

Scandinavian Forest Economics

No. 47, 2017



**Proceedings from joint seminar arranged by
NB-NORD and NOFOBE
Lappeenranta, Finland, June, 2017**

**Hans Fredrik Hoen,
Cathrine Glosli (eds.)**

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Preface

This volume of Scandinavian Forest Economics presents Abstracts from oral presentations given at the Lappeenranta scientific conference “Industrial Scale Bioeconomy and its Requirements”, which was arranged 2017.06.14-16. This was a joint effort between the two Centers of Advanced Research (CAR), NOFOBE and NB-NORD, funded by Nordic Forest Research (SNS). For those interested in learning more about the activities in these CARs, you find information here:

NOFOBE: <http://nordicforestresearch.org/nofobe/>

NB-NORD: <http://nordicforestresearch.org/nb-nord/>

The conference gathered more than 50 participants from the Nordic-Baltic countries. The program consisted of a combination of invited keynote presentations and more than 30 oral presentations from the conference participants.

On behalf of NOFOBE and NB-NORD, I thank our keynote speakers Director General Juha S. Niemelä, Ministry of Agriculture and Forestry, Vice President, R&D Heikki Ilvespää, UPM-Kymmene, Professor Kaisu Puumalainen, LUT School of Business and Management, Research Director Jarmo Hämäläinen, Metsäteho, Head of Research Magnus Thor, Skogforsk and Head of Business Development Kalle Kärhä, Stora Enso Wood Supply Finland, for interesting and carefully prepared presentations.

A field trip, in splendid June-weather, during the afternoon of Thursday June 15th visited pulp-, sawmill- and bioenergy-operations and research-centers of UPM Kaukas - Lappeenranta, MetsäFibre - Joutseno and Stora Enso Research Centre - Imatra. The field trip demonstrated cutting edge industrial operations at an impressive scale.

The organisers and the participants wish to express their sincere gratitude to Samnordisk skogforskning (SNS) for indispensable financial support to the Biennial meeting. A special thank goes to Heikki Pajuoja and Laura Kammonen at Metsäteho for an excellent job with preparing and organizing the conference and Cathrine Glosli for careful and efficient work in editing and preparing the layout of this volume.

Ås, November 2017
Hans Fredrik Hoen

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CONFERENCE PROGRAMME

WEDNESDAY 14 June 2017

Board and Working groups

- Transport & Roads (Pirjo Venäläinen)
- Value creation in the forestry chain – how can we work together? (Mia Iwarsson Wide)

OPENING

- Opening Managing Director Heikki Pajuoja, Metsäteho Oy
- Finnish Bioeconomy – current topics Director General Juha S. Niemelä, Ministry of Agriculture and Forestry
- The shaping of industrial scale bioeconomy – UPM perspectives Vice President, R&D Heikki Ilvespää, UPM-Kymmene

PARALLEL SESSIONS

L1. ROAD TRANSPORTATION WITH HCT TRUCKS – EXPERIENCES IN FINLAND AND SWEDEN

Chair: Kari Väättäinen, Natural Resources Institute Finland (Luke)

- L1.1. Impacts of HCT trucks on logistics costs Pirjo Venäläinen, Metsäteho Oy
- L1.2. Impacts of HCT trucks on traffic safety Mauri Haataja, University of Oulu
- L1.3. Operational experience of HCT trucks in Sweden (Fuel consumption, load ratio, technical calamities & transport economy) Gunnar Svenson, Skogforsk
- L1.4. HCT vehicles in the Swedish transport system Victor Asmoarp, Skogforsk

V1. VALUE CREATION IN THE FORESTRY CHAIN

Chair: Mia Iwarsson Wide, Skogforsk

- V1.1. Productify for optimal fuel base Mia Iwarsson Wide, Skogforsk
- V1.2. Utilization of high resolution harvester production data for improved pre-harvest planning John Arlinger, Skogforsk
- V1.3. Smart thinning of young dense stands for simultaneously extracting and keeping ecosystem service values Dan Bergström, SLU
- V1.4. Correlation between outer and inner quality attributes of forest stand Heikki Alanne, Metsäteho

PARALLEL SESSIONS

L2. IMPROVING EFFICIENCY OF BIOMASS ROAD TRANSPORTATION

Chair: Gunnar Svenson, Skogforsk

- L2.1. Simulation of timber truck transport logistics – Case Central Finland Kari Väättäinen, Natural Resources Institute Finland (Luke)
- L2.2. Cost analysis of transporting forest chips and forest industry by-products with large truck-trailers in Finland Juha Laitila, Natural Resources Institute Finland (Luke)
- L2.3. Modeling cost reductions for multimodal transport in Norwegian wood supply Dag Fjeld, Norwegian Institute for Bioeconomics
- L2.4. Optimal biomass truck load size and work models for loading of loose biomasses Heikki Ovaskainen, Metsäteho

- L2.5. Biorefinery feedstock assessment made easy: Luke's tools to analyze harvesting potential, competition situation and transport distances for any given location
Perttu Anttila, Natural Resources Institute Finland (Luke)

S1.

Chair: Hans Fredrik Hoen, Norwegian University of Life Sciences

- S1.1. The influence of institutional innovation to the development of the Estonian forest sector Meelis Teder, Estonian University of Life Sciences
S1.2. Public perceptions of forest industry innovativeness on the road to bioeconomy Sami Berghäll, University of Helsinki
S1.3. Techno-economic comparison of promising biofuel conversion pathways in a Nordic context – effects of feedstock costs and technology learning Walid Fayez Mustapha, Norwegian University of Life Sciences
S1.4. Utilization of wood ash in forest fertilization: options and impact on tree growth in Latvia Modris Okmanis, Latvian State Forest Research Institute 'Silava'
S1.5. Wood-based businesses in the next era of manufacturing Teppo Hujala, University of Eastern Finland
S1.6. Sustainable forest-based bioeconomy: A case of biorefinery as a multi-product firm Jenni Miettinen, University of Helsinki

THURSDAY 15 June 2017

PLENARY SESSION

- Evolution of CSR in the forest industry Professor Kaisu Puumalainen, LUT School of Business and Management
- Wood supply digitalization in Finland Research Director Jarmo Hämäläinen, Metsäteho
- Productive forest operations with a soft footprint
- report from a strategic work programme in Swedish forestry Head of Research Magnus Thor, Skogforsk
- Seasonal Variation of Production in Forest Industries and Wood Procurement in Finland Head of Business Development Kalle Kärhä, Stora Enso Wood Supply Finland

FIELD TRIPS

- UPM Kaukas, Lappeenranta
- MetsäFibre, Joutseno
- Stora Enso, Research Centre, Imatra (+ coffee)
- General presentation: Stora Enso Consumer Board, Innovation and R&D Director Veli-Matti Niemelä
- General presentation: Stora Enso, Biomaterial and Pulp Competence Centre Joni Lapatto
- Life Cycle Assessment at Stora Enso Tiina Keskiäsaari
- HCT demonstrations during the visits in UPM Kaukas and MetsäFibre

FRIDAY 16 June 2017

PARALLEL SESSIONS

T1.

Chair: Heikki Pajuoja, Metsäteho

- T1.1. Research activities of planting and sowing mechanization in Latvia Dagnija Lazdina, Latvian State Forest Research Institute Silava (Presenter: Andis Lazdiņš)
- T1.2. Integrated roundwood and biomass terminals – 0,1 TWh case Heikki Ovaskainen, Metsäteho
- T1.3. Detection of stems and tree damage in softwood stand by a machine vision algorithm based on color analysis Jyry Eronen, University of Eastern Finland
- T1.4-5. Factors affecting productivity of Vimek 404 T5 harvester in pre-commercial thinning / Fields of application of Kranman Bison 10000 and other small forwarders Santa Kalēja, Latvian State Forest Research Institute 'Silava'
- T1.6. Measuring timber piles with TRESTIMA stack Sari Nurmela, University of Helsinki
- T1.7. Productivity of Logbear F4000 forwarder on soils with low bearing capacity Santa Kalēja, Latvian State Forest Research Institute Silava (presenter Ainārs Lupiķis)
- T1.8. Impact of Small and Middle Sized Forwarders to Soil Compaction During Mechanized Thinning in Young Stands Ainārs Lupiķis, Latvian State Forest Research Institute 'Silava'

S2.

Chair: Teppo Hujala, University of Eastern Finland

- S2.1. Utilization of industrial side streams originating from sawmilling – challenges and suggestions Janni Kunttu, University of Eastern Finland
- S2.2. Identification of wet areas in forest by using LiDAR based dem Jānis Ivanovs, Latvian State Forest Research Institute 'Silava'
- S2.3. GIS and remote sensing based planning of forest regeneration Gints Spalva, Latvian State Forest Research Institute 'Silava' (presenter Jānis Ivanovs)
- S2.4. Diversification of the Finnish forest industries: Role of new products Elias Hurmekoski, European Forest Institute
- S2.5. Economic and climate change mitigation potential of forest fertilization in state forests in Latvia Andis Lazdiņš, Latvian State Forest Research Institute 'Silava'

L1. ROAD TRANSPORTATION WITH HCT TRUCKS – EXPERIENCES IN FINLAND AND SWEDEN

1. Impacts of HCT trucks on logistics costs

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Key words: Road transportation, Transportation costs, HCT Transport.

