Lamminen[1], Matti Sirén[1], Kari Väätäinen[1] and Antti Asikainen[1]*

Modern forest machines with hydrostatic transmission and CAN-bus engine and transmission management can be used or converted to measure power used in travelling. At constant speed on level ground this power is expended in overcoming motion resistance, which in turn is directly related to wheel sinkage and hence vehicle mobility or site trafficability. The harvester always precedes the forwarder on the site, making it feasible to use it to collect data on site trafficability to produce a mobility map for the forwarder. The process can be fully automated and the additional costs caused would be negligible. The study is part of Forestcluster Ltd's EffFibre- research program.

CAN-bus mobility mapping was tested with an 8-wheeled Ponsse Fox harvester and 8-wheeled Ponsse Wisent forwarder equipped for measuring transmission power expenditure, ground speed, wheel sinkage and wheel rut depth. Steel tracks for poorly bearing conditions were mounted on both front and rear bogies. Ultrasonic transducers were utilized for measuring wheel sinkage and rut depth. The depth of wheel rut was additionally measured manually at 4 m intervals. Tets track was laid partly on mineral soil and partly on peatland with varying peat deposit depth and bearing capacity. Shear modulus of the surface layer of the track was measured with the spiked shear vane at 4 m intervals on both left and right hand side of the track (Figure 1).

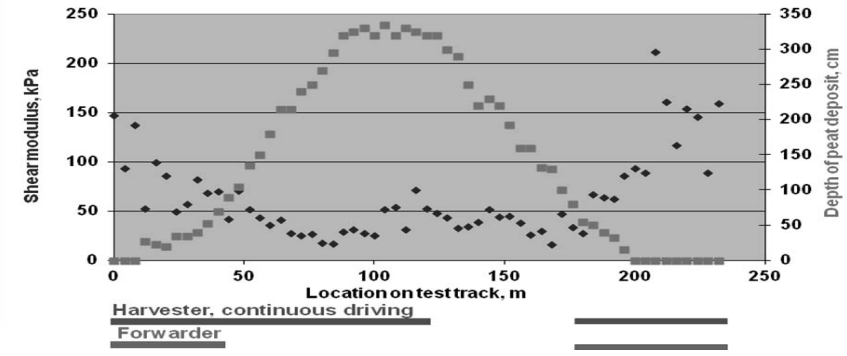

Figure 1. Average test track properties and test drive scheme.

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The test track was first driven by the harvester. First part of the track was driven with constant speed, then cutting timber in a normal manner and finally with constant speed. Harvester transmission power expenditure in continuous driving was converted into motion resistance coefficient using vehicle forward speed and gross vehicle weight (Figure 2). Further on net traction coefficient was calculated by substracting coefficient of motion resistance from the estimated net traction coefficient.

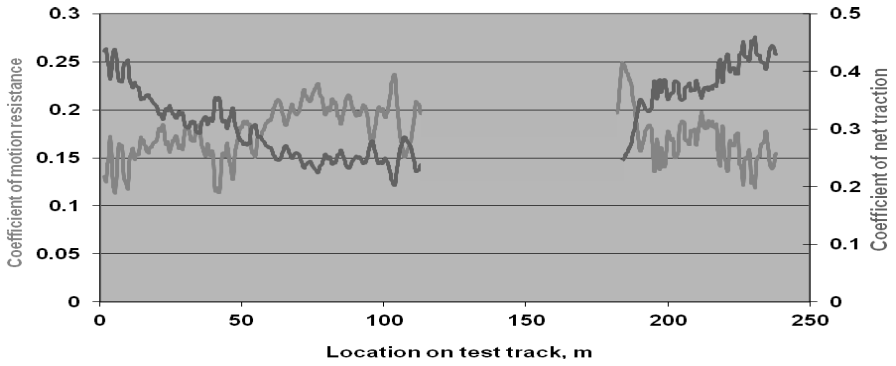

Figure 2. Harvester coefficient of motion resistance and net traction on the test track.

Logical connection between motion resistance and wheel sinkage/rut depth was found. Comparison of wheel sinkage and rut depth showed considerable soil rebound, indicating loading well below the strength of the surface layer (Figure 3). The track was thereafter passed by the forwarder. The operator judged the bearing capasity of the track partly insufficient and it was therefore traversed only partly. Wheel sinkage and rut depth measurements showed little soil rebound, indicating considerable destruction of peatland surface layer structure.

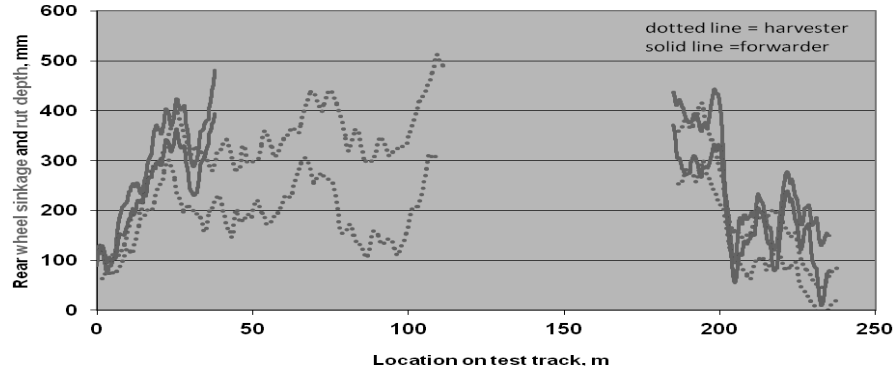

Figure 3. Rear wheel sinkage and rut depth on the test track at constant speed.

Comparing the mobility indicators from previous harvester pass with measured forwarder wheel sinkage and rut depth is the key factor in judging the validity of the CAN-bus based mobility mapping .Comparison indicated good potential for CAN-bus based mobility mapping. Estimated harvester net traction coefficient best described the track from forwarder mobility point of view. The absolute values of wheel sinkage and rut depth may vary, since the calibration of the ultrasonic transponders was made on a gravel road with no vegetation, whereas on the test track the effect of vegetation had to be filtered out. Also, rainy weather proved difficult for the ultrasonic measurements.

Keywords: *terrain trafficability, vehicle mobility, peatland, CAN-bus*

DISCRETE-EVENT SIMULATION OF COLLABORATION BETWEEN TRANSPORT ORGANIZATIONS

Dag Fjeld[1]

Many studies have examined the potential for cost reduction through optimized transport planning. Common areas of interest range from strategic transport system development to tactical wood flow planning and operational routing. A particularly interesting study by Carlsson and Rönnqvist (1998) developed a tactical model for combining simple and complex flow planning with certain routing restrictions to identify potential backhaul flows. This principle is an important element of transport management, and in practice relies on direct collaboration between independent contractors to coordinate the operational exchange of backhaul flows or loads (Lindström and Fjeld 2011).

The study examines the effect of various collaboration configurations on the operational success of exchanging backhauls between transport organisations. A discrete-event simulation model was built in ARENA to mimic the collaboration process. The simulation model was placed within a relatively simple supply system. Within the restrictions set by higher processes, the configuration of the backhaul exchange processes is varied by adjusting three variables. These include:

- the minimum number of loads that the organisation requires in its roadside stocks before a load can be included in a "bank" of potential backhauls available to the partner organisation,
- the interval that partner organisations communicate to exchange backhauls
- the maximum period that a load is allowed to spend in the backhaul bank waiting for a possible exchange before being returned to the roadside stock for direct transport.

Some general results were generated including a) how the transport output (tkm/yr) achieved by the trucks varied with the average size of their roadside stocks, b) how the number of potential backhaul loads varied with the average size of the organisations' backhaul bank and c) how the operational feasibility of the potential backhauls varied with the balance of potential backhauls between organisations.

Referring to the effect of specific variables, the results show how decreasing the *minimum roadside stock criteria* for allowing inclusion in the backhaul bank resulted in increased transport output, increased number of potential backhauls per year (and a larger average backhaul bank) and increased feasibility of potential backhauls (and increased number of successful backhaul exchanges per year).The results also showed how decreasing the time *between exchange of backhauls* resulted in reduced transport output, a reduced number of potential backhauls per

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year (and a smaller average backhaul bank) and increased feasibility of potential backhauls but a reduced total number of successful exchanges per year. The study did not, however, clarify the effect of decreasing the *maximum time that potential backhaul loads were permitted to spend in the backhaul bank*. This factor appears to influence annual transport output and backhauling only marginally. The results of the study are far from definitive, but the chosen method of offers further opportunities for simulating operations management processes in a number of contexts.

REFERENCES

Carlsson, D and M Rönnqvist 1998. Tactical planning of forestry transportation with respect to backhauling. Lith-Mat-R-1998-13.

Lindström, J and D Fjeld 2011. Routing of self-loading logging trucks in Sweden. Proceedings 34th Council on Forest Engineering. June 12-15 2011 in Quebec City.

TEMPERATURE IMPACT ON DISTRIBUTION OF ENTOMOLOGICAL DAMAGE IN NORWAY SPRUCE *PICEA ABIES* (L.) KARST. YOUNG FOREST STANDS

Luguza S.[1], Miezīte O.[1], Liepa I.[1], Indriksons A.[1] and Ruba J.[1]*

Due to the climate change annual temperature in Latvia increases. According to different authors rise in last 50 years ranges 0.8 – 1.4 degrees. Total sum of annual precipitation during last 40 years vibrates in between 169 mm and 692 mm but common tendency especially in winter period shows increase as well. Both the climatic factors mentioned above lead to changes in soil condition of forest stands.

Norway spruce is the second economically important tree species after Scots pine in Latvia. According to statistical data (State Forest Service, 2011) large territories of Latvia are covered with young stands of Norway spruce (in state owned forests – 178643 ha, in other owner forests – 104274 ha) – that is almost a half of the total area of all spruce stands.

Spruce is productive and precocious especially in young forest stand period. Because of being flat root system is subject for different risk factors – risk of root mortality is very height if some heightened precipitation period acquires that, could lead to massive tree die off. Prolonged draught periods cause similar effect: water deficit restricts root formation, initiates prolonged peace period of petite roots and obstructs longitudinal growth of main roots holding down process of mycorrhization.

Research results in Russia and Belorussia show that main negatively effecting factors of Norway spruce young forest stands are precipitant temperature change in winter, late spring and early autumn frost, strong cold wind, heightened level of precipitation and depleted soil. All of these factors can lead even to total degradation of trees. Forest biological stability is negatively caused by recession of groundwater level, ropy aeration and industrial pollution.

Climate change cause not only growth of forest stands but also dynamics of number of forest pests. Impact can be direct – resulting in changing parameters of individual tree growth and development as well as indirect – interaction to other species and abiotic components of environment, e.g. pests fertility arise and pupal growth occur faster if weather is quite dry.

Because of increasing impact of risk factors in forestry – both abiotic and biotic – can do cause significant economical loss to forest owner. Studying complex impact of all risk factors, choosing the most suitable model of forest management afterwards allow to avoid possible loos or at least decrease its impact.

In frames of research there is sanitary condition of Norway spruce *Picea abies* (L.) Karst. young forest stands evaluated in Zemgale, Kurzeme and Vidzeme regions. Main forest pests

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observed in sample plots in different parts of Latvia are spruce bud scale *Physokermes piceae* Shrnk., eastern spruce gall aphis *Sacchiphantes abietis* L. and bud moth *Cephaleia abietis* L. Proportion of occurrence of different damage is significantly different among regions as well as in separate forest stands.