Abstract

In Finland, transport companies may apply for a trial permit for HCT (High Capacity Transport) trucks (i.e. articulated vehicles that are heavier than 76 tonnes or longer than 25,25 m). One precondition for the permit is to have a sound research plan to study the impacts of HCT. Metsäteho has compared logistics costs of five round wood HCT trucks with their 76 tonne control trucks. The total weight of HCT trucks ranges between 84–104 tons.

84 ton forest truck brings 12–13 % cost saving (per m³) in comparison to 76-tonner (regardless of the transport distance). Bigger HCT trucks need terminals or other areas for transferring wood from forest truck to HCT truck. Therefore, the cost-efficiency of HCT transport chains via terminals is highly dependent on transport distance and the method of reloading. In transport distance of 300 km, cost savings of nearly 20 % are obtainable. Beforehand loaded trailers and swap bodies are a fast and flexible solution to tackle the extra costs caused by transport via terminals. They ensure cost-efficiency of HCT transport chains already in average Finnish transport distances (about 100 km).

Terminals are already today used in wood logistics for several reasons (removal of wood from spring thaw areas, chipping energy wood in terminals, transporting by-product chips from saw mills to pulp mills, etc.). If HCT trucks are used in these cases, reloading wood to HCT truck can not be considered as extra cost as reloading brings benefits whose monetary value is hard to estimate (reliability of wood deliveries, quality management of energy wood, etc). In between-terminals transport 104-tonne truck brings more than 20 % cost savings regardless of the transport distance.

Fuel consumption (per transported green ton) of various truck sizes effects not only on cost-efficiency but also on environmental impacts (emissions) of transport. 84-ton forest truck decreases fuel consumption by app. 10 %. HCT transport chains are more fuel-efficient already in transport distances of less than 100 km. In longer transport distances, the fuel savings with HCT transport amount to more than 20 %.

Three HCT chip trucks have recently received a trial permit, and the potential of cost reductions in chip transportation will be the focus of the further research.

2. Impacts of HCT-vehicle combinations on traffic safety

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Key words: HCT Vehicle Combination, Lateral Stability, Experimental Methods, Computational Methods, Dimensioning

Abstract

Amendment of vehicle regulation in Finland in 2013 has made possible to use HCT vehicle combinations that have gross combination weight over 76 tons and total length over 25,25 m under a licensed permit. Reasoning behind the regulation change has been higher energy efficiency, better cost effectiveness of transport and lower road and environmental loads. In 2017 there are currently 35 HCT vehicle combinations operating under the licensed permit in timber, liquids and freight transport (Trafli). The lateral stability of longer and heavier HCT vehicle combinations is problematic, especially in the changing road and weather conditions of Finland during the fall and winter season due to low friction. The study of experimental methods and data acquisition of HCT vehicle combinations began in the university of Oulu in 2015, where the traffic safety and mobility of the vehicle combinations are determined. One of the studied vehicle combinations is 104 tons, 13 axles and 33 m long HCT vehicle combination used for transporting timber in Northern Lapland between the road route of Ivalo and Rovaniemi. Measurements focus on the variables concerning the driving dynamics of vehicle combinations and on the variables concerning the deformations of the drawbar, fifth wheel and load structure. Other objective of the measurements is to provide conception regarding the dimensioning of HCT vehicle combinations and possible development needs on the vehicle regulations. The driving dynamics of the HCT vehicle combinations are also studied with theoretical multibody dynamics software models, where the vehicle combination can be modeled relatively completely. Tire models used in the simulations are parametrized based on tire force measurements from experimental measurements. Simulation models are used to simulate different driving tests used to assess the stability of a vehicle combination according to ISO 3888-1 and ISO 14791 standards and the simulation models are verified based on corresponding full scale vehicle tests. The correlation between simulation model output and full scale experimental measurements is significant. During the study it has been established that dimensioning of a HCT vehicle combination, simulations and full scale vehicle testing are essential to ensure the traffic safety and to promote mobility. So far the studied HCT vehicle combinations have coped as well as other vehicle combinations with the challenges of the winter season. In the study of HCT vehicle combinations, one of the requirements have been to determine the tire models in order to improve the reliability of the simulation models. The HCT study is a public project funded by ERDF. The project has established interest in Sweden via multiple visits from officials, amongst other. The final results of the project will be published in a seminar at the beginning of 2018.

3. HCT trucks in Swedish forestry – operational experiences

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Key words: GVW, ETT project, HCT project, fuel consumption, transport economy

Abstract

Transport accounts for more than 25% of the Swedish forest industries' roundwood procurement cost, and is a cost that has been increasing rapidly recently. In Sweden, more than two million transports are carried out annually, with an average transport distance of 91 km and a total cost of EUR 700 million.

Together with forest companies, truck companies, manufacturers and the Swedish Transport Administration, Skogforsk has been working on the One More Pile (ETT) project. The aim is to reduce emissions and roundwood transport costs by increasing gross vehicle weight (GVW), without increasing road wear or jeopardizing road safety.

The first truck, the 30-metre, 90-tonne ETT vehicle (11 axles), was commissioned in 2009, followed by ST trucks (25.25 metres, 74 tonnes, 9 axles). More than 20 trucks are currently operating in the ETT project. A further 30 trucks are running in other parts of the Swedish transport sector in the HCT project (High Capacity Transport).

The ETT project has shown that fuel consumption can be reduced by 7-13% for the ST vehicles and by up to 20% for the ETT vehicle. A calculation indicates that transport costs can be reduced by 5% for a 74-tonne combination compared with a truck with the current maximum GVW of 64 tonnes.

In the ST project, extra volume is added to each pile on the vehicles. The low density of the material makes maximum payload difficult to attain, with negative impact on load ratio and transport efficiency.

In Sweden, most 74-tonne timber trucks comprise truck + full trailer, although some are tractor + link + trailer, both with 9 axles. Drivers report that 650-700 HP is usually sufficient power. Traction problems can be overcome by front-wheel hydraulic drive, crawl gear, CTI, liftable axles, or air-dump. The axle configuration makes them significantly more agile than most 64-tonne trucks.

HCT trucks have been involved in two driver-related accidents and one overtaking incident. Some cracks in the frame and timber banks, and bent stakes, have been found, but nothing of major significance.

Results from research into road and bridge wear do not indicate any major problems except where bridge span is greater than 12 m, and therefore must support much of the vehicle weight.

A new road class (BK4), allowing up to 74-tonnes GVW, is approved but not yet implemented. The first roads with the new class will be opened in mid-2018, mostly in densely-forested parts of Sweden.

4. HCT vehicles in the Swedish transport system

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²SLU, Swedish University of Agricultural Sciences

Key words: HCT vehicles, roundwood transportation, transport economy, transport emissions

Abstract

A lot of research has focused on measuring differences in economic and environmental performance of single HCT vehicles and conventional vehicles. However, in two different Master's theses supervised by Skogforsk, the focus has been on consequences for the transport system in a Swedish context rather than single vehicles.

The first study concerned how an introduction of HCT vehicles would affect the amount of wood transported on railway, since reduced truck transportation cost would favor road transport over railway. But is it really that simple?

The study was performed as a comparison between a conventional transport system (max. GVW 60 tonnes) and an HCT system (max. GVW 74 tonnes). The study area was in northern Sweden, and focused on a forest company that uses both train and trucks.

The results showed a small shift in transport mode, with approximately 2% of the total volume shifting from railway to road. Transport cost for the entire transport system was reduced by 9% and emissions by 7%. This case study was carried out before Sweden increased the maximum GVW to 64 tonnes, so today the effect would have been slightly smaller.

The second study concerned the effect on the total cost for a combined fleet with both conventional and HCT vehicles, where the HCT vehicles were restricted to a limited road network. The HCT vehicles reduce transport costs, so they will be prioritized in the assignment of transport tasks. Optimal route planning would therefore increase the amount of unloaded driving for both conventional vehicle and HCT vehicle.

The study involved transports over two weeks and 24 trucks at a hauler organization in western Sweden. Two different HCT road networks were tested against the road network used today as a reference, one very compact and concentrated around a cluster of industries, and the other extending over a wider area.

The results showed that a restricted road network for the HCT trucks would affect transport efficiency even for the conventional vehicles. The correct proportion of HCT trucks in relation to the open road network is important, otherwise there is a risk of increased costs and emissions.

V1. VALUE CREATION IN THE FORESTRY CHAIN

5. Productify for optimal fuel base

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Key words: Characterization, product descriptions, quality assurance of fuel, measurement

Abstract

The desire for more efficient ordering and delivery of the right forest fuel to the right consumer are important issues for both forest and energy companies. Today large values are being handled and sold, but the products are not well defined, which is a concern for the players. In order to enable quality-driven development and rational biofuel management, efficient and rapid methods are required to characterize and quality-assure demanded fuels. In order to facilitate communication within the various business, a characterization must be linked to international standards for biofuels. This is a prerequisite for the delivery of biofuel to be smooth and predictable.

Better product descriptions are expected to produce a number of positive effects for the forest fuel industry:

- Efficient and rapid characterization and quality assurance of fuel.
- The buyer can make a clear and unambiguous order of requested fuel.
- The supplier gets a clear and clear target image for the fuel to be delivered.
- Enable homogeneous fuel mixtures with respect to fraction size, moisture, heat value.
- Buyer / supplier receives quick and clear forecast / feedback on ordered / delivered fuel through regular business systems.

By further developing structure and communication, as well as methods for efficiently and quickly characterizing and quality assurance of fuel, the business can be clarified and facilitated. The industry-wide IT support for business measurement and reporting needs to be developed and adapted to the needs and requirements of biofuel trade.

Through technology and method development, a coherent information chain regarding handling, preparation, measurement and characterization of fuel can be made possible and lead to more homogeneous fuel mixtures.

6. Utilization of high resolution harvester production data for improved pre-harvest assessment

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Key words: Pre-harvest assessment, harvester data, ALS

Introduction

Detailed standardized production data (hpr- or pri-files) is collected by all modern CTL harvesters (Anon 2013, www.skogforsk.se/stanford2010). Several new implementations based on harvester data is under introduction, including machine productivity, thinning evaluations, regeneration planning etc. A new application where harvester data is used for pre-harvest assessments is described in this presentation.

Detailed harvester data

Measuring data for each stem and log are reported, including e.g. dimensions, species, coordinates, time etc. These data can be used in order to re-construct the trees and the forest (figure 1 and 2). When reconstructing stems a number of filtering algorithms has to be implemented in order to e.g. handle stem breakage. Algorithms has also been developed (Bhuiyan et al, 2016) to calculate the harvested area using stem coordinates and segmenting the site into sub-areas based on dominant height.

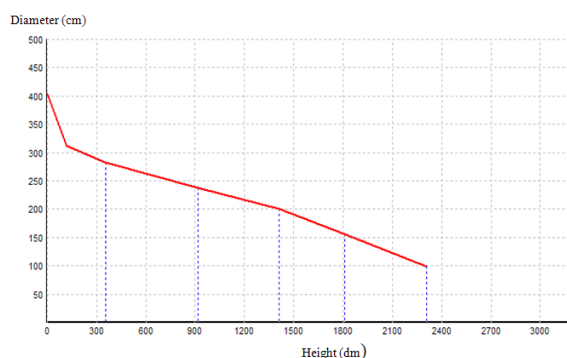


Figure 1: Harvested stem with 5 logs

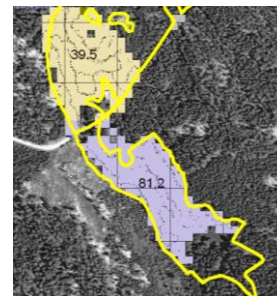


Figure 2: Site segmented into 2 separate sub-areas based on variation in dominant height. Improved pre-harvest planning (yield estimations)

A new pre-harvest assessment method is developed by Skogforsk jointly with some Swedish forest companies. The method is based on calculating a number of key figures per harvested sub-area (figure 2 and 3).



Figure 3: Examples of harvested sites (white polygons) 300 km west of Stockholm, Sweden, used in imputation to find harvested sites as similar as possible to planned sites that are not yet harvested.

When planning a new site identical key figures (DBH, basal area, height, species distribution) are collected using field measurements, remote sensing and existing inventory data. Using imputation (Söderberg, 2015) the most similar harvested sub-areas are selected. The results from the imputation can then be used for predicting the outcome of the planned site based on what was harvested on previous sites (figure 4) or a new synthetic stem database can be created in order to do bucking simulations. In one study the standard deviation for the total commercial volume decreases from 16% to 9% when comparing the traditional method with the new pre-harvest assessment. The imputation method is still under development.

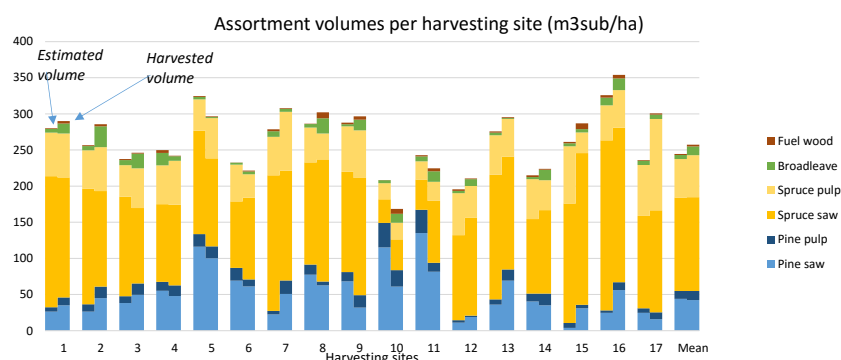


Figure 4: Preliminary imputation results from tests at 17 different harvesting sites in the south-east of Sweden. The first bar describes the estimated volumes based on an imputation while the second bar describes the harvested volumes as measured by the harvester.

Conclusion/Discussion

All preliminary results indicate that the new assessment method gives a better prediction than existing methods. Systematical errors are avoided and the standard deviation decreases.

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- Söderberg, J. 2015. A method for using harvester data in airborne laser prediction of forest variables in mature coniferous stands. Master's thesis. Swedish University of Agricultural Sciences.

7. Smart thinning of young dense stands for simultaneously extracting and keeping ecosystem service values

Bergström, D.¹

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Keywords: Biomaterials; forestry; early thinning; value creation.

Abstract

Boom corridor thinning (BCT) has been proposed as a cost-effective technique for biomass thinning in young dense stands. The objective of this study was to determine how various BCT operations affect stand structure following biomass thinning and to compare the results with conventional selective thinning methods. Two series of field experiments were established; BCT 1-series: Three sites in south of Sweden with five treatments, including a control, conventional selective thinning and three BCT treatments. The second BCT series: Three regions in Sweden (in the north, centre and in the south), with two stand sites in each region with different tree heights. Treatments were control, pre-commercial thinning (PCT), conventional selective thinning and BCT (high and low thinning).

Following the first biomass thinning, BCT regimes and selective thinning methods resulted in similar stand structures based on the number of possible future crop trees (>80 mm in diameter at breast height). However, BCT maintained a higher diversity of tree sizes as well as more stems per hectare, including deciduous species, than the selective thinning approaches.

In conclusion: The stands after BCT should have more vertical complexity, especially when compared to PCT. The structural heterogeneity resulting from BCT may also increase stand biodiversity and ecosystem service values.

Ref.

Ahnlund Ulvcróna, K., Bergström, D. & Bergsten, U. (2017). Stand structure after thinning in 1–2 m wide corridors in young dense stands. *Silva Fennica*, 51(3), id 1563.

8. Correlation between outer and inner quality attributes of forest stand

Räsänen, T.¹, Alanne, H.¹, Peuhkurinen, J.²

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Keywords: Wood quality, X-ray tomography, ALS

Abstract

Timber quality is essential factor in sawmilling profitability. Quality of the logs determines quality of sawn goods, it is not possible to upgrade quality in basic sawing. If the quality of the forest stand would be known prior to purchasing and logging of the stand, all operative decisions in wood harvesting could be done optimally. Preharvest methods based on field work could deliver this information, but they are too time consuming and costly for today's forestry.

The aim of the study is to test in operative scale how accurate quality characteristics based on airborne laser scanning (ALS) represent inner quality of timber cut from the same stands. For that purpose correlation between quality attributes based on remote sensing are analyzed against wood intake and x-ray measurements.

Stands are selected from an area which is interesting for forest industry, has relatively new ALS-data and contains enough x-ray measured stands. In the first phase of the study x-ray data of pine-logs from 1012 forest stands was collected from one sawmill. Based on this data comparisons between outer and inner quality attributes will be produced using existing predicting models and new ones developed during the study.

L2. IMPROVING EFFICIENCY OF BIOMASS ROAD TRANSPORTATION

9. Simulation of timber truck transport logistics – Case Central Finland

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Key words: discrete-event simulation, timber truck, transport logistics, operation model, multi-assortment load method

Abstract

In Finland, the operating environment in timber transports by trucks is challenging. Difficulties in logistics are caused by the dispersed and small sized timber storages at roadsides, high number of timber assortments as well as high fluctuation in road trafficability, in the weather affecting bearing capacity of roads and in the timber demand of mills. Forest industry together with logistics companies and timber truck entrepreneurs has eagerly searched for the solutions for improving timber transport efficiency.

The logistical case study in Finland tried to find cost-efficient operation models in timber transport logistics by trucks in a preset case environment in Central Finland. As an objective of this presentation, the influence of a multi-assortment load method was studied and compared to a single-assortment load method. In the single-assortment load method only one timber assortment can be transported during one transport cycle whereas in the multi-assortment load method different timber assortments can be transported in the same load.