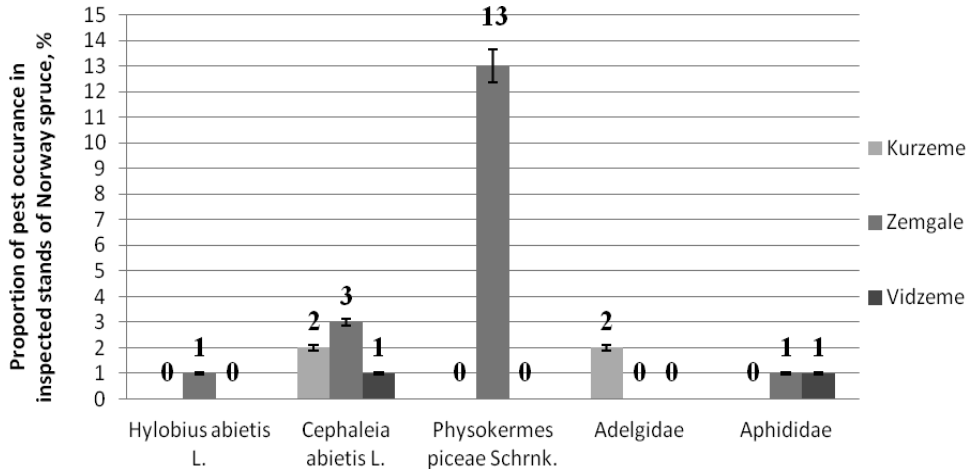
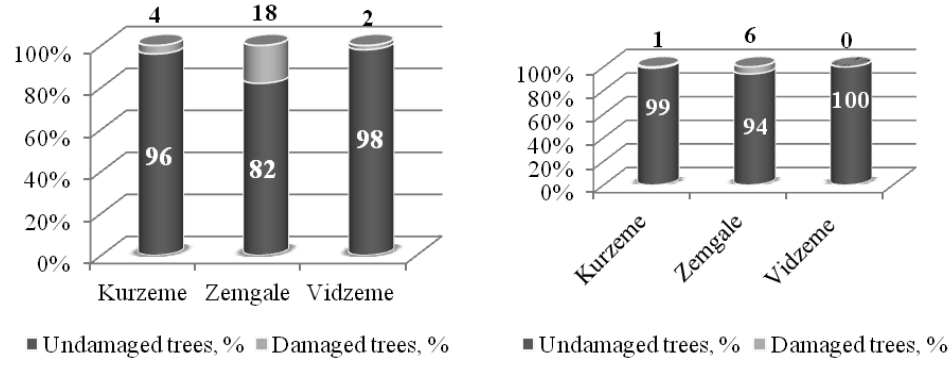


Figure 1. Proportion of pest occurrence in inspected Norway spruce Picea abies (L.) Karst. young forest stands in different regions of Latvia.

The most damage in inspected Norway spruce young forest stands is done by spruce bud scale *Physokermes piceae* Shrnk. (Fig. 1) as its occurrence in several stands is 0–90%.



A B

Figure 2. Pest damage situation in inspected Norway spruce Picea abies (L.) Karst. young forest stands in different regions of Latvia: A – proportion of occurrence, %, B – proportion of intensity, %.

Proportion of pest occurrence (18%) and proportion of damage intensity (6%) is found in Zemgale region but the lowest – in Vidzeme region.

Keywords: *Picea abies, entomological damage, temperature*

This research was funded by the European Regional Development Funds project 'The support system of planning and decision making for the sustainable forest management' (State Education Development Agency, Latvia University of Agriculture, contract number: 2010/0208/2DP/2.1.1.0/10/APIA/VIAA/146).

INVESTIGATION OF HEAVY METAL IN URBAN FOREST PARK

Seyed Armin Hashemi[1] and Setareh Koochaki Chenani[1]*

Unquestionably, the urban green space and environment should be considered to be among the most fundamental elements of the sustainability of natural and human life in the new citizenship. The present research is intended to evaluate the impact of irrigation using urban waste water of Iron (Fe) and Zinc (Z) in leaves of the buttonwood trees of Rasht in the forest territories of Rasht. For this purpose, following the exact specification of the geographical and topographical attributes of the observant area and under treatment area sample trees were implemented randomly – systematically in each compound studied. Approaching the end of growth season, 120 trees were selected randomly and samples of leaves were collected from the parts near to the end of the crown and the part which was adjacent to the light. The results of the present research suggest that urban waste water can be used as a source of irrigation whereas muck can be employed in forestation and irrigation with precise and particular supervision and control.

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APPROBATION OF THE ROAD INFRASTRUCTURE FRIENDLY TRANSPORT TECHNOLOGIES ON THE LOW BEARING CAPACITY LOCAL ROADS

Atis Zariņš[1], Kārlis Būmanis[2] and Māris Lietuvietis[2]*

Latvian low volume roads and particular – their pavements shows serious problems in form of cracking, rutting, other deformations and which finally leads to weak serviceability and short lifetime of the road structure. In many cases these problems has been associated with heavy goods transport, overloaded vehicles and their impact. To find the role of heavy loads, and in particular – timber haulage transport, on road pavement deformations and evaluate their prevention possibilities, as well as to investigate the efficiency of freight transport, and establish conditions that will allow to do it, a study is carried out by the Forest and Wood Products Research and Development Institute (MeKA) in cooperation with Riga Technical university (RTU) within research program of Latvian State Forests JSC.

As option for load impact reducing, the Central Tire Inflate system (CTI), installed on the test truck, is being checked. The research methodology is based on deflection measurements with LWD together with dielectric constant measurements in a road structure using percometer. Measurements are taken in the various pavement structure layers in different depths, during full-scale loading and in different moisture/temperature conditions. Increase of the contact surface is established using the CTI, which was installed on the test truck with total weight of 52 t. Data obtained after three test sessions indicate that using tires with lowered pressure can increase service life of road up to 50%. Results for comparison are collected in the Table 1. The number of test vehicle passes with each type of tire pressure, until clear indications of pavement collapse was fixed, are recorded in the table.

Table 1. Comparison of test vehicle passes until pavement collapse

No of Test session	0.35 MPa (with CTI)	0.8 MPa (standard pressure)
1	>22	17
2	>23	18
3	>26	17

Using lowered pressure (0.35 MPa) tires collapsing condition of the road structure were not observed after designated count of passes.

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As fixed in current research, structure of typical low volume road can be collapsed by passing of less than twenty close following heavy vehicles. To prevent this, considering of traffic intensity margins is necessary. These margins define boundaries of pavement workability. Most of low volume roads with unbound pavement can carry on some ordinary heavy vehicle passes. Each of them breaks pavement structure in some extent. Current research establish that reasonable number of close following heavy vehicle daily passes on typical low volume road not exceed 15-20. Exact number of close passes varies depending on subsoil, pavement, and drainage condition. That number can be increased up to 50% by using lowered tire pressure. This prevents of upper layer damage and supports pavement compaction. It was concluded, that the reduced pressure in tires significantly reduces the impact on the upper layer of the pavement.

Keywords: *road, pavement, bearing capacity, dielectric permittivity, CTI, LWD*

ORGANIZATIONAL ANALYSIS OF CABLE YARDING OPERATIONS IN THE NORWEGIAN WESTLAND

Giovanna Ottaviani Aalmo[1]

This paper presents the preliminary results of a research assessing the relationship between work and workers' wellbeing in a cable logging operation in the Norwegian Westland. In order to evaluate the working conditions, a full organizational analysis considering all phases of the work will be performed using the Method of Organizational Congruences by Bruno Maggi.

After about 50 years of purposeful afforestation, coastal and fiord areas developed significant resources, probably the largest Norway has had over the last 300 years.

Because of the geomorphological conditions only a lower level of mechanization is permitted hence the use of cable yarding harvesting systems to yield is basically, the sole solution. This type of operations, compared to ground based harvesting systems, are considered labour-intensive.

The working procedures on steep terrain are heavier, more physically demanding and dangerous, as only partial mechanization is possible. The predominant system for clear-felling these areas is the motor-manual/tree-length extraction method. The trees are felled by chainsaw and then extracted for processing to a landing by a skyline. Two types of skyline systems are in use: the standing skyline and the running skyline in our study we will consider both systems.

Forestry workers have always been considered as an occupational group at high risk of work-related injury. Considering factors affecting injury among them a major proportion of the literature relates to tasks involving chain saws, such as felling and delimbing, and the operation of forestry machinery (Slappendel, Laird *et al*. 1993). The present labor situation in Norwegian slopes is dependent on migratory workforce that has no initial skills in mountain logging. The almost total lack of professional training, as learning by doing is still frequent, amplifies the safety risks of work that is already potentially very hazardous.

To assess the working conditions, all phases of the work will be investigated the Method of Organizational Congruences (Maggi). The study takes into consideration different crews operating on running and standing skylines. The analysis will lead to identify for each technical action the typical elements of organizational constraints (OC) affecting the physical, mental and social well-being of the workers.

The expected outcome of the study is to identify solutions in order to assure high

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productivity, avoidance of illness and injury risks as well as increased gratification among the workers. Ergonomic benefits reducing work strain, danger or discomfort of working with cable yarders would likely benefit the industry through improved recruitment productivity and retention within the forestry sector (Ottaviani, Talbot, Nitteberg, Stampfer).

TERRAIN TRAFFICABILITY CLASSIFICATION OF LOGGING MACHINERY ON PINE MIRES

Uusitalo Jori[1] and Ala-Ilomäki Jari[1]*

During the last decades the Finnish Wood Industry has directed its logging activities mainly towards mineral soil forests. The pronounced reduction of suitable logging sites on mineral soils will, however, force the industry to increase the volume of logging activities in peatland forests. More intensive utilization of peatland forests calls for logging activities to be increasingly carried out during unfrozen conditions.

Peatlands are problematic from a logging operations point of view. The mean tree size and stand density are generally lower than on mineral soils leading to low harvesting removal. The ditch network weakens machine mobility and the average primary transportation distance is generally double compared to mineral soils. The most severe factor affecting timber harvesting is however poor trafficability of the peatland forests (the ability of terrain to support vehicular traffic).

The paper presents a terrain trafficability classification based on logging machinery and characteristics of soil and growing stock. The classification system is based on series of field studies carried out in southern Finland in 2008 and 2009. The classification system can be used in assessing the suitability of vehicle types and equipment needed to carry out logging in unfrozen peatland forests.

Keywords: *tree harvesting, peatlands*

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ABSE09 – A GREAT SUCCESS

Niklas Fogdestam[1] and Anna Furness-Lindén[2]*

ABSE09 – A GREAT SUCCESS

ABSE09 is a so called agreed document. Agreed documents are by juridical definition industry-specific, standard agreement, settled between buyer and seller. Typically, these are formulated by a committee, including buyer and seller representatives from major companies or organizations of the business. By referring to this set of standard formulations in every specific contract, the agreed documents are held legally binding. Agreed documents typically consider matters such as liability, cancellation, damages on third party, delimitations on warranties, right of interpretation and actions undertaken in case of dispute. A set of agreed documents is often found in industries where contracting processes are undertaken in a quite repetitive way and where products or services sold are relatively homogenous. Standardizing and thereby rationalizing the otherwise quite extensive purchasing work as such, is of course an overall purpose, combined with the aim to minimize costs within the buyer-seller system, created by experienced uncertainty. Facility management, construction, transportation, manpower leasing and software subscriptions are examples of industries all using a well-established set of standard agreements.

AGREED DOCUMENTS IN FORESTRY

Benefits of standard agreements also apply to the business of forestry. Today in Sweden contractors are carrying out the major part of forestry operations (both in silviculture and logging), and the structure of the forestry services market is similar to other entrepreneur-based businesses. In Sweden, a set of forestry-specific agreed documents, "Allmänna Bestämmelser för Skogsentreprenad" (in short ABSE09) were launched in December 2009, after negotiations of one year and a half. Also, a set of templates was developed.

THE SITUATION TODAY

Today more than half of Sweden's forest land is managed by companies and contractors who have adopted ABSE09. A couple of surveys and interviews have been performed and they all show that the users of ABSE09 are very satisfied with it. Time consuming negotiations about details can be reduced to more substantial talks about remuneration. Right now (June 2012) a master thesis work at the Swedish University of Agricultural Sciences (SLU) about the implementation and practical use of ABSE09 is being carried out. The preliminary result from this thesis will be presented at OSCAR.

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THE FUTURE

The goal of the committee is that all forestry management in Sweden will be conducted in accordance with ABSE09. The benefits are substantial, e.g: the parties will be encouraged to find ways to conduct a continuing dialogue, as well as display openness and trust for their mutual benefit. Good cooperation, communication and clarity are necessary in order to reach the intended result in all kinds of contracted work. The committee is convinced that ABSE09 would be beneficial for all countries in the OSCAR-network.