Discrete-event simulation was used for studying the timber truck transports for the Finnish case. Simulation model included four trucks operating in Central Finland and supplying 25 different timber assortments to 12 end-use facilities being eight saw mills, two pulp mills and two train loading terminals. The total timber demand of end-use facilities over one year was 258,000 solid-m³.

The multi-assortment load method was on average 3.3% cheaper than the single assortment load method. In addition, the driving performance - presented as solid-m³ of timber per 100 kilometers - was 4.0% higher with the multi-assortment load method. Small assortment piles at roadsides caused difficulties in efficient timber transport due to driving between piles and the need of loading many small piles for filling the entire load space. The multi-assortment load method decreased drastically the number of rides between piles and, therefore, improved the performance of the fleet.

The developed model can be used to analyze in depth the effect of different logistical concepts on, e.g., transport costs, transported volumes and the utilization rate of capacity. The model can also be extended to other geographical regions.

10. Cost analysis of transporting forest chips and forest industry by-products with large truck-trailers in Finland

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Keywords: Transporting, truck-trailer, forest chips, bark, sawdust, sawmill chips.

Abstract

Laws mandating the physical dimensions of freight transport vehicles were changed in Finland and the new legislation enables higher gross weights as well as larger load capacities. The aim of this study was to examine truck transportation costs associated with forest chips and forest industry by-products as a function of transportation distance and procurement volume in order to determine the most cost-effective vehicle type for each assortment and find out how much the new vehicle types can improve the efficiency of wood biomass transportation. The transported assortments were whole-tree and logging residue chips produced at roadside landings, sawdust, and bark or sawmill wood chips from forest industries and ground stumps from terminals. The transportation costs were calculated as a function of permissible payload and transportation distance from the loading point to the end-use facility on the basis of existing driving speed models, productivity parameters, GIS data and hourly cost data. The results of this paper indicate that the new measures, technology and weight limits for heavy vehicles represent a significant cost reduction and efficiency improvement potential when transporting forest chips and forest industry by-products. The 69-tonne truck-trailer was a feasible choice when the payload was not limited by the bulk weight of the forest industry by-products. With heavier forest industry by-products, such as sawmill wood chips and bark, the 76-tonne truck-trailer was the most feasible choice. The results showed clearly that the transporting costs associated with using the new type truck-trailers were lower than those for conventional 60-tonne truck-trailers in all assortments.

Original article: Laitila, J., Asikainen, A., Ranta, T. 2016. Cost analysis of transporting forest chips and forest industry by-products with large truck-trailers in Finland. *Biomass and Bioenergy* 90(2016): 252-261.

11. Modeling cost reductions for multimodal transport in Norwegian wood supply

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Keywords: Rail transport, terminal network, demand scenarios

Abstract

Structural development towards fewer and larger mills in the Nordic forest sector has resulted in increasing transport distances and a subsequent need for more efficient logistics solutions. Earlier Swedish studies of multimodal roundwood transport have quantified the effects of rail system configuration on both costs and flexibility. This study examines the potential for cost reduction through development of the current rail system in south-eastern Norway.

The case models the main wood supply basin in southeastern Norway where 2 million m³ of pulpwood is transported annually to 2 main demand markets (domestic and export). The base case represents the current situation with 5 active roundwood terminals distributed along two rail branches. Terminals are fed from supply areas with varying limits for maximum vehicle weight, reflected by the respective truck transport tariffs. Rail lines serving terminals vary with respect to electrification and annual handling capacity. Cost functions for rail transport reflect the load capacity of available diesel vs. electric locomotives as well as the number of turns possible per period at the varying distances. A simple linear programming model optimizes the wood flows per link to minimize the sum of truck, terminal and rail costs for alternative configurations of between 4 and 7 active terminals. In order to find more robust alternatives, system costs were also compared between alternative scenarios for branch electrification and domestic vs. export demand.

The system cost from forest to mill for the base case (5 existing terminals) was modeled to just under 150 NOK/m³. Compared to the base case, the potential for cost reduction with new configurations varied from 1 to 17 %. Because of the relatively high costs for truck transport, the main driver for system costs was truck transport distances from forest to terminal. While a reduced number of active terminals generally increases truck transport distances (55 km in the base case), relocation of fewer terminals to areas of higher harvesting intensities enabled a 4 % reduction of average transport distance without further electrification (53 km for 4 active terminals, 140 NOK/m³) and 13 % with full electrification (48 km for 4 active terminals, 130 NOK/m³). This consolidation requires, however, increased annual handling capacity at existing terminals (downstream terminals in the current situation and upstream terminals for further electrification).

12. Optimal biomass truck load size and work models for loading of loose biomasses

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Keywords: bioenergy, truck transport, payload, work model, compression, optimization

Abstract

The most cost effective way of truck transport is to enable driving with full payloads. Typically, loose biomass payloads (e.g. stump and logging residue loads) are much under the allowed weights due to loose material characteristics. The payload weight is also dependent on the material moisture content and the material type. Work methods to load loose biomasses into the load space influence also the total payload size. In other words, how much time or what kind of compression techniques are used during the loading cycles.

In Finnish conditions the total weight of typical bioenergy truck is 64 tons and the volume of load space is about 160 m³. Weight of empty truck is about 31 tons. A typical payload size of stumps or logging residues is under 25 ton. 34 ton maximum payload is not often reached. It is also obvious that on short driving distances truck drivers should not use too much time for load compression operations because it might be possible to transport one extra load during the day driving period in the extra loading/compression time. Work methods and techniques to compress the load are also crucial to reach high payloads.

This study was divided into two parts and the objectives of the studies were to: calculate optimal payload size on different transport distances and describe productive work models for biomass truck loading with loose biomass materials. A model for optimal payload size was formed based on the given work phase time consumptions. Three different kinds of work models were described: a work model for loading of small sized stump material, a work model for loading of normal sized stump material, a work model for loading of middle size stump load with short loading time and a work model for loading of logging residues.

13. Biorefinery feedstock assessment made easy: Luke's tools to analyze harvesting potential, competition situation and transport distances for any given location

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Key words: biomass availability, GIS, transportation, supply costs

Abstract

Assessments of the availability of biomass feedstocks are critical to determine the feasibility of siting biorefineries or energy production facilities relying on locally-sourced materials. Biomass sources are usually scattered on large areas which emphasizes the importance of transport distances in feedstock supply. Investments are typically capital intensive and made for decades.

Therefore, the following questions should be answered before making an investment decision:

- How much biomass is sustainably and economically available?
- What kind of materials do feedstocks include?
- Where are they located?
- How does the availability fluctuate over time?
- What is the cost of feedstock at plant?
- What is the best logistical solution for supply?

Wall-to-wall datasets have been created and GIS-based tools developed in Luke to answer the above-mentioned questions. The existing datasets consist of technical harvesting potential of forest chips and agricultural residues, and spatially-explicit demand scenarios and balances for forest chips (Fig. 1). Automated GIS tools enable fast calculation of potentials as a function of transport distance (Fig. 2). Furthermore, addition of tailor-made demand scenarios is possible. These data, in turn, will be used when comparing different logistical set-ups and their costs. In this presentation examples of data and methods will be presented.

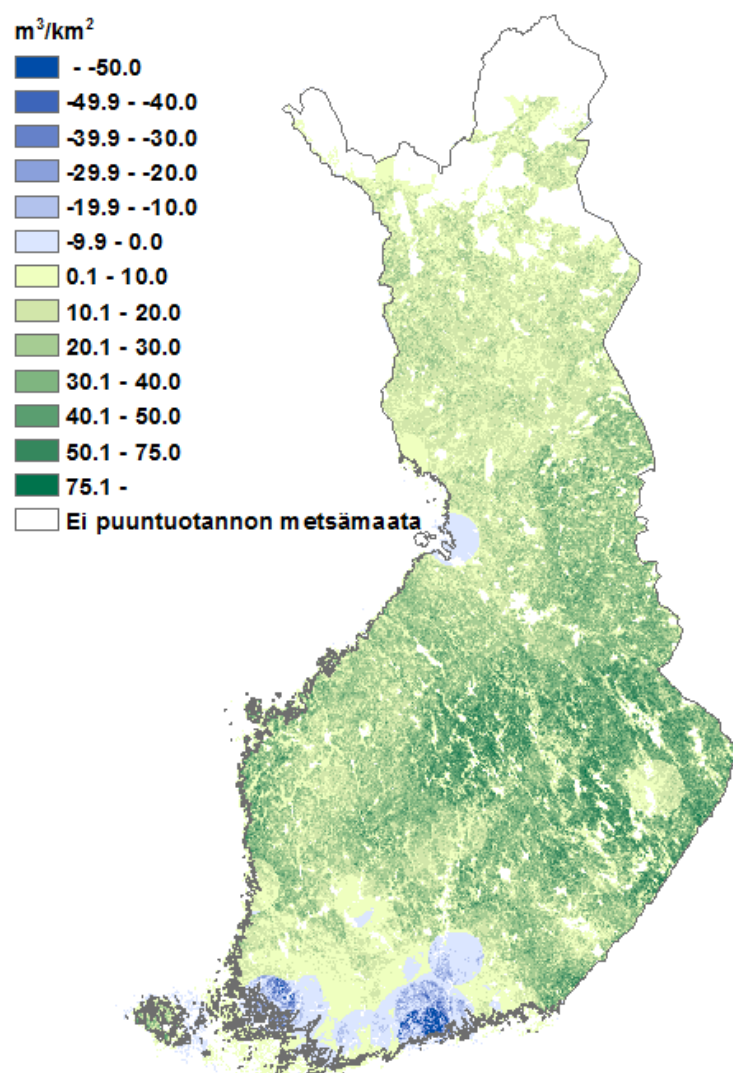


Figure 1. An example of forest chip balance of logging residues in 2030.

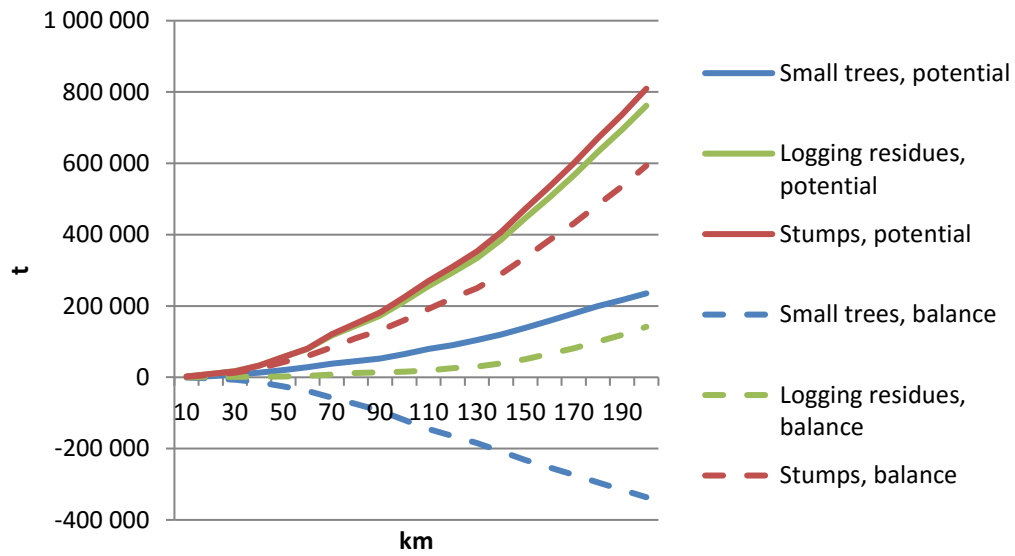


Figure 2. Forest chip potentials and balances as functions of transport distance in a potential biorefinery location.

S1.

14. The influence of institutional innovation to the development of the Estonian Forest sector

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Keywords: forest policy analysis, institutional innovation, forest sector, woodworking sector, revealed comparative advantage.

Abstract

Despite the economic importance of the forest sector in the Estonian economy, little attention has been paid to innovation of this sector. The aims of the presentation is to analyse how the innovation is included in the Estonian forest policy documents, to describe and analyse the main policy driven innovations in Estonian forestry governance, management of state-owned and privately owned forests and in forest industries;

According to the results, the illegal logging has been one of the fostering factors for forestry legislation changes. Forestry related institutional innovations are mainly targeted at controlling the forest owners' and forest managers' activities. Some of the Estonian forestry related activities are among the most controlled in Europe. For forest management planning (as well as forestry advisory services) a special activity licence or permit is required in addition to the compulsory forestry education. At the beginning, the implementation of control mechanisms and felling restrictions had a negative influence on the timber flows in the domestic market.

Some of the innovations, e.g. state register for the accounting of forest resource, were created for forestry authorities, but later various applications have become available to the general public

Political lobbying or politicians' activities have had both a positive and a negative influence on the forest sector innovativeness. Lobbying was needed for legislative changes, which led to the wood based electricity production by CHPs. Examples of negative political influence are innovative ideas in forestry legislation that were not fully enforced, the implementation rules or procedures were not developed and they were later repealed

The competitiveness of Estonian wood industries sub-sectors is analysed by using foreign trade statistics and revealed comparative advantage indices. In worldwide comparison the prefabricated buildings industry is the most competitive forest based industry subsector in Estonia.

The Estonian institutional innovation and changes in legislation have influenced not only forest owners and forest management practices but the whole national forest related sector.

15. Public perceptions of forest industry innovativeness on the road to bioeconomy

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Keywords: forest bioeconomy, innovations, public perceptions

Abstract

Creative destruction is taking place in the forest sector with many products maturing and factors for competitiveness changing in development towards bioeconomy. We investigate public perceptions related to forest industry innovations using data from an online questionnaire during May-September 2015. Altogether 218 valid responses were received and the data was analysed using descriptive statistics, t-tests, and factor analysis. We analysed past industry innovativeness using 13 bioeconomy products and services. Our respondents were in strongest agreement that forest industry has since year 2000 produced innovations for wood building systems, construction materials and composites. The lowest image of innovativeness since year 2000 was associated with organizational side: development of new marketing channels and recognized brands. The factor analysis produced a two-dimensional model of past innovations: one dimension describing product innovations and the other describing intangible innovations. While involvement with the sector had a significant effect on the way innovations were perceived only few saw radically new innovations. For instance, regarding nanocellulose over 1/3 of the respondents were incapable of evaluating either past or future innovation activity, indicating lack of public awareness. Results indicate the need to strengthen of both industry R & D and public awareness of the innovation efforts.

16. Techno-economic comparison of promising biofuel conversion pathways in a Nordic context – effects of feedstock costs and technology learning

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Key words: Biofuel; Techno-economic assessment; Forest biomass; Nordic countries; Partial equilibrium model; Feedstock costs

Abstract

Global demand for oil is increasing because of demand for transportation fuels. Decarbonization strategies for transportation modes currently include biofuels because these, in general, can be applied in the current vehicle fleet with little modification. The Nordic countries are at a vantage point in securing investments in second-generation biofuel production facilities; they have direct access to significant amounts of forest-based feedstock and have extensive experience with forest-biomass processing technologies. However, forest-based feedstock compositional complexity and variability poses challenges for biorefining technologies and fossil fuels are considerably more cost-competitive at the current oil price. This study compares the techno-economic feasibility of five promising forest-based biofuel conversion pathways for road transportation in the Nordic countries. We present (I) a literature review of techno-economic estimates detailing biofuel costs at various capacities, (II) estimate a scale-wise normalized cost-comparison of the conversion pathways, and (III) estimate the feedstock cost changes with increasing biofuel facility deployment in the Nordic Forest Sector Model. The results indicate that fast pyrolysis and hydrothermal liquefaction are the most cost-competitive options among the reviewed conversion pathways. We found fast pyrolysis costs to range from 0.7 €^{-L} to 1.1 €^{-L} while hydrothermal liquefaction costs range from 0.8 €^{-L} to 1.0 €^{-L}, depending on the techno-economic data used and forest-biomass marked demand. This is generally higher than costs identified in the literature and is due to comparatively higher Nordic feedstock costs. The conversion pathways are not cost-competitive with current fossil alternatives but may be cost-competitive with current biofuel conversion pathways, given nth plant cost levels. At a biofuel production level corresponding to 20% of the Nordic fossil fuel consumption for road transport, feedstock costs increase 12% to 35%, depending on the conversion pathway and the restrictions imposed on what constitutes biofuel feedstock. This corresponds to an increase ranging from 9% to 25% on the total costs. This highlights the importance of using models with endogenous handling of biomass such as Nordic Forest Sector Model for cost analysis of forest-biomass based technologies. Technology learning may decrease the overall biofuel costs with additional facility deployment, but this effect may be outweighed by the increase in feedstock costs, depending on the learning rate applied and conversion pathway. The results of this study can potentially aid policy creation for conversion pathway evaluation and support schemes and contributes to understanding important aspects related to the feasibility and potential for proliferating a forest-based biofuel industry in the Nordic countries.

17. Utilization of wood ash in forest fertilization: options and impact on tree growth in Latvia

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Key words: wood ash, forest fertilization, mechanized spreading

Abstract

Consumption of woody biomass as a renewable energy source has been increasing over the last decades. Whole-tree harvesting for biomass production and intensified removal of residues from forests can cause significant nutrient loss in soil. Nutrients can be returned to forest ecosystem by fertilizing soil with wood ash, which is generated as a by-product of combustion in wood-burning power plants and heating plants. Many studies on forest fertilization with ash have been done worldwide, however many aspects have not been analysed in Latvia, for example, variety of ash from different combustion systems, applicability of the ash for forest fertilization according to laws and regulations, impact on volume increment and options of mechanized ash spreading.

In the research wood ash samples from 53 companies were collected and chemical composition of the samples was determined. Use value of ash was analyzed according to national legislation and limitations. Some fertilization experiment of middle aged Norway spruce stands on drained soil was made in 2011 and additional stock volume increment was calculated. Later few experiments of mechanized ash spreading were made and productivity and costs of this operation was determined.