Keywords: *ABSE09, contractors, entrepreneurs, apse and agreed documents*

REFERENCES

Furness-Lindén, A. Nytt avtalspaket för effektivare upphandling av entreprenader i skogen. Skogforsk, Uppsala. Resultat 3, 2010.

Lindskog, C. in prep. Master Thesis. Implementation and use of ABSE09. SLU.

ABSE09, Standard Conditions for forestry-related contracting. 2009.

PREDICTING MOISTURE CONTENT IN A PINE LOGWOOD PILE FOR ENERGY PURPOSES[1]

*Gernot Erber[2], Christian Kanzian[2] and Karl Stampfer[2]**

Determining the moisture content of naturally dried fuel stock without frequent measuring is a problem still unsolved. Modeling moisture content based on automatically captured meteorological data could provide a solution. An accurate model would allow the drying period and the point of chipping to be optimised. For the experimental study, a metal frame supported by load sensors and loaded with 17 tons of logwood was set up next to a meteorological station. A multiple linear regression model was used to link meteorological and load data to provide a formula for determining the moisture content. The pile dried for a period of 14 months (average temperature of 7.3 degrees, a humidity of 81 %, and 777 mm of rainfall). The overall moisture content dropped from 50.1 % to 32.2 %. The regression model, which based on daily means and sums of meteorological parameters, provided a mean deviance from the observed curve of -0.51 % ± 0.71 % within the period of investigation. Relative humidity was found to be most important parameter in drying. Increased moisture content resulting from rainfall greater than 30 mm per day reverted back to pre-rainfall values within two to three days, if no other rainfall events followed. Covering the pile would have a positive effect on the drying performance. In terms of economic benefit it could be shown that natural drying is beneficial. Overall this study shows that meteorological data used in site specific drying models can adequately predict the moisture content of naturally dried logwood.

Keywords: *moisture content, natural wind drying of fuel wood, modeling, log pile*

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COMMINUTION PRODUCTIVITY OF FOREST CHIPS DURING LAST 30 YEARS IN FINLAND

Kalle Kärhä[1]*

There are several comminution time studies conducted during the last 30 years in Finland. We gathered together all Finnish comminution time studies of forest chips. The aim of the survey was to clarify the productivity development of comminution work during the last 30 years in Finland when comminuting different raw material of forest chips (whole trees, delimbed energy wood, logging residues, and stump and root wood). Besides, we investigated how carefully each study has been documented, in other words, can the reader evaluate the effects of different key factors (i.e. operator, comminution machinery, storage conditions, and logistic facilities) on the productivity of comminution work at the roadside landings, terminals, or energy plants in the time studies.

All comminution time studies applying with farm tractors and terrain chippers were excluded out of final survey data. Total number of comminution time studies in the survey was more than 15 studies. There were only some time studies of stump crushing and delimbed energy wood chipping made in Finland during the last 30 years. Therefore, the productivity developing was produced only from the comminution of whole trees and logging residues.

The results indicated that the productivity of chipping whole trees at roadside landings has not increased during the last 30 years in Finland (Figure 1). Correspondingly, according to the time studies of comminuting logging residues in the survey, the productivity has significantly improved in Finland (Figure 1).

The survey illustrated that all comminution time studies has not been reported properly. For instance, there is a lack of information about the working experience of machine operator in the study, what has been the moisture content of raw material, and covered storages or not. Hence, there are problems to perform the comparisons between different comminution time studies. The survey calls for some guidelines and harmonization of reporting more carefully comminution, and also the other time studies.

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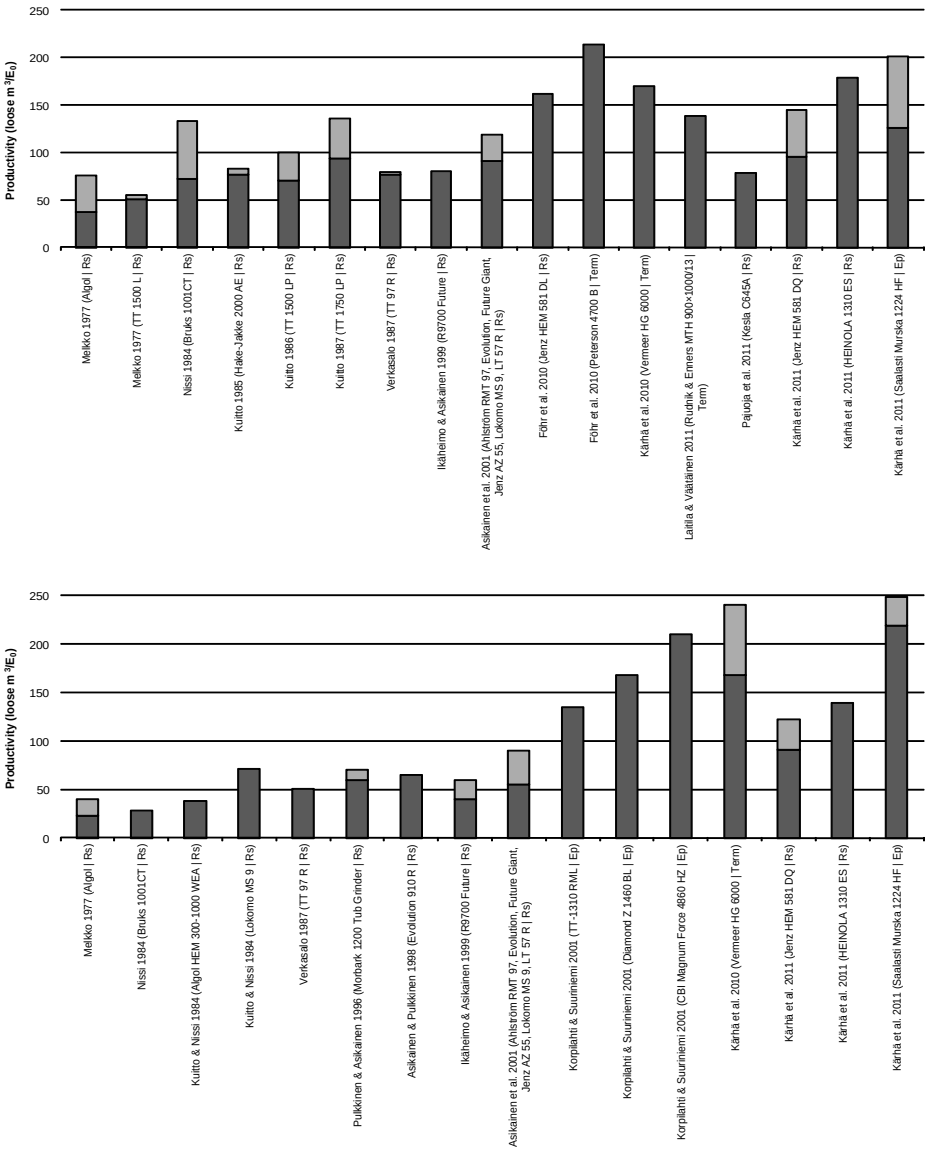

Figure 1. The productivity of comminuting of whole trees (top) and logging residues in the time studies in 1977–2011 in Finland. (Comminution place: Rs=Roadside, Term=Terminal, and Ep=energy plant).

Keywords: *comminution, productivity, wood chips*

DIGITAL INFORMATION FLOWS IN SWEDISH FORESTRY – BOTTLENECKS AND POTENTIALS

Karin Westlund[1] and Maria Nordström[1]*

Access to and use of digital information is increasing in forestry as well as in other sectors. However, to be able to leverage the potentials that digital information offer, well-functioning data management systems as well as a suitable organization of work must be in place. If these prerequisites are fulfilled, the information obtained can be used to streamline business operations. In Swedish forestry of today, the flows of digital information are typically interrupted so that data that could be of use later in the wood supply chain is trapped on the way. These problems are partly explained by the fact that data is not always stored and communicated in a standardized way. On-going work is performed to develop existing data standards as well as establishing new standards when there is currently a lack. Difficulties also arise in getting different data management systems to interact with each other and so that information can flow through the different logistic nodes in the wood supply chain in order to increase overall efficiency and performance.

This project aims at identifying common bottlenecks in the digital information management in Swedish forestry, estimating potentials for improving efficiency and profitability through better use of digital information. The aim of the project is also to identify a number of key indicators that can be used for continuous monitoring of performance in the value chain. As a basis for this analysis, process mapping in selected use cases has been performed. The scope of the process mapping has been to describe the flows of material and digital information from the landings in the forest to the receiving industry. This includes handling of data around products as they are first stored at roadside, then transported to and received at a mill. Through the process mapping, the interfaces and roles of information ownership have also been studied. The project points out potentials to increase efficiency and thereby profitability in the Swedish forestry value chain by improving the quality and function of information flows. The project specifically highlights the value of accurate and timely information to the right audience. A method for continuous measuring and follow-up of the forestry value chain performance and efficiency was suggested through a set of selected indicators, KPIs.

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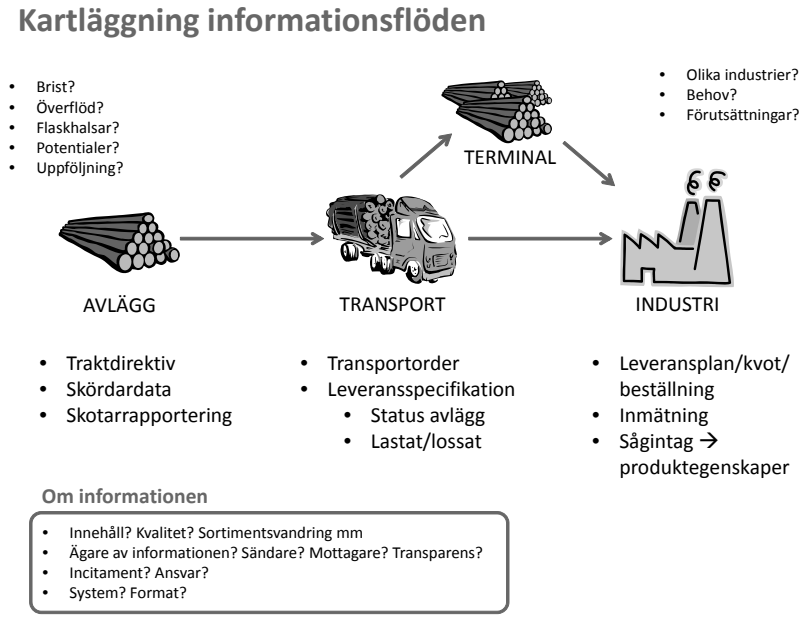

Figure 1. Interface nodes for the digital information flow, from landing to mill.

Keywords: *information flow, digital information*

A REVIEW OF MECHANICAL METHODS FOR WOODY BIOMASS COMMINUTION AND SORTING

Gunnar Eriksson[1], Dan Bergström[1] and Tomas Nordfjell[1]*

The increased demand for woody biomass for e.g. power generation and biorefining means that the trees biocomponents must be used efficiently. To meet the coming increase in raw material supply, biomasses such as e.g. small diameter trees from early thinnings, logging residues and stumps must by utilized to a higher degree. Sorting of these materials biocomponents may increase their value considerably, and the challenge is to maximise the overall values of the different fractions for different users and minimise the supply chain costs. Comminution of biomasses to e.g. to chips and chunks and sorting the trees components, e.g. separating bark and needles from stem wood, are important processes in this optimisation.

The purpose of this study has been to make a worldwide literature review of principles for mechanical comminution and sorting suitable for woody biomasses. The results show for examlpe that more efficient comminution methods can be developed when the wood is to a larger extent cut along the fibre direction, and closer to the surface (with less pressure to the sides of the knife). By using coarse comminution (chunking) rather than fine comminution (chipping) render significantly increases in efficiency at the same time as the material get better storage and drying properties. Rolls and flails can be used to an increasing extent for removing foliage and twigs, possibly for in-stand operations. Physical parameters used for sorting of the main components of trees include e.g. particle size, density and shapes. The results of the review give possiblities to design possible future systems for efficient handling of woody biomass components.