Wood ash chemical composition depend on many factors including capacity of combustion system, which has significant impact on texture, potassium, carbon and cadmium content. Although national legislation does not restrict use of wood ash in forests, the environment pollution, biodiversity and safety concerns should be considered before returning of wood ash back to forest and further development of regulations and guidelines should be done. Average additional stock increment of Norway spruce on drained organic soils 4 years after application of wood ash in spruce stands varied from 2.1 m³ ha⁻¹ to 4.8 m³ ha⁻¹ yearly. Productivity of ash spreading on average is about 5 ha in working shift (8 hours), however this kind of operation is more cost-effective than land-filling and some technological improvements of ash spreading could increase productivity. Additional cost should be considered for treatment of wood ash and quality control to avoid spreading of untreated ash in forest land.

18. Wood-based businesses in the next era of manufacturing

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Key words: Disruptive technologies; Industrial revolution; Internet of Things; Woodworking industry

Abstract

The concept “Industry 4.0” (later: I4.0) is commonly characterized by the Internet of Things (IoT), cyber-physical manufacturing systems, big data, cloud computing, and virtualization. Such industrial and societal development is disruptive and revolutionary. Futurists have anticipated that over the next 30 years the world will change more than during the past 300 years. While already evidencing the growing number of functional cloud services in the consumer market and simultaneously testing the first operational 5G networks, it is evident that the industrial scale IoT will soon become commonplace. According to research by PricewaterhouseCoopers (2006)¹, pulp, paper and packaging companies anticipate over a 3% increase in revenue and over a 4% decrease in costs, annually, over the next five years due to digitization. Wood-based businesses are indisputably embracing the tools of I4.0. This presents a significant opportunity to move away from commodity production and towards mass customization. In fact, I4.0 may represent a critical culture-changing phenomenon that is essential for the future competitiveness of forest sector companies operating in the bioeconomy of tomorrow. This contribution provided an overview of the characterizing features of “Wood I4.0” to make sense of the already advanced and yet-to-be-revolutionized parts of forest-based bioeconomy. First, a desktop study reviewed the phase of current discourse linking wood industry with I4.0. Second, the aspects emphasized within wood-based businesses were compared with general I4.0 literature. Third, examples of modularity with tallwood buildings, and consumer-driven furniture design were used to illustrate the ongoing and future developments within wood-based I4.0. Finally, the key benefits of wood-based manufacturing industry embracing the I4.0 were outlined along with relevant research foci.

¹PriceWaterhouseCoopers, 2016. Industry 4.0: Building the digital enterprise. Forest, paper and packaging key findings. www.pwc.com/gx/en/industries/forest-paper-packaging/industry-4-0.html

19. Sustainable forest-based bioeconomy: A case of biorefinery as a multi-product firm

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Keywords: bioeconomy, forest biorefinery, new forest products, policy instruments, pulp and paper industry

Abstract

The business environment in forest sector has changed due to several grand societal challenges and related policy drivers affecting the markets. Thus, appropriate economic incentives and policies are needed to promote the shift from the current forest industry to a forest bioeconomy.

Our study develops a new analytical framework of biorefinery, producing a variety of forest-based products, and applies it numerically to the Finnish forest sector. Modeling the biorefinery as an integrated multi-product industrial ecosystem is based on the hypothesis that the most efficient path towards new products relies on traditional forest industry production. The model provides that demand for timber for conventional forest products (pulp and paper) can be linked to its supply in order to examine how prices evolve under different policies. Hence, the policy framework is that of equilibrium forest bioeconomy. The forest bioeconomy model allows us to examine synergies and conflicts among the alternative production lines created by changes in demand or relative prices. Especially important cases are those where conflicts are created by a shortage of sidestreams and biowaste from traditional forest industry production, which lead to increasing prices or competing demand for roundwood from traditional and new production lines.

To examine the role of discretionary policies, we include in the biorefinery model different climate instruments and instruments promoting research and development for new products. We also aim to develop new instruments facilitating the efficient use of all biowaste grades among single and multiple firms within the biorefinery. Finally, we focus on policy coherence between general tax and other policies and instruments promoting the shift to a forest bioeconomy.

PLENARY SESSION

20. Wood supply digitalization in Finland

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Key words: big data, forest data, digital technology, Kuutio, open source data, forest inventory, sensor technology

Abstract

Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities. Wood supply digitalization can be regarded as a process, which has started already tens of years ago. But now we have excellent possibilities to take a major leap in the process through fast development of core technologies boosting digitalization. This kind of drivers are for example development of sensor technology and automation, improved data transfer and storing capacity, expansion of open data sources and advanced methods for big data analyses. Digitalization gives a great tool pack for forestry to improve the productivity and resource-efficiency of wood procurement and wood production. Improved data brings also new options to get more value from wood raw material.

The main goal in current R&D is to produce a solid basis for next generation's forest data ecosystem. Forest resource data produced on grid-level by advanced forest inventory systems has a central role in the future, but that information will be enriched through operational data sources like harvester data and x-ray data from sawmills. Main question in current research is how to improve cost-effectively the content and quality of grid data, and road data as well, to serve a reliable base for wood supply. On the other hand, essential activities enhancing data availability are in progress including renewal of forest data legislation and recommendations concerning usage of forest machine data.

The benefits of improved data can be realized through advanced planning, control and decision support systems. Many new data fusion, delivering and utilization concepts have been tested and productized in the last few years. One core application supporting wood supply digitalization is a web-based wood trade service Kuutio (www.kuutio.fi), which was launched recently.

21. Productive forest operations with a soft footprint - report from a strategic work programme in Swedish forestry

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Key words: Decision support, forest machine technology, innovation system, mechanized silviculture, operational planning.

Abstract

In 2014-2016 Skogforsk completed a strategic R&D-program totalling SEK 50 million. The goals were to improve productivity and environmental performance. The program was divided into three areas;

- innovation of forest machine technology,
- decision support for operational planning and
- more-efficient forest regeneration.

Being initiated by the Board of Skogforsk, the program had strong stakeholder involvement. Representatives of Skogforsks member companies formed steering committees, prioritizing and steering of projects. The projects were carried out according to the 'the innovation triangle' concept, simultaneously engaging users, manufacturers and researchers.

Machine technology projects included e.g. test and demonstration of forwarder concepts with low impact to sensitive soils, boom automation, head-up displays and a feller-buncher for small-diameter tree harvesting. A test rig for technical evaluation of bucking was developed and used e.g. of the studies of the V-cut saw bar.

Several projects on Decision support addressed improved efficiency in logging and terrain transportation while minimizing rutting. An aim was to implement tools based on 'big data' usage, including LIDAR data, digital terrain models, new StanForD data etc. Projects included development of routines to use the digital terrain models and depth-to-water maps in logging and scarification; a decision support tool for optimizing the main extraction routes in logging; assortment mix forecasting, and operations sequence planning.

Forest regeneration projects pursued the vision of continuous mechanized planting on inverted, compacted plough tilts. The main project concerned a technology for inverting, being a prerequisite for the vision. Other projects compared inverting with conventional technologies, and rationalising the interface between nursery and planting machine. Effects of inverse scarification on dead wood substrate was also investigated.

In conclusion over 25 projects addressing strategic areas of R&I identified by the sector were completed. Often, the strategic program was used to reinforce existing projects and as an "entrance fee" to join EU projects (EFFORTE - decision support and OnTrack - novel forwarder technology). The total cost of the projects is considerably higher than the program budget which, used alone, would have sufficed for only one or two of the major projects. On the other hand, if just one innovation, such as the V-cut saw bar, is realized the revenue of improved bucking will widely exceed the cost of the whole program.

The programme added value to Skogforsks R&I. Notable achievements are; implementation of digital terrain models, DTW maps and decision support systems; machine innovation, especially concerning soft footprint, and further development of technology for soil preparation.

22. Reducing seasonality in wood harvesting operations in Finland Kärhä, K.¹, Tamminen, T.², Leinonen, T.², Suvinen, A.¹

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Key words: seasonal variation, wood harvesting, forest machines, cost-efficiency, Finland.

Abstract

A survey was conducted by Stora Enso Wood Supply Finland (WSF) to map out the main causes of seasonal variation in wood harvesting operations, the most important ways to decrease seasonality, and how the different ways to reduce seasonal fluctuations were currently used. Furthermore, the potential for the future utilisation of the various means of reducing seasonal variation was determined.

The study was carried out as a Webropol survey in December 2016. The participants of the survey included forest machine contractors of Stora Enso WSF, wood harvesting employees of Stora Enso WSF, personnel of the Tornator Group, forest machine and equipment manufacturers, as well as representatives of R&D organisations. A response link for the query was sent to a total of 193 persons, of whom 149 replied to the questionnaire (response rate: 77.2%).

Respondents felt that weather conditions (the season of bad roads during spring and autumn, as well as short and mild winters) were the main cause of seasonal variation in Finland. They also listed other factors for seasonality, such as limited standing stocks, the poor condition of road infrastructure, variations in the wood consumption of mills, and the prejudice of forest owners towards summertime wood harvesting in Norway spruce stands and peatland forests.