Keywords: *biorefining, chipping, crushing, forest residues, screening*

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DIRECT LOADING SYSTEMS IN SWEDISH FORESTRY – OPERATIONAL FORESTRY, STUDIES AND ANALYSIS

Isabelle Bergkvist[1]

Direct loading systems is the generic term for systems in logging operations were the logs are processed and loaded onto the loading-space of the terrain transport equipment. In contrast to systems used today were the logs are processed and left on the ground by the harvester and collected and transported to roadside by the forwarder. The idea and gain of direct loading systems is to reduce work elements (loading from ground etc.) and thereby increase efficiency and decrease fuel consumption. The system can consist of one combi-machine or a harvesting unit together with one or more transport units, where some of the units can preferably be unmanned. The Harwarder (combi-machine) and the Besten-system (unmanned harvester with two manned forwarders) are two examples that have been tested in operational forestry in Sweden. A system with a manned harvester and unmanned shuttles has been simulated in studies. Neither of those systems are built or sold in serial-production but some interesting innovations and test systems are starting to come out on the market. In studies, evaluations of practical operations and theoretical analysis the direct loading systems appears to have a great potential to be competitive compared to harvester/forwarder systems. In addition different direct loading systems are seems to be competitive under different conditions.

The aim of this presentation is to show some examples on benefits and disadvantages of different systems based on knowledge from practical use. The comparison focus on following aspects:

I. Operators attitude towards tested systems
II. Results in studies concerning production and cost
III. Competitiveness under different conditions
IV. Potential of development

Direct loading are of many seen as the next big technical step of development. Correctly used and with a high potential of improvement the method might contribute to 20% higher productivity and > 30% reduction of fuel-emissions.

Further, those systems show other benefits such as better handling of the logs (less dirt on the logs), minimizing lead time for the industry and improved ergonomic conditions for the forest workers.

Keywords: *logging, direct loading, timestudies and systems analysis*

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AIRBORNE LASER SCANNING FOR PREDICTION OF BEARING CAPACITY OF PEATLANDS

Lindeman Harri[1], Ala-Ilomäki Jari[1], Siren Matti[1] and Uusitalo Jori[1]*

Airborne laser scanning (ALS) data is commonly utilized in forest inventories to predict stand estimates. Utilizing ALS data is already in production use in forest inventories in Finland. There are plentiful of ALS data scanned by different forest organizations. It would be reasonable to find out other ways to utilize quite expensive ALS data in forestry. The new approach is proposed here for prediction of bearing capacity of peatland forests.

In the study, two different ALS data will be utilized to predict bearing capacity. Densities of ALS data are 4 hits per m^2 and 1 hit per m^2. Stand estimates of dense data were predicted using tree crown approach method. The area based approach (ABA) was used with sparse data. Canopy height model (CHM) and digital elevation model (DEM) will be also utilized in prediction of bearing capacity.

Both stand estimates and elevation model will be utilized in prediction of bearing capacity. Both timber volumes and basal areas will be used in predictions. Greater growing stock will be supposed to define better bearing capacity. DEM will be edited to find out elevation differences in small-scale. Those areas, which are above neighbourhood, will be supposed to have better bearing capacity than those areas, which are below neighbourhood. Possibilities to replace stand estimates in prediction by CHM will be studied.

Predictions of bearing capacities will be tested during summer 2012. There is a peatland stand in Rautavaara, Pohjois-Savo in Finland, where studies will be carried out. Stands will be thinned. Growing stock, vegetation and soil features of sample plots will be measured. Study stands will be harvested with a harvester and a forwarder. The ruts of trails will be measured after harvesting.

Keywords: *ALS, tree harvesting, peatlands*

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DEVELOPING AND IMPLEMENTING A CONCEPT FOR QUALITATIVE AND QUANTITATIVE ASSESSMENT OF FOREST INFRASTRUCTURE USING GEOGRAPHIC INFORMATION SYSTEMS

Adrian Enache[1,2], Ewald Pertlik[2] and Valentina D. Ciobanu[1]*

Assessment of existing road networks represents the first step in the process of enhancing forest infrastructure, providing relevant information required for planning new forest roads, while skidding distance is one of the most relevant parameters used for evaluating the quality of a forest road network. Classic methods for calculating structure indexes of road networks require an in depth and time consuming analytic approach. But sound decision making in forest engineering requires effective and easy to use tools that provide quality relevant data prior to technical designing and construction of new forest roads. In this paper a concept of qualitative and quantitative assessment of existing forest roads and skid trails in a mountainous region, using Spatial Analyst Tools™ and Network Analyst Tools™ from ESRI® Arc GIS and MS Office Excel®, based on a geometric approach and multiple criteria analysis will be presented. In this respect, a project area of about 903 ha from a Romanian private forest enterprise located in mountain regions has been used. The status quo of existing forest roads in project area has been evaluated, surveying and mapping out specific categories of road quality issues. In GIS, a grid (raster) of 100 by 100 m has been defined for deriving shortest skidding distance from each management unit (sub-compartment) to existing forest roads, which was further used for calculating mean skidding distance at the level of the entire project area and for calculating other structural indexes of the forest infrastructure. The mean skidding distance resulted from this geometric approach has been compared with the real mean skidding distance calculated based on field measurements through classical methods. Approximately 71,5 km of existing skid trails and skid tracks have been mapped using a Garmin 60 CSx GPSMAP device at recording at intervals of 5 seconds. Recorded data has been used in ESRI® Arc GIS for calculating the existing real mean skidding distance and for sensitivity analysis. Buffer zones representing maximum skidding distance have also been used to assess the quality of the road network and for calculating the relative openness index of the project area. The buffer zones have been defined considering current Romanian standards and harvesting technologies, while thinking also on possible envisaged mean

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skidding distance values for new harvesting technologies. The length of necessary forest roads that need to be planned in order to achieve a complete relative openness of the project area has also been calculated. GIS assessments and sensitivity analysis were proved to be useful tools for decision making in tactical and operational planning regarding the reengineering of forest infrastructure.

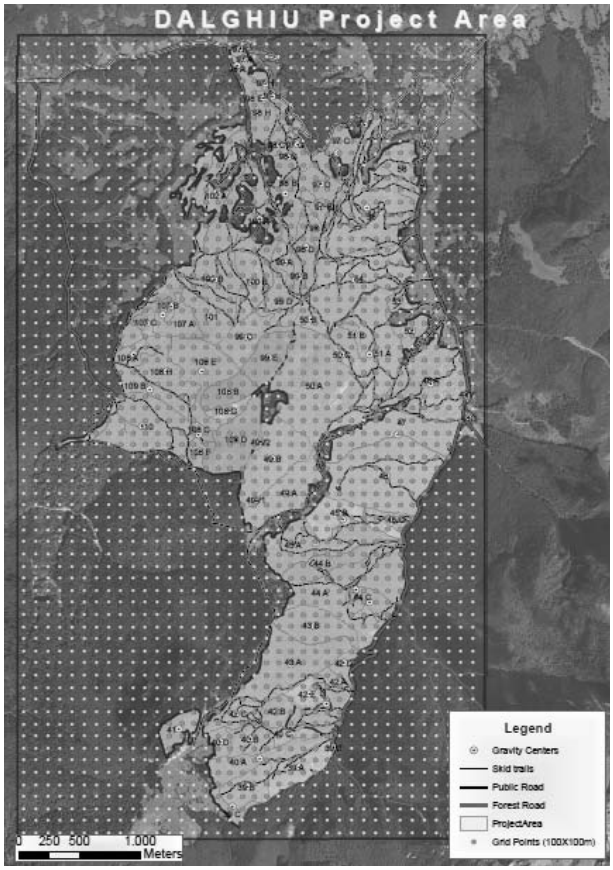

Figure 1. Project area with mapped skid trails network and surveyed points.

Keywords: *forest road network, qualitative assessment, operational planning, decision making*

SIMULATING THE EFFECT OF FLEET MANAGEMENT ROUTINES ON MILL DELIVERY PRECISION AND TRUCK UTILIZATION

Dag Fjeld [1]

Delivery precision is an important dimension of mill service and is most often defined as the percent of agreed volume per assortment delivered per period. A typical goal for a single supplier's delivery precision has been +/- 10 percent per month and many mills are now aiming for +/- 5 percent with a more even flow within the month. Monthly delivery goals per mill and assortments are typically termed quotas. For transport management, mill quotas may be broken down to contractor-specific quotas to be filled from each contractor's portfolio of transport orders (assigned responsibility for harvesting sites).

Transport management routines vary between organizations, but a typical element is quota follow-up. This is an interim control of how transport contractors are fulfilling their monthly quotas. In practice, interim follow-up is typically done on a weekly interval. A transport manager's responses to deviations between actual deliveries and the assigned quota can vary from priority signals to accelerate the flow of certain assortments to a full stop of other flows.

The effects of different transport management routines on *delivery precision* and *truck utilization* have not been quantified in earlier studies. **The aim of this study** was therefore to mathematically model the effects of different quota follow-up routines on the two above variables.

Methods – The study focused on the dynamics of the quota follow-up process. An object-oriented discrete-event simulation model was constructed in ExtendSim for monthly delivery periods. The model is based on a simple structure with three districts (and their respective contractors) transporting roundwood from roadside stocks to three mills. The model implements two corrective measures which are triggered if deliveries pass the upper or lower deviation limits at the interim follow-up. When the sum of deliveries to a mill exceeds the upper allowable limit, a full stop of all deliveries to that mill is imposed and the transport resources are re-routed to the other road-side stocks. When the sum of deliveries to a mill fails to reach the lower allowable limit, a priority is attached to all loads destined for that mill, and these are given first right to all transport resources. The corrective measure is then maintained until the next follow-up. Weekly and daily follow-up intervals were modeled with 10 and 5 percent limits for allowable delivery deviations. Because oversupply is common in midwinter and undersupply during the spring thaw or after summer holidays,

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the different management routines were nested within three different supply scenarios: 10 % oversupply, supply balance and 10 % undersupply. 15 runs were made for each alternative (see table 1 below).

Table 1. The distribution of simulations per combination of follow-up interval, delivery deviation limit and supply scenario

Supply scenario	Delivery deviation limit	Quota follow-up interval	No. of runs
10 % oversupply	+/- 10 %	Weekly	15
		Daily	15
	+/- 5 %	Weekly	15
		Daily	15
Supply balance	+/- 10 %	Weekly	15
		Daily	15
	+/- 5 %	Weekly	15
		Daily	15
10 % undersupply	+/- 10 %	Weekly	15
		Daily	15
	+/- 5 %	Weekly	15
		Daily	15

Results – Delivery precision: For the supply scenario where wood availability was balanced with mill demand, daily quota follow-up resulted in a match between the delivered volume and mill demand for both levels of allowable delivery deviations. Variation in delivered volumes was greatest for a supply scenario of 10 percent oversupply and least for 10 percent undersupply. Average delivery volumes were higher for daily follow-ups than weekly follow-ups for all modeled combinations. The differences between delivered volumes for daily and weekly follow-ups were greatest for the oversupply scenario and least for the undersupply scenario. Given the same follow-up interval, and assuming there was "enough wood" (oversupply or balance), deliveries were always higher for an allowable delivery deviation of 10 % than 5 %.

Truck utilization: The average truck utilization ranged from 96–99 % for oversupply to 91–94 % for supply balance and 84–85 % for undersupply. In most cases, average truck utilization was higher for daily than weekly follow-ups. For the supply scenarios with "enough wood" (oversupply or balance) the two following results should be noted: 1) For daily follow-ups, narrower limits for allowable delivery deviations (5 percent) increased truck utilization, 2) For weekly follow-ups, narrower limits for allowable delivery deviations reduced truck utilization. The effect of ambitions for higher delivery precision on truck utilization depends therefore on quota follow-up interval.

Conclusions – Increasing delivery precision (from +/- 10 percent to +/- 5 percent)

requires a higher frequency of quota follow-ups. The effect of quota follow-up routines on delivery precision depends on the supply situation. During periods of sufficient road-side stocks, narrower limits for allowable delivery deviations implemented with daily follow-ups increased average truck utilization. Narrower limits for allowable delivery deviations implemented with weekly follow-ups reduced truck utilization.