Forest machine contractors and wood harvesting employees predicted that the biggest opportunities for reducing seasonal fluctuations in the next few years would be through a common planning and steering system in wood harvesting (i.e., WoodForce™) as well as with sufficient standing stocks and by improving road infrastructure in Finland. Personnel of the Tornator Group, correspondingly, estimated that the greatest potential for utilisation would be through decreasing the ground surface pressure of harvesting machinery with wide load-bearing tracks, enhancing the skills of operators, and increasing the use of weather and soil information in harvesting operations.

According to the forest machine manufacturers, the largest utilisation potential was with the WoodForce™, the development of tutoring systems for forest machine operators, the reduction of ground surface pressure of harvesting machinery, the participation of the forest machine contractor in the client's annual planning, and peatland wood harvesting in the summertime. Similarly, the representatives of R&D organisations listed that the biggest potential for exploitation was through better forecasting of the mobility of forest roads, developing tutoring systems for operators, the renovation of road infrastructure, a more accurate classification of harvesting sites, and better utilisation of soil data in wood harvesting operations.

T1

23. Research activities of planting and sowing mechanization in Latvia

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Keywords: mechanized planting, mound, birch, spruce, pine, soil, forest regeneration.

Abstract

The forest regeneration and afforestation research group resumed investigations on mechanization of forest regeneration in 2007 after a gap of twenty years since the last activities in this area. Main experimental activities took place nearby Riga in cooperation with "Rīgas meži" SIA and Joint stock company "Latvia State forests".

The first studies were targeted on mechanized planting of coniferous and deciduous container seedlings on mounds. In cooperation with SIA "Intrac" mechanized planting device Bracke P11a was tested to evaluate productivity in Latvian conditions when pine, spruce or birch seedlings are planted on various soils (silt, loam and clay). Two methods were compared in the study: direct mechanized planting on mounds and manual planting in area prepared by disc trencher. The study approved that in conditions characteristic to Latvia mechanized planting of one seedling takes less time, but due of requirement to plant more trees per ha in compare to Nordic countries, planting of one ha takes more time. Ingrowth of seedling was the same or better in compare to ordinary in late autumn plantings. One year later (2008) mechanized planting device M-planter were tested in "Rīgas meži" SIA forests, shape, size and quality of mounds were more appropriate for Latvia conditions as in previous experiment, here by repeated experiments were done in May 2017 to establish experimental – demo compartments in JSC Latvia State forests where mechanized planting and manual planting on mounds done. Results of mechanized planting with the device having two planting tubes, which is able to prepare simultaneously two planting spots, demonstrated better productivity (25 % less time per ha in compare to Bracke P11.a) in 2008. One head M-planter used in 2017 experiment set. Results of first experiments shows that pine and spruce on mounds grow better, have higher year increments and are more vigorous. Only limiting factor for implementation mechanized planting in forest practice is cost and number of planted seedlings required in forest regeneration rules – at least 2000 for pine and 3000 for spruce which is almost twice more as in Finland.

Trials of mechanized sowing were done twice – the first experiments with Bracke S35 sowing device mounted on Bracke M25.a moulder were established nearby Riga in 2008, second set of trials of mechanized sowing by Sigma and disc trencher was established nearby border of Estonia, close to Valka city. Both sowing experiment established by hiring service from Estonia, where sowing is ordinary forest regeneration practice. Results of sowing in all stands are good and sowing could be recommended for implementation as forest regeneration practice for pine on bare sandy soils.

Acknowledgements to Forest development fund, SIA "Rīgas meži", JSC "Latvijas valsts meži".

24. Integrated roundwood and biomass terminals – 0,1 TWh case

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Keywords: terminal, roundwood, biomass, costs, TWh, HCT-trucks

Abstract

The aim of this study was to estimate the cost saving potential of integrated roundwood and biomass terminal. The idea for the integrated terminal comes from the need to utilize a terminal area in a central traffic location such a way that it serves both roundwood and biomass storing and refining needs.

In a basic scenario, an integrated terminal operates in a way that during the late winter and spring the terminal is filled with roundwood from low condition roads and during the spring thaw period, the terminal storage of roundwood is used for plant's needs. During the summer the terminal will be filled with biomasses: delimbed small sized trees, large decayed trees and stumps. In autumn, the biomass is ready for heating needs for the coming winter. When taking some material out of the terminal, some other material is brought to the terminal.

Primarily, the terminal is a biomass terminal so it has environmental licenses to perform comminution operations and store biomasses on the area. The benefits of integrated terminal are reached from the effective terminal area use and integrated terminal machine use. When storing materials intensively to same storage area, the utilization rate of the area is high.

In Finland, the aim is to design and develop road network so that there would be loading terminals for HCT-trucks (over 76 t). HCT-trucks do not have own loaders and they can run only on highways. Thus, HCT-trucks need easily accessible loading terminals where they are loaded by some other trucks or terminal loaders. Hence, integrated terminals could serve HCT-transportations, too. In addition, integrated terminals enable round-trip load option: transporting of delimbed energy wood to terminal and taking pulp wood load to pulp mill, for example.

In this study, a terminal size of 0,1 TWh was examined. The minimum size for the terminal area was calculated to be 2.9 ha that is needed in September when the terminal is almost solely in biomass storage use. The infra costs were calculated to be 1.2 €/sob-m³, material handling costs 4.2 €/sob-m³ and thus the total costs 5.4 €/sob-m³. If roundwood and biomasses are stored in separate terminals, the total costs would be 6.3 €/sob-m³. The cost savings of integrated terminals would be about 14 % compared to separate terminals.

25. Detection of stems and tree damage in softwood stand by a machine vision algorithm based on color analysis

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The abstract will not be published by the author's wish, as it will be soon published in a formal publication series. If the publication will be completed very soon, the abstract can be published also in this series.

26. Factors affecting productivity of Vimek 404 T5 harvester in pre-commercial thinning

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Keywords: Vimek harvester, productivity, thinning

Abstract

The aim of the study is to evaluate productivity of Vimek 404 T5 harvester in the first thinning. The study was carried out in spring (16.8 ha) and in summer (9.6 ha). In spring 1109 m³ were extracted (D1.3 = 10 cm, stem volume – 0.08 m³), in summer – 350 m³ (D1.3 = 9 cm, stem volume – 0.04 m³).

In the spring trials on average 82 trees were processed and 6.5 m³ of logs were produced per productive hour. In summer trials 118 trees were processed and 5.1 m³ logs were produced per productive hour. Significantly higher productivity was observed in spring trials in areas without undergrowth trees. Better productivity in spring was observed in *Hylocomiosa* stand type, which might relate to thinner branches and shorter crowns. In summer trials better productivity was observed in *Myrtillosa mel.* stand type. In naturally regenerated stands better productivity was obtained during extraction of smaller trees (D1.3 < 17 cm), in artificially regenerated stands – during extraction of bigger trees. Harvesting with 2 “ghost tracks” instead of one significantly decreased productivity. Weather conditions have also impact on productivity – during moderate rainfall productivity significantly decreases.

Three types of forwarders were compared – Kranman Bison10000 6WD, John Deere 810 and Logbear F4000. In total 1089 m³ logs were forwarded, including Kranman Bison (average load 2.2 m³), John Deere 810 (average load 7.9 m³) and Logbear (average load 5.5 m³). Productive time (excluding driving) per 1 m³ with John Deere 810 was 5.5 min. m⁻³, Logbear F4000 – 5.9 min. m⁻³ and with Kranman Bison 10000 4 WD – 11.8 min. m⁻³.

Prime cost of a working hour of Vimek 404 T5 harvester is 44 €. Prime cost of a working hour of the machine set consisting of Vimek harvester and Logbear F4000 forwarder is 73 €, Vimek harvester and Kranman Bison forwarder – 63 €, Vimek harvester and John Deere forwarder – 81 €. Prime cost of log production ranges from 14.6 € m⁻³ (with Logbear F4000) to 16.4 € m⁻³ (with Kranman Bison 10000 6WD).

Research was implemented in Latvian State Forest Research Institute “Silava” within the scope of memorandum between JSC “Latvia state forests” and LSFRI Silava from October 11, 2011 “On cooperation in scientific research”.

27. Fields of application of Kranman Bison 10000 and other small forwarders

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Keywords: Kranman Bison 10000, productivity, thinning

Abstract

The aim of this study is to investigation of potential uses of Kranman Bison 10000 6WD forwarder in thinning under normal and difficult forwarding conditions, determination of productivity, average load size, driving speed and forwarding costs.

In this study forwarding productivity data are obtained in stands, where roundwood is extracted with a chainsaw and Vimek 404 T5 harvester working in normal and difficult forwarding conditions. "Normal forwarding conditions" mean that soil bearing capacity is good and moist areas are not crossed, whereas "difficult forwarding conditions" mean that soil bearing capacity is moderate or weak, moist areas are crossed and it is necessary to strengthen strip-roads with harvesting residues. John Deere 810 forwarder was used to compare productivity of Kranman forwarder with that of a medium-sized forwarder under normal conditions.