EVALUATION OF SITE IMPACT AFTER HARVESTING IN STEEP TERRAIN WITH EXCAVATOR ASSISTED GROUND BASED SYSTEMS

Bruce Talbot[1], Daniel Kindernay[2], Giovanna Ottaviani Aalmo[1], Nicholas Clarke[1] and Jan Bjerketvedt[3]*

This presentation reports on the results of a post-harvest evaluation of stands harvested using excavator-assisted ground based CTL systems in steep terrain. The practice of using an excavator to assist a conventional harvester in gaining access to steep terrain – by excavating a series of temporary strip roads – is expanding rapidly and is now commonly found along the entire coastal region of Norway and in the mountainous parts of Sweden.

Applying this method, the excavator alternates with the harvester after all trees within crane reach have been harvested, and opens up another 6-8 metres of road at an acceptable slope, then once again yields to the harvester. Studies of the technical and economic performance of this system showed the harvesting cost to be roughly 50% of cost of using cable-based systems in similar terrain (Lileng 2007) . However, concern has been expressed as to the sustainability of this practice, as it is commonly performed on steep slopes in high rainfall areas and it includes little or no planning, no drainage, and no stabilization. Cable-yarders by comparison do not require access into the stand, and when the load is suspended on the skyline, there is no impact on the soil surface.

The stands, located in Hordaland County in western Norway, were harvested between 0-6 years prior to the evaluation. Factors included in the evaluation were; slope analysis and classification (10m*10m grid), the identification of potential erosion hot-spots (confluences of road run-off) for further monitoring, and calculating strip road length to area ratios. The strip roads were measured using a handheld GPS. All analyses were done using ArcGIS 9.3.

Intermediate results show that very high strip road densities, over 1500 m ha^{-1}, are sometimes necessary in providing sufficient access to the stand and that these could be reduced by increasing the degree of motor manual felling to the machine. Severe point and gulley erosion has occurred in some stands but this has generally been stayed by the underlying rocky colluvium (Fig. 1).

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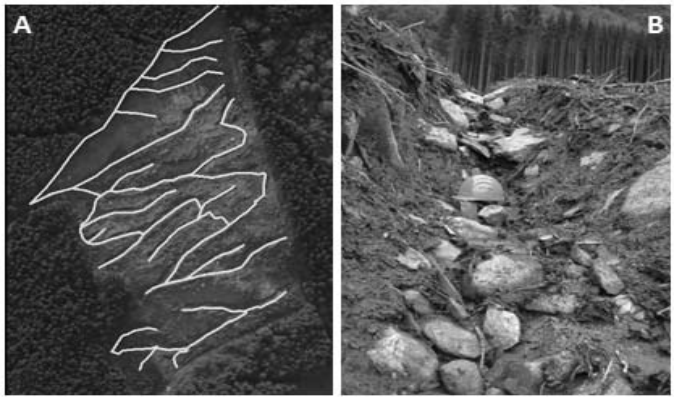

Figure 1. (A) high density of strip roads on the steep slope (B) erosion gulley from forwarder wheel track inhibited by underlying material.

While a significant area of the site is disturbed, those harvested up to six years prior to the evaluation were found to have recovered to a degree where vegetation on and between the strip roads was indistinguishable. Some roads continue to lead water and therefore constitute an erosion threat which could have been alleviated through the construction of simple cross drains at harvesting time.

Erosion losses are initially large from specific points and gullies and do cause increased turbidity and silting in smaller streams, but the combination of high rainfall, and steep and turbulent streams and the very short distance to the fjords make this difficult to quantify. Further comparative studies with cable-yarding systems in similar terrain are needed in order before drawing broader conclusions as inter-site variability is high. The excavator assisted harvesting could be further developed through stricter planning requirements, improved de-activating of strip roads, and a higher degree of motor-manual felling to the harvester, thereby reducing the strip road density.

REFERENCES

Lileng, J. (2007). Harvester and Forwarder in steep terrain. 3rd Forest Engineering Conference – Sustainable Forest Operations. J.-F. Gingras. Mont-Tremblant, Quebec.

Keywords: *logging, erosion, environmental performance*

POSSIBILITIES TO USE AUTOMATIC AND MANUAL TIMING IN TIME STUDIES ON HARVESTER OPERATIONS

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Since the introduction of the first harvesters in the Nordic countries in the 1970s, investigations of harvester work have relied on time study which is the most common work measurement technique for work studies. During that period timing techniques in forestry operations have developed from decimal watches to 2000-millenium's automated recorders of harvesters. In the mid-1980s hand held field computers started to replace decimal watches and paper forms in time studies, providing better possibilities for measuring more detailed and accurate time phases. The advantage of electronic hand held field computer was to record simultaneously the continuous cumulative working time and time consumptions of each work phases more accurate and easier than using traditional decimal watch. In the 2000s, it became possible to collect time study data automatically by using a harvester computer connected to CAN-bus (controller-area network) channels. The benefit of the CAN-bus for time studies on harvester operations is the possibility to record large amounts of time study materials with highly detailed and accurate projection of the harvester work per each processed stem.

This study concentrates to the use of automatic and manual timing (using a hand held field computer) in time studies on harvesting operations. The results based on three case-studies analyze the suitability of automatic and manual timing to choose the most suitable time study technique depending on the research problem.

In the future the automation of harvesters continues. Also the computer-based systems supporting the operator's work are already today an essential part of productive wood procurement chain. The results indicate that automatically recorded time study materials are accurate and large and their division of work phases is highly detailed. Furthermore the time consumptions of work phases of automatic recording can be combined with the information of various machine and operator functions in stem and log level. This is necessary for technical machine development and to better understanding of the structure of human-machine work. However the harvester operation includes unforeseen situations which can confuse the automatic time study projection.

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Furhermore the results revealed that the measuring accuracy of manual timing is limited, especially in intensive time studies. However, there is still a need for manual time studies, when measuring new work process. This is especially true in short studies, with quite limited data; and in fairly varying circumstances, where the presence of a observer is required to detect unexpected working situations on the logging site. The presence of the observer during the experiment gives a visual and practical overview about the work performance which decreases the risk of systematic errors in time study data. Also the reliability of automatic recording increases if the view of the observer about the work performance is compared with the interpretation of the results of automatic timing.

Keywords: *harvester operation, work study, time study*

FIELD STUDY OF A FORWARDER TRAILER CONCEPT – LOWER COST AND FUEL CONSUMPTION AT LONG DISTANCES

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In ground based transport of products from the forest to roadside the impact on the soil should be minimized, which implies small (i.e. light) loads and careful driving. However, economical rationality implies large loads and high speed. Recently, the concept of adding a trailer to a conventional forwarder has revived, with the objective to comply with both concerns and to fit into the current mechanized CTL system.

Here we present the results from field experiments of the forwarder trailer concept compared to conventional forwarding at final felling operations. The tested forwarder's ordinary payload was 15 tonnes, and the trailer added another 10 tonnes. This increased the total travel time and fuel consumption during transportation, but resulted in a reduction of time and fuel required per forwarded tonne. To load and unload the trailer took longer time and required more fuel than for the forwarder. Thus, viability of trailer usage was dependent on the transportation distance. The results show that usage of the forwarder trailer should reducing fuel consumption for transportation distance over circa 300 m single way. Given the costs for the tested forwarder and the rather simple trailer (cost ca 20 000 €), the trailer should be cost-efficient at distances over circa 500 m. However, those distance limits are under more or less optimal condition (i.e. flat terrain). There was no recorded soil disturbance differences between forwarder with or without trailer, most likely due to the good bearing capacity of the stand's till soil.

The field studies indicated some practical limitations with the tested trailer. The attachment of the trailer needs further development and some kind of load fixation should be considered, to prevent slippery logs to slide off in slopes. Moreover, the continuous use of trailers might harmfully stress the forwarder's crane and powertrain components, and should be evaluated before large scale implementation. Nevertheless, based on the results it can be concluded that there are environmental and economical potentials that warrant a further investigation of the forwarder trailer concept, which currently is tested in practice on several places in Sweden.

Keywords: *forwarder, ground pressure, productivity, cost-efficiency, fuel consumption, comparative field study*

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WOOD HARVESTING MACHINERY MARKET IN RUSSIA

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IDENTIFICATION OF THE MARKET

There is expected to be a remarkable growth in Russian forest machine markets in the long run mainly because of a need for renewal of current machines and because of a huge cutting potential. The total Russian market for harvesting machinery is approximately half of billion Euros per year. There are about 20 enterprises producing harvesting equipment in Russia, but the market has an oligopoly character: most of the machines are produced by *Machinery & Industrial Group N.V*. Domestic machinery production has collapsed after the USSR collapse in both quantity and models from over 20,000 harvesting machines per year in the soviet time to 2,000 in 2007-2008 and 254 (10 feller-bunchers, 76 skidders, 48 delimbers, 120 over-the-cab loaders) in 2009. As a result, only half of the total Russian harvesting machine fleet is in a good state. Therefore, importing of machinery has been increasing substantially and was reached about 1,000 machines per year in 2007-2008 and 800 machines (€300 million) in 2011. Relief of customs duties on the imported high-tech equipment further improves export opportunities. The development of sharing among different logging methods, such as cut-to-length (CTL), full-tree (FT), and tree-length (TL), is going to have a significant influence on division between market shares. The fleet of FT&TL machines in Russia is estimated to be 20,000 machines including the imported machines from North America. Western machines for FT and TL are available on the Russian market: about 30 feller-bunchers and 120 skidders per year were imported to Russia in 2005-2011. However, the share of western machinery in FT and TL fleet is small; only about 1,400 machines. The recent development of forest operations includes the fast implementation of CTL harvesting, transfer of technology, introduction of commercial thinning and energy wood harvesting. The traditional Russian systems are used side-by-side with Nordic technology. More than 25% of wood is harvested with the CTL method including 20% with a harvester nowadays. The fleet of CTL is estimated to be 2,000 forwarders and 1,700 harvesters; mostly imported machines. Approximately 240 harvesters and 270 forwarders per year mainly produced in Nordic countries are imported to Russia in 2005-2011.

DEVELOPMENT OF THE CTL MACHINE MARKET

Over 20 years of experience with the operation of CTL harvesting machines have demonstrated their effectiveness to logging companies in Russia; *i.e.* better labour conditions in terms of ergonomics and safety, and less environmental damage and reliability in combination with convenient operation and maintenance. CTL harvesting was introduced

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in the Russian regions along the Finnish border in the 1990s, mainly because Finnish entrepreneurs and forest machines from Finland operated in this cross-border area. The CTL method has become even more common in the 2000s, alongside with an increase in the import of harvesters and forwarders. The proportion of harvesting done using CTL systems has increased, especially in Northwest Russia, where more than 50% of harvested wood is already logged with the CTL method. The domestic production of harvesters is quite low in Russia, whereas companies in Nordic countries are major CTL machine producers in global markets. The import duty on harvesters has been quite low (5%) in Russia. At the beginning of 2007 harvesters were freed from the import duty, but at the end of 2009 the duty was restored to 5%. Finland dominates in the CTL machine market in Russia (70% of all imported CTL machines in 2011). The export of harvesters from Finland to Russia increased substantially during 2002–2008 (Fig. 1). The record of over 50 exported harvesters to Russia in one month was achieved in November 2007. At the end of 2008 exports decreased sharply, and at the beginning of 2009 export almost ceased, but is recovering after 2010. Three manufacturers dominated on CTL market: *John Deere* (43% of all harvesters and 34% of all forwarders imported in 2011), *Ponsse* (29% and 27%) and *Komatsu Forest* (18% and 25%). Most popular CTL models are *John Deere* 1270 harvester (35%) and *Ponsse BUFFALO* 8W forwarder (17%). Russian forest machine manufacturers have tried to design and produce domestic harvesters and forwarders, but have been unsuccessful.

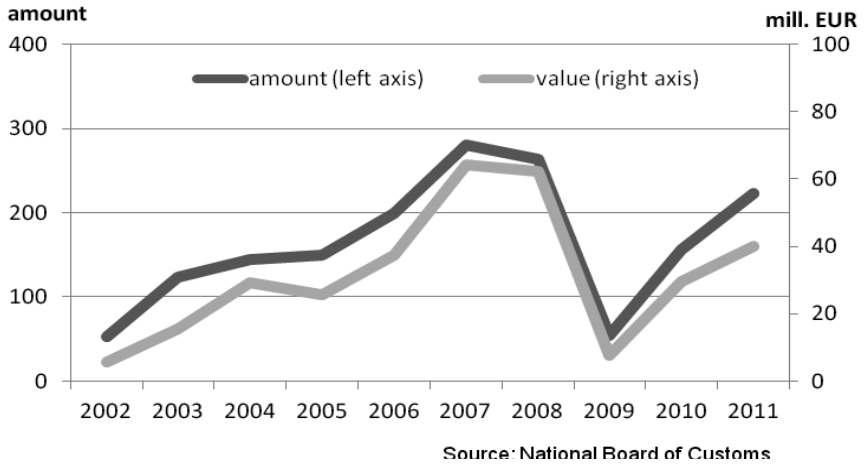

Figure 1 Export of harvesters from Finland to Russia in 2002–2011.

IDENTIFICATION OF CUSTOMERS

Russian end-users of wood harvesting are generally logging enterprises with leased forests and in some cases contractors. Some large enterprises had wood harvesting employees within the firm. Most of the enterprises that contract out or hire wood harvesting employees

are large firms that specialized in producing sawn timber, pulp and paper, or both. Due to productivity and environmental pressures, those end-users need mobile, versatile, efficient, and environmentally friendly harvesting machinery. The challenge of adhering to strict environmental regulations in the face of intense competition has increased the demand for new CTL systems in many Russian regions, such as the Leningrad. The total number of logging enterprises registered in the Leningrad region in 2010 was 631 with 11,488 employees; however, only about 100 enterprises lease forests for wood supply. Harvesting operations are concentrated into large and medium-sized enterprises, which usually belong to international pulp and woodworking mills. The annual allowable cut (AAC) of the 30 largest forest leasers was about 5 million m^3 with actual harvest of 3 million m^3. The four largest logging companies with an annual harvested wood of more than 200,000 m^3, i.e. *International Paper* and *Metsäliitto*, represented the key players in pulp industry. The companies with 100-200 thousand m^3/a, i.e. *Svedwood* and *Mayr-Melnhof-Holz*, represented the largest players in sawmilling. This means that nine key companies procured approximately half of the region's annual harvest. The next 14 companies with 50-100 thousand m^3/a provided about 30% and approximately 50 small companies harvest the rest 20%.

SCENARIOS FOR THE ESTIMATION OF MACHINERY MARKET SIZE

The estimation of machinery market size for industrial and energy harvesting in the Leningrad region (as a case study) was based on three scenarios: "Actual", "Allowable", and "Potential". Scenario "Actual" assumed continuing the current level of wood harvesting. It means the current utilization of AAC. The estimated potential for energy wood from logging operations was 3.5 million m^3/a based on 7.9 million m^3 actual harvest. About 2.3 million m^3 was non-industrial round wood and felling residues in the cutting areas and 1.2 million m^3 derived from the central processing yards. The volume harvested with CTL was 3.2 million m^3 within 40% of actual harvest in 2006. Scenario "Allowable" assumed increasing availability of energy wood resources based on full utilization of AAC, utilizing current logging technology and increasing sawn timber production according to the green-field projects, such as *Metsäliitto*, *Mayr-Melnhof-Holz* etc. The Allowable scenario means that the annually harvested stem wood volume in the final felling would increase from 5.1 million m^3 to 9.5 million m^3. It is assumed that current proportions in logging technologies remain, but that the share of felling by harvesters increases from 1/3 to 2/3. The amount of energy wood available from logging could be as high as 5.3 million m^3 if the entire AAC of 9.5 million m^3 were utilized, if collected. About 3.3 million m^3 is non-industrial round wood and felling residues in the cutting areas. The volume harvested by CTL is 4.9 million m^3. Scenario "Potential" assumed increasing availability of energy wood due to implementation of intensive forest management; resulting from a significant increase of commercial thinnings, full utilization of AAC with CTL, and increasing sawn timber production according to available sawlog output in the region. According to "Potential" scenario, commercial thinnings would increase from 1.5 million m^3 to 4.6 million m^3 and 100% implementation of fully mechanized CTL. The amount of energy

wood available from logging could be as high as 7.2 million m^3 if also thinnings were done in full scale, if collected. The assumption is that all is harvested with CTL technology, i.e. 15.3 million m^3 of which 40% is from thinnings.

ESTIMATION OF MACHINERY MARKET SIZE FOR THE REGION AND LOGGING ENTERPRISES WITH LEASED FORESTS

The results indicated that the annual market for CTL machinery in the Leningrad region can be approximately 20-30 medium sized purpose-built harvesters/forwarders and short-wood trucks each (about €20 million per year). The market could be 30-40 units/a in the future, if AAC is utilized or even 50-60 harvesters, forwarders and short-wood trucks per year, if also commercial thinnings are done on a full scale. The current market for energy wood machinery can be approximately 4 biomass forwarders, 10 mobile chippers and woodchip trucks per year. The market could be about 15-20 units/a in the future, if AAC is utilized or 30-40 biomass forwarders and mobile chippers per year, if also commercial thinnings are done on a full scale. Only one third of the current forest leasers in the region have enough leased forest resources and could be users of fully mechanized CTL technology based on the Actual scenario. These 41 enterprises need 270 CTL machines altogether – 90 harvesters, 100 forwarders and 80 trucks. Thirty-seven companies need 50 chippers, 50 biomass forwarders, and 60 woodchip trucks for energy wood harvesting. The share of the 10 largest enterprises would be half of the total fleet. Sixty percent of forest leasers in the Leningrad region had enough leased forest resources and could be users of fully mechanized CTL based on the Allowable scenario. These 68 enterprises need 500 CTL machines altogether – 160 harvesters, 190 forwarders and 150 trucks. Fifty-six companies need 100 chippers, 100 biomass forwarders, and 110 woodchip trucks for energy wood harvesting. The share of the 10 largest enterprises would be half of the total fleet. Sixty percent of current forest leasers in the region have enough leased forests resources and could be users of fully mechanized CTL based on the Potential scenario. These 71 enterprises would need 770 CTL machines altogether – 260 harvesters, 280 forwarders and 230 trucks. Seventy companies would need 150 chippers, 150 biomass forwarders, and 180 woodchip trucks for energy wood harvesting.

In retrospect, the development of logging companies in the Leningrad region during 2005-2010, which reported €21 million/a of annual CAPEX, proves indirectly the justice of our methodology. The rate of wear of fixed assets was declined from 50% in 2005 to 16% in 2010. The economical indexes of technology development shows positive signals, as the renewal rate increased from 14% in 2005 to 55% in 2010. Now there are also better possibilities to finance purchase of technology.

Keywords: *feller-buncher, skidder, delimber, harvester, forwarder, truck, mobile chipper*

IMPROVEMENTS OF VALUE CHAINS BY SIMULATIONS AND PRODUCTION REPORTS FROM CUT-TO-LENGTH HARVESTERS

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CTL-HARVESTING OPERATIONS ARE INTEGRATED PARTS OF DIFFERENT MANUFACTURING PROCESSES

Physically, the manufacturing process of wood based products starts with the logging operations. Consequently the forest conditions, infrastructure, industry structure, demand and preferences for certain wood properties, competition and market pricing will be of large importance for wood suppliers. Cost and availability of forest machinery, skilled personnel, efficient information systems and tools for decision support are other important prerequisites. Thus, the planning operation includes several interconnections between Cut-To-Length (CTL) harvesting of logs and the subsequent industrial processes aiming for different end products. To facilitate increased efficiency and profitability in combination with reduced environmental load detailed knowledge of the conditions and developed tools for estimating and mastering benefits, costs and risks are needed. Each value chain starts with expressions of customers' needs matched with characterization, valuation and pricing of the available forest resources and estimated costs for harvesting, alternative sorting and deliveries in relations to the sum of demands from contracted industrial customers.

STANDARDIZED INFORMATION FOR IMPROVED PLANNING AND PRODUCTION

Skogforsk and collaborating partners in R&D, machine and system manufacturing, practical forestry, harvesting and logistics have developed communication standards ("StanForD for all information to and from forest machines", "Standard for information on forests and forestry in Sweden", papiNet for deliveries and business to business forestry to industry") and toolboxes all aiming for more flexible and valuable production chains. The intention is to support value chains as follows:

1) **General characterisation of mature forest resources.** The Swedish National forest inventory (SLU) is a valuable resource for such analyses. At the present time it includes annual sampling of about 100 000 individually measured trees (e.g. diameter and age (bh), tree height, detectable stem faults) from more than 10 000 sample plots distributed to provide a good statistical sample of regional forest resources. This information and/or

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other forest inventories including ALS and production files from harvesters can also be used to design bucking instructions and calibrate our recently released system for tree pricing including tree size, stem segmentation, value indices and estimated frequencies of stem faults now introduced by the Swedish companies Sveaskog and Södra.

2) **Run bucking simulations controlled by alternative bucking instructions.** Different alternatives to meet customers demand at actual harvesting and delivery can be compared. In addition to the bucking simulator a number of models predicting stem, wood and fibre properties and the amount and composition of forest residues (tops, branches, needles and stumps) add additional information of value for different production processes and products. As simulations of CTL-harvesters produce results as logs from stems these logs can be characterised and valuated according to both geometric external and internal properties in relation to different customers' demands.
3) **Harvesting and transportation costs** to alternative industries can be approximated by cost functions and benefits of deliveries different customers can be estimated by pricelists and value indices. By these analyses and business agreements standardised harvesting directives including synchronised bucking instructions will control the fleet of harvesters, forwarders and trucks.
4) **Detailed production reports** of all logs produced also including control measurements for quality certification of harvester measurements and information to customers, contractors and forest owners are transferred by broadband connections according to the information standards. Detailed production reports including individual stem profiles, stem faults and quality indices can then be used to provide improved information on properties of logs and forest residues to customers to forest owners (including tree price) and to logistic organizations.

NEW POSSIBILITIES COMING CLOSER

As the quality of information improves and get standardized and the impact of different log properties can be statistically proven and economically evaluated development and use of optimization tools to control log production, i.e. CTL forest products and logistics become increasingly important. Such tools aiming for control of several parallel value chains provides great opportunities to improve total chain efficiency, decrease waste and environmental load and increase profitability.

Keywords: *value chains, cut-to-length harvesters, production reports*

MORE EFFICIENCY WITH INTELLIGENT OPERATOR-TUTORING SYSTEMS IN WOOD HARVESTING

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Cut-to-length (CTL) harvesting with sophisticated forest machines in Nordic logging conditions requires high level of operator expertise and skill. On-the-job learning period to reach the ultimate level of productivity can be up to 1 to 2 years. Intelligent operator tutoring systems could ease the work and improve its quality especially for inexperienced operators, although more experienced operators are also expected to benefit in some areas of the work. In the future, semi-automation and intelligent operator tutoring systems are expected to increase the productivity of logging operations. In varying situations and conditions of logging, operator tutoring system is seen as a potential instrument for a) decreasing decision making related strain and uncertainty, b) promoting cost efficient work methods and techniques, and c) guiding the operator towards efficient yet gentle way to operate the machine.

This report combines two studies related to the potential and development of operator assisting systems in forest operations and other industry. On top of that, report demonstrates a "LoggingMap"-concept, which assists the operator in planning and decision making by presenting precisely analyzed and classified spatial data with a new screen view.

The first study highlights the main findings of the state of the art -study of the operator tutoring/assisting systems in varying sectors of industry. The second study points out the potential of computer-based intelligent tutoring and assistance in harvesting operations - both in cutting and forwarding. The inquiry study was conducted amongst forest machine operators, logging entrepreneurs, as well as students and teachers of vocational schools for mechanized harvesting. Presented results are a part of the "Intelligent operator tutoring systems for wood harvesting" – project and belogs to the Forest Cluster Ltd's EffFibre-program conducted in Finland.

According to the state of the art study, during the last decades, investments in operator tutoring system R&D have been large particularly in traffic and transportation sector. The development of sensoring, data transferring and information technology have enabled automatic monitoring of machine functions, operator action and operating environment with increasing accuracy and reliability. Efficient data handling and analyzing provide information for the operator tutoring systems easing the planning and decision making tasks of machine operators. Most of the operators are willing to receive more feedback concerning their work.

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Intelligent assisting and feedback systems have mainly received positive response from the users. Potential negative effects should still be carefully taken into account in system development.

Results of the inquiry study revealed that forest machine operators were fairly willing to receive real-time intelligent assistance and guidance. Harvester operators preferred tutoring and guidance in locating protected areas on logging sites, locating cutting borders and monitoring harvesting damages. Forwarder operators needed guidance in locating roadside storages, information on the trafficability of strip road network and assistance in locating cut timber on the site. In the future it is expected, that substantial benefits will be gained from the intelligent operator tutoring systems by boosting the learning and by improving the overall performance in mechanized loggings.

As an example of more sophisticated map view with additional tutoring features, LoggingMap-concept is demonstrated. Basic idea of the LoggingMap-concept is to calculate and illustrate new types of information to the screen of the forest machine's on-board computer, which is essential to the operator in part of his decision making process. LoggingMap-concept is a viewer-software with some modern features of GIS. It includes possibility to add any kind of spatial data and precisely analyzed and classified data by user specifications. It also has possibility to view data sets in 2D or 3D modes if the elevation model is included and possibility to add real time GPS-information. LogginMap has been so far tested with digital elevation model (2x2m), waterway and road network, base map for basic information of site, aerial photographs and tree height model (ALS).

DIFFERENCES BETWEEN CONVENTIONAL AND TORREFIED PELLETS AND THEIR INFLUENCE ON LOGISTICS – CONTRIBUTION OF THE SECTOR PROJECT

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TORREFACTION

The torrefaction of biomass materials is considered to be a very promising technology for the promotion of the large-scale implementation of bioenergy. Torrefaction involves heating biomass in the absence of oxygen to a temperature of 250-320 °C. At these temperatures, a dry, torrefied product is obtained, which is stable, brittle and water resistant. This makes it much easier to grind than the parent biomass material and reduces biological degradation in storage. By combining torrefaction with pelletisation or briquetting, biomass materials can be converted into a high-energy-density commodity solid fuel or bioenergy carrier with improved behaviour in (long-distance) transport, handling and storage, and also with superior properties in many major end-use applications.

Provided that the torrefaction process is conducted in an energy-efficient manner, i.e. with heat recovery and integration, overall biomass-to-torrefied-pellets energy efficiencies in excess of 90% (based on lower heating value) can be reached. In this way the overall energy efficiency of torrefaction-based biomass supply chains is increased, simultaneously reducing the CO_2 footprint and costs. In addition to the possible reduction of CO_2 emissions, torrefaction can help to exploit the large potential of residues. An increased use of residues might be one possibility to ease challenges for a sustainable bioenergy supply such as food vs. fuel issues or direct and indirect Land Use Change effects.

Torrefaction has the potential to provide a significant contribution to an enlarged raw material portfolio for biomass fuel production inside Europe by including both agricultural and forestry biomass. The main focus will be on residual materials. It may enable the opening of new feedstock sources worldwide and allow import into Europe in an economically and environmentally sustainable manner. For example, due to the high energy density of torrefied and densified materials, typically three to five times higher than the original biomass, the energy requirements for intercontinental transport can be limited to only a few percent of the energy content of the bioenergy carrier. This is similar to the transport energy levels for coal, and due to the consistent quality of the torrefied product, it is possible that trading schemes

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similar to those for coal can be applied. With respect to the end-use, torrefaction-based bioenergy carriers may form a good starting point for (thermo-chemical) biorefinery routes.

THE SECTOR PROJECT

SECTOR is a new large scale EU-project in FP7 and started in January 2012 with a duration of 42 months. The presentation will introduce the concept and objectives of the project, the partners and the expected outcomes of the project. Due to the strong project consortium of 21 partners from industry (e. g. EON, Vattenfall, RWE Innogy and Doosan Babcock etc.) and science (e. g. DBFZ, OFI, TFZ) nearly all parts of the biomass value chain – different raw material input, production of torrefied biomass and conditioning, biofuel logistics and end use in large and small scale technologies – will be investigated and analysed.

The SECTOR project is focussed on the further development of torrefaction-based technologies for the production of solid bioenergy carriers up to pilot-plant scale and beyond, and on supporting the market introduction of torrefaction-based bioenergy carriers as a commodity renewable solid fuel.

The project is centred around four torrefaction technology options:

- Rotary-drum torrefaction technology (as developed by ETPC/BioEndev and CENER)
- Moving-bed torrefaction technology (as developed by ECN)
- Torbed torrefaction technology (as developed by Topell)
- Fluidised-bed torrefaction technology (as developed by VTT)

The focus of the work is on a thorough technology development, taking into account the specific characteristics of the torrefaction regime and the process requirements for obtaining proper product quality. Three of these technology options have been proven for a limited set of feedstock at pilot-scale already and demonstration-plants are in preparation or under construction. Furthermore, the project builds on state-of-the-art knowledge concerning:

- Densification via pelletisation as well as briquetting,
- Biomass co-firing, entrained-flow gasification and pellet combustion,
- Analysis and testing methodology and
- Market deployment strategies and sustainability assessment

In this way, the SECTOR project is expected to shorten the time-to-market of torrefaction technology and to promote market introduction within stringent sustainability boundary conditions.

THE PROJECT STRUCTURE

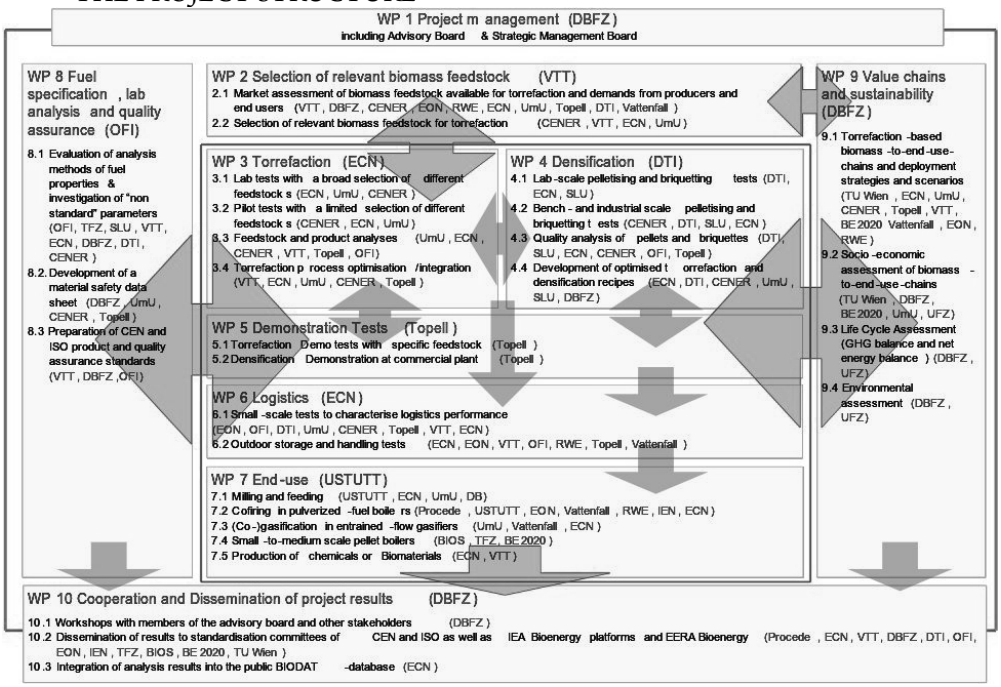

Figure 1.

Keywords: *torrefaction, torrefied biomass, bioenergy, pellets, densification*

THEORETICAL INVESTIGATION OF STUMP WOOD USE FOR FUEL IN LITHUANIA

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Lithuania as many other Europe countries aimed on the responsibility to increase the use of renewable energy sources. Nowadays one of the most important source of renewable energy is wood. However, seeking to increase the use of wood for fuel it is essential to search for new or not investigated application perspectives of wood fuel sources. Thus, stump wood may be as the alternative for wood fuel production.

The stump wood is not yet in used in Lithuania. For that, it was aimed theoretically to investigate the stump wood use for fuel taking into the account the experience of other countries.

The stumps harvesting condition as well as ecological restrictions in Lithuania were estimated adopting the stump wood harvesting recommendations prepared by other countries. The stumps harvesting in recommended to be done only in unprotected areas in IVth forest group forests and in the clear cutting areas. It is also recommended to harvest the stumps of coniferous and deciduous tree species tree species – spruce, pine, birch, aspen, grey alder, respectively. However, there were harvesting restrictions estimated according the forest site fertility, thus, it was recommended to leave stumps in buffer zones not harvested due to biodiversity purpose.

It was estimated that potential stump wood production in Lithuania coverable to 1.3 mill. m^3 per year. However, considering the ecology restrictions, only 0.6 mill. m^3 per year could be use as wood fuel. Coniferous and deciduous forest stands could possibly produce 0.39 mill. m^3 per year and 0,26 mill. m^3 per year stump wood, respectively.

It was estimated that to produce 0.5 mill. m^3 of stump chips the investment of 55 mill. litas (about 16 mill. EUR) is required. The cost of stump chips delivering to the end user can vary from 114 to 156 litas per m^3 (33-45 EUR per m^3). In comparison to the present price of wood chip, the production from stumps chips wood is not profitable.

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COMPARISON OF PRODUCTIVITY OF SOIL SCARIFICATION WITH CONVENTIONAL EXCAVATOR BUCKET AND MOUNDER MPV-600

Dagnija Lazdiņa[1], Andis Lazdiņš[1] and Agris Zimelis[1]*

The scope of artificial forest regeneration is to produce valuable and healthy forest stands able to secure sustainable deliveries of hight quality roundwood and biofuel to industries and to contribute to implementation of environmental and social functions of forest ecosystems. In 2011 about 35 kha of forest stands were regenerated in Latvia; artificial regeneration was applied to 37 % of the stands, mainly in state forests. Clear-felling, including sanitary and re-constructive felling at the same time was done in 68 kha. This means that considerable part of clear-felling areas are not regenerated timely. According to the National forest inventory about 37 % of forests in Latvia grows on wet or drained soils (excluding organic peat soils), where scarification of soil with disc trencher is complicated or even impossible and do not secure good growth conditions for seedlings. Alternative method of scarification is mounding with caterpillar excavator using conventional bucket or specialized mounding devices. The scope of the study was to estimate productivity, quality and cost of soil scarification using caterpillar excavator with conventional and specialized bucket on peat soil and wet mineral soil.

MPV-600 is prototype of mounding device for caterpillar excavator (Figure 1) produced in Latvia by LSFRI Silava and engineering company Orvi SIA. The initial idea of building of the device was to compare productivity and quality of soil scarification with and without stump extraction. The main benefit of the device in compare to similar products is large surface area of mounds (600 cm^2), which simplifies weed control during first years after planting.

Figure 1. Mounding bucket MPV-600.

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The MPV-600 and conventional excavator bucket (70 cm long) was tested in spring (2012) in clear-felling sites on wet fertile mineral and peat soils nearby Lubāna city (total area of the trial 9 ha). Both devices were mounted on New Holland E165 excavator and operated by professional excavator operator with no experience in forest operations. A half of the prepared sites were regenerated few days after scarifying with Norway spruce (planting density 2000 plants ha^{-1}) and another half – with Scots pine (planting density 3000 plants ha^{-1}). Working conditions were classified as very complicated – wet, heavily covered by dead wood, lost roundwood assortments and harvesting residues. None of the sites were suitable for preparation with conventional disc trencher.

The productivity figures were recorded using Allegro field computer with SDI program. Time consumption was accounted separately for periods between excavator movements in the field. The working time was split into: (1) driving into and from stand; (2) driving in stand; (3) site cleaning; (4) mounding; (5) moving crane and tower; (6) pressing, compacting of mounds; (7) other operations; (8) non-work operations.

Share of productive working time were similar for both devices (87 % of scheduled working time), productive time excluding driving into and out of stands were 82 % of scheduled working time. Site cleaning and mounding operations took considerably more time, when working with conventional bucket (Figure 2).

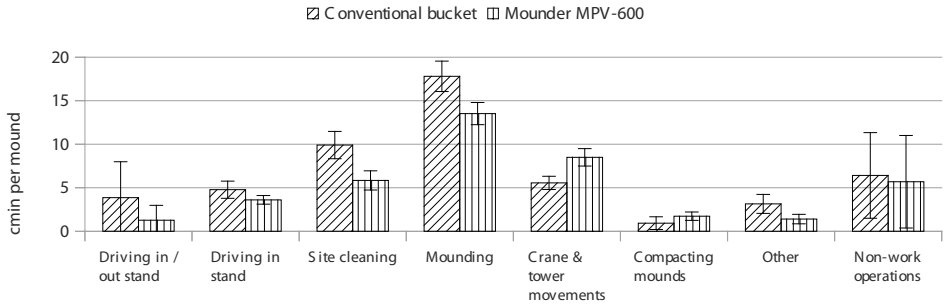

Figure 2. Comparison of time elements.

If the necessary number of planting spots (mounds) is 1600 per ha, excavator with conventional bucket needs 13 hours of productive working time per ha and with MPV-600 – 10 hours; productivity is, respectively, 142 and 174 mounds per productive hour. If operator is not compacting mounds, productivity increases to, respectively, 156 and 200 mounds per productive hour. Assuming that there is no need for site cleaning (harvesting residues and dead wood is removed) productivity theoretically can additionally increase by 20 % in compare to the scenario without additional compacting of mounds (respectively, to 208 and 252 mounds per productive hour).

Prime cost of soil preparation in the base scenario (with compacting, site cleaning and

necessary number of planting spots 1600 per ha) would be 477 EUR ha^{-1} with conventional bucket and 390 EUR ha^{-1} with the MPV-600. If there is no need for additional compacting and site cleaning prime cost of soil scarification can decrease to 324 EUR ha^{-1} and 270 EUR ha^{-1}. Cost of disc-trenching in normal conditions is about 170 EUR ha^{-1}; however, disc trencher could not prepare soil in the studied sites.

The study demonstrated that the required number of planting spots and site conditions are the most important factors affecting cost of soil scarification with excavator. If number of necessary mounds would be reduced to 1000 per ha and slash would be removed for bioenergy, price of scarification with excavator would be able to compete with disc-trenching. Specialized device MPV-600 is more productive than the conventional bucket; moreover, if operator would change working method "from digging to scarifying", productivity could be higher and quality – better. Technical improvements in terms of hardness of construction should be done to the MPV-600, because site cleaning and crane manipulations (reclining and pulling excavator) during crossing wet sites causes deformation of certain frame elements.

Keywords: *forest regeneration, mounding, excavator*

REMARKS

Research was supported by Join Stock company "Latvijas valsts meži" project No 5-5-9.1.-0061-200-12-49.

PRODUCTIVITY OF TENDING DEPENDING ON INTENSITY OF OVERGROWTH

Dagnija Lazdiņa[1], Agris Zimelis[1], Valentīns Lazdāns[1] and Andis Lazdiņš[1]*

The goal of study is to elaborate mathematical equations characterizing impact of density and height of vegetation on productivity of tending operation using motor-manual instruments in young forest stands.

Ground vegetation in the experimental sites was characterized according to the ICP Forest monitoring methodology dividing overgrowth plants into fore groups (scrubs, coppice's, semi scrubs , grasses and caulescent plants). Time studies were done in 30 forest sites with different intensity of overgrowth, where pine and spruce was planted 1-3 years ago. Soil preparation in all sites was done using trenching method. In 10 sites overgrowth plants were completely removed by bush-saw, in remaining 20 sites 1 m wide row was cleared around seedlings (Figure 1).

Before complete removal of overgrowth

Before of tending in rows

After removal of owergrowth

After cleaning of rows around seedlings

Figure 1. Tending of young coniferous stands – before and after application.

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Projective coverage of all groups of vegetation was counted together as a total projective coverage, because the vegetation layers were overlapping. The total projective coverage in spruce stands was 50-90 %, while in pine stands – 3-70 %. Evaluation of the productivity figures approved that the total projective coverage has significant impact on the productivity of tending, while the "ordinary projective coverage", which is used in environmental studies do not shows significant differences. because the introduced total projective coverage characterizes also density of vegetation. Denser vegetation is a reason for more difficult finding of the planted seedlings. Height of overgrowth had no significant impact on productivity.

The highest level of correlation between the total projective coverage and tending productivity was found in case of tending in rows, particularly in pine stands (Table 1).

Table 1. Productivity of tending depending of overgrowth and tending method, ha h^{-1}

Total projective coverage		10	20	30	40	50	60	70	80	90	100
equation	coverage group (%)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
$y=0.49*x^{-0.27}$ ($R^2=0.34$)	average values	0.26	0.22	0.2	0.18	0.17	0.16	0.16	0.15	0.15	0.14
$y=0.18*x^{-0.15}$ ($R^2=0.13$)	complete removal of overgrowth	0.13	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09
$y=0.95*x^{-0.43}$ ($R^2=0.74$)	**tending in rows**	**0.35**	**0.26**	**0.22**	**0.19**	**0.18**	**0.16**	**0.15**	**0.14**	**0.14**	**0.13**
$y=0.34x^{-0.21}$ ($R^2=0,15$)	spruce stands, tending in rows	0.21	0.18	0.17	0.16	0.15	0.14	0.14	0.14	0.13	0.13
$y=0.88x^{-0.39}$ ($R^2=0.76$)	pine stands, tending in rows	0.36	0.27	0.23	0.21	0.19	0.18	0.17	0.16	0.15	0.15

There were no spruce stands with relatively loose overgrowth (easy working conditions) in the experiment. This might be a reason for lack of correlation between productivity of tending and owergrowth characteristics.

Keywords: *tending, overgrowth, productivity*

REMARK

Research was supported by Join Stock company "Latvijas valsts meži" project No 5.5-0.1/00fy/200/11/177.

SMALL SCALE COMMUNITY FORESTRY PROGRAM IN NEPAL: HOW IT MAINTAINS ECOSYSTEM SERVICES?

Bidur Khadka[1]

Small scale community forestry of Nepal is providing different environmental services such as biodiversity conservation, water conservation and regulation, soil conservation, livelihood for poor people and carbon storage from the past 30 years. This poster tries to describe how the small scale community forest is enhancing different environmental services and contributing to mitigate climate change and enhance green economy in local level.

INTRODUCTION

Nepal is a small country lies in Indian sub continent between China and India. The total area of the country is 14.7 million hectares and the total population of the county is 26 million (CBS 2005). Small scale community forestry is a participatory forest management system in Nepal which is started from 1970s decade. These forests are national forests handed over to the local user groups for protection, management and utilization according to the Forest Act, 1993. Till date 15,500 community forest is managing directly from the 1.5 million people which is about one third of households of Nepal are involved in managing the forests (DoF, 2011). Community Forest is considered quite a successful in terms of improving the condition of forests and people in Nepal. Community forestry aim primarily to fulfill the basic forestry product needs such as firewood, timber, fodder and leaf litter for compost-making (MPFS, 1989). Community forestry has been advocated by many practitioners as an important management model to achieve the twin objectives of forest conservation and livelihood security (Malla 2000, 2003, Gilmour *et al.* 2004). Perspective of payment for environmental services (PES) is a new thematic area of discussion in community-based forestry in Nepal. Forests can play an important role in regulating hydrological flows and reducing sedimentation. Forests are commonly associated with a range of environmental services delivered at watershed scale including regulation of water flow that is, maintenance of dry season flow and flooding control; maintenance of water quality, that is, minimization of sediment load, nutrient load, chemical load and salinity; control of soil erosion and sedimentation; reduction of land salinalization and/or regulation of ground water level (Bishop *et al.* 2004). Nepal is vulnerable to several types natural disasters, including droughts, flood, landslides, windstorms, hailstorms, cold waves, disease epidemics, glacial lake outburst flood, fire and earthquakes, climate change, global warming.

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DISCUSSION

Small scale forestry program is playing a crucial role in the economic and environmental development in Nepal. This forestry program is providing several environmental services provided such as provisioning services, regulatory services, cultural services, supporting services, biodiversity conservation, water purification and regulation, soil erosion protection, forest recreation and carbon storage are gaining some attention and need to protect the future of the forests linking commercial market and climate change adaptation and mitigation issues activity to conservation objectives from past 30 years. In the case of Nepal, according to research more than 90 % people lives in village and around 31 % of current population lives below the poverty line and 72 % of these individual are forest dwellers, largely compromised of indigenous ethnic groups (Dhital *et al.* 2009) and these people livelihood is heavily depended upon forest due to several reasons such as fuel wood, fodder, timber, non timber forest products. Government of Nepal is trying to enforce different climate change mitigation strategies such as Payment for Environmental services and Reducing Emissions from Deforestation and Degradation program. The forest certification is one of the tools for the forest management which is proving jobs in to the local people. Total 21 User Groups (CFUGs) with 14,086 hectors at Dolakha and Bajhang district received FSC forests management group certification covering 24 forest products where 4,695 household are getting directly getting benefit (Subedi 2005). On a global scale, land-use change and forestry mostly deforestation is estimated to account for 17.4 percent of anthropogenic GHG emissions; global transportation accounts for only 13.1 percent (IPCC 2007). Degradation of forests through logging, fire, disease and pathogens also contributes to CO_2 emissions. Nepal is one of the ten most vulnerable developing countries because of its geography, poor physical infrastructure and the low level of development of its social sectors (OECD, 2003). The temperature of the Nepal is increasing rapidly than other countries. Between 1977 and 1944, Nepal's average temperature rose at rate of 0.03-0.06 Celsius per annum, with a higher rate in the mountains than in lowlands (Shrestha *et al.* 1999). After hand over of forest to local community, the growing stock of forest has been improving increasingly. At time, the biodiversity of the resources has been increasing. There is also increasing trends of the group fund. Rural poor are those who rely more heavily on natural resources to sustain their livelihood, the potential role of decentralization and community forest reforms can be remarkably effective to improve the livelihoods of the poor (Bene *et al.* 2009). The government of Nepal is developing different policy and management plan how can get more benefit from the community forest such as Payment for ecosystem services, Carbon market, Reducing Emissions from Deforestation and degradation plus, ecotourism, green jobs from the forest etc which can make direct benefit to the community people and helps to cope with climate change. Community forestry has been rewarded with US$ 95,000 (approximately Rs 6.8 million) for reducing emissions in the atmosphere causing climate change through enhancement of carbon stocks and sustainable management of forests which was basically in the three watershed area and by comparing the

carbon stock in 2009 and 2010 and these money are using for the different sources such as livelihood improvement, plantation etc (ICIMOD, 2011).

CONCLUSION

The small scale forestry program is very much suitable for the climate change mitigation and cope with the global warming. It has seen that community forestry is also providing different green jobs which can also lead to the sustainable development and green economy. The program such as REDD plus and PES mechanism is very much suitable for enhance more environmental services which is one of the best tools for climate change mitigation. The community forestry program is also contributing for the poverty reduction, it creates green jobs, provides sustainable rural development, ecotourism activities.

Keywords: *Community forest, Livelihood, Global warming, Climate change*

REFERENCES

CBS, 2005. Central Bureau of Statistics, Nepal.

DoF, 2011. Department of Forest, Nepal.

OECD, 2003. Development and Climate Change in Nepal. Focus on water resource and hydropower.

Gilmour, D, Malla, Y. and Nurse, M., 2004. Linkage between community forestry and poverty. Regional Community Forestry Training Center for Asia and the Pacific (RECOFTC).

ICIMOD 2011. ICIMOD pilot first forest Carbon Trust Fund in Nepal. Helps communities benefit from forest conservation and sustainable use.

Malla, Y., 2003. Community Forestry: Current State and Emerging Challenges and Opportunities.

MFSC 1989. Master Plan for Forestry Sector. Ministry of Forest and Soil Conservation, Nepal.

Pagiola, S., 2009. Payment for Environmental Services in Costa Rica. Environmental Department, The World Bank, Washington.

Subedi, S., 2005. Forest User Group Moving for international market that care sustainability.