In 2016 Kranman Bison 10000 forwarder had worked in total 697 hours, including about 250 hours in forests of Forest Research Station during the trials. In total 230 loads were forwarded during the study, including 63 loads from areas, harvested with a chainsaw, and 167 loads from areas, harvested with Vimek 404 harvester. The average forwarded load is 2.0 m³ (the maximum load is 2.5 m³ therefore the average load capacity is 80%). In average 33 minutes of productive work time were spent by forwarding one load (the proportion of productive working time is 94% from total engine hours of the machine). The average length of forwarding road in trials is 286 m. Forwarding of 1 m³ takes 16 minutes of productive working time, but in difficult forwarding conditions the time consumption increases by 15%. The average forwarder fuel consumption is 1.8 L per hour. Accordingly, 0.4 L of fuel is consumed to forward 1 m³ roundwood. In comparison, John Deere 810 under similar conditions consumed 1.3 L fuel to forward 1 m³ roundwood.

Prime cost of a Kranman Bison 10000 working hour with a 5% rate of return is 20 € (prime cost of a productive working hour is 24 €). Roundwood forwarding prime cost, when working 1172 productive hours annually, is 7.2 € m⁻³. Forwarding prime cost is significantly influenced by forwarding distance and machine utilization rate (average annual working hours). Forwarding prime cost significantly increases, when tractor works less than 1000 hours annually.

Study results prove that the best application of Kranman Bison 10000 is forwarding small stands or individual trees, when logging with a chainsaw. Forwarder can work on soils with weak bearing capacity, however productivity can be significantly hindered by stumps and uneven terrain.

Research was implemented in Latvian State Forest Research Institute "Silava" (LSFRI Silava) within the scope of memorandum between JSC "Latvia state forests" and LSFRI Silava from October 11, 2011 "On cooperation in scientific research". Forwarding trials were conducted by Forest and Wood Products Research and Development Institute (MeKA) involving qualified operators and monitoring operational cost.

28. Measuring timber stacks with TRESTIMA Stack

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Key words: timber inventory, Trestima, mobile measuring, accuracy, time consumption.

Abstract

TRESTIMA Stack is a mobile application innovated by Trestima Ltd. It is based on machine vision which measures the volume of a timber stack from images taken by a smartphone or a tablet device. The aim of the study was to determine the accuracy and time consumption of the TRESTIMA Stack application compared with the conventional method of measuring timber stacks. In addition, potential development areas for TRESTIMA Stack were investigated in the study.

The use of TRESTIMA Stack was clarified with both smaller roadside timber stacks and larger wood terminal and intermediate yards. Research data consisted of a total of 60 timber stacks of which 32 were measured in large terminal yards and 28 at roadside landings. The control volumes of the stacks were measured in October 2016 – February 2017 in Stora Enso Anjala, Imatra and Varkaus mills by weight scale sampling with immersion. The total control volume in the research was 11,957 m³ solid over bark (sob).

In the whole data of the research, the accuracy of TRESTIMA Stack was +2.7%. In large terminal yards, accuracy was better (+0.7%) than at roadside landings (+4.5%). When utilising the conventional method of measuring timber stacks, measurement accuracy was almost at the same level: -4.8% in terminal yards and -4.9% at roadside landings. There were statistically significant differences between the measurement methods used. The average effective time consumption with TRESTIMA Stack was 10 s/m³ sob and 16 s/m³ sob with the conventional method of measuring timber stacks.

The most common reason for inaccuracy with the TRESTIMA Stack application was empty space in the final image framing around the stack. Consequently, TRESTIMA Stack assessed the gross volume of the stack too high. Although TRESTIMA Stack is very accurate especially when measuring large quantities in terminal and intermediate yards, the use of TRESTIMA Stack in narrow gaps between timber stacks is not easy. In terminals, timber stacks are normally stored side by side due to the lack of space. Those timber yards are currently measured by multiplying the volume of first stack by the number of stacks behind it because measuring the middle stacks is impossible. TRESTIMA Stack will not remove the challenges of volume evaluation in such timber yards. Therefore, we recommend TRESTIMA Stack for inventorying timber stacks at roadside landings.

29. Productivity of Logbear F4000 forwarder on soils with low bearing capacity

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Keywords: Logbear F4000, productivity, thinning

Abstract

The aim of the study is to test tracked forwarder Logbear F4000 in thinning in forest stands with bad or extreme forwarding conditions (on wet and drained mineral and organic soils), including productivity, fuel consumption, load capacity, driving speed and forwarding costs. The trials were conducted in 2016 and 2017 by forwarding logs in thinning with bad or extreme forwarding conditions (wet mineral and organic soil), where harvesting was done by John Deere 1070 harvester and chainsaws.

According to the study results Logbear F4000 forwarder is suitable for extreme and bad forwarding conditions in pre-commercial and commercial thinnings, but it can be also used in salvage loggings and, when necessary, in final felling; however, larger machine is recommended for the final felling. The machine set required for optimal organization of work is team of workers with chainsaws (4 persons) or a harvester suitable for soils with low bearing capacity (for example, Vimek 404 T5) and Logbear F4000 forwarder working in two 8 hours long shifts. The relatively rapid depreciation of tracks and towing cog-wheels lead to assumption that the Logbear F4000 should be used primarily on organic soils and planning of the operation should be done in a timely manner and avoiding working on mineral soils. In order to empirically prove this hypothesis, long-time observations of machinery operated under different conditions are necessary. Use of the Logbear F4000 forwarder should be avoided in felling sites, where previous forwarding attempts with a wheeled tractor were unsuccessful and deep ruts on forwarding trails and strip-roads are already formed.

Logbear F4000 can transport 16.9 thousand m³ logs (18.8 thousand m³ with bark) annually. According to the study assumptions the forwarder works 2905 productive hours annually and an average forwarding distance is 270 m. The productivity is significantly influenced by increase of forwarding distance and the number of hours worked. No significant difference was found in forwarding productivity, when logging was done with a chainsaw or a harvester. In average 15.5 minutes of productive work time were spent for loading, 4.7 minutes for unloading. The average load was 3.6 m³ and the average driving speed – 45 m min.⁻¹. Prime cost of timber forwarding was 6.83 € m⁻³. One of the possible solutions to reduce the cost is use intermediate yards in a felling site. However, in order to introduce this solution, possible advantages and disadvantages should be assessed.

The average fuel consumption of Logbear F4000 is 4.9 L per hour (0.7 L m⁻³). It was concluded that the tested fuel accounting system is not suitable for research purposes and the information on fuel consumption is underestimated. In order to obtain a data set that is suitable for the operational monitoring, network interface should be improved, invalid data should be filtered and summaries of data from felling sites should be prepared.

The study was implemented by Latvian State Forest Research Institute “Silava” (LSFRI Silava) in a collaboration with SIA “Saulkrastu meži” within the scope of memorandum between JSC “Latvia state forests” and LSFRI Silava from October 11, 2011 “On cooperation in scientific research”.

30. Impact of Small and Middle Sized Forwarders to Soil Compaction During Mechanized Thinning in Young Stands

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Keywords: thinning, forwarding, soil compaction, penetration resistance

Abstract

Impact of a variety of forestry machine types on soil compaction is evaluated in this study according to the measurement of soil penetration resistance at 0 to 80 cm depth. It is concluded in the study that soils with poor bearing capacity (PBC), comparably small penetration resistance and organic layer thicker than 5 cm are less vulnerable to soil compaction. The use of small-size forwarder Vimek 610 allows to reduce soil compaction to an insignificant level in comparison to the control sites, and most or ruts disappear within a few days in PBC conditions. Whereas John Deere 810E, which belongs to the middle-size class of forwarders, significantly compacts soil through the whole measured depth in similar conditions. Rottne F10B and John Deere 810E forwarders represent the same weight category, and soil compaction due to the use of these machines on soils with moderate bearing capacity (MBC) is similar too; however, on soils with weak (WBC) and good (GBC) conditions results are different, mostly due to a different amount of extracted roundwood in both trials. Tracked forwarder was used only in GBC conditions and the results demonstrated significant compaction only down to 22 cm depth. The trials confirm that the depth of the intensity of impact depends on the weight of the machine and amount of material extracted; however, additional measurement data are necessary to characterize the impact quantitatively in different conditions.

S2

31. Utilization of industrial side streams originating from sawmilling – challenges and suggestions

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Keywords: by-products, circular economy, sawmilling, side streams, value adding use

Abstract

According to the Finnish Sawmills Association, the Finnish sawmilling industries is increasing the production volumes, in line with the Finnish bio-economy strategy. Consequently, the side streams consisting of bark, sawdust, and wood chips are increasing. By-products form around 50% of the total output of saw mills. Therefore, utilization rate of by-products have an important role in the profitability of sawmilling. Bark and sawdust are mostly used for heat and electricity, but high quality wood chips are used in pulp production – pulp chips are also of much higher value than dust or bark. Other possible uses for by-products include for example particle board, wood-based composite and biofuel production.

The market situation of by-products can be challenging to follow, as for example during summer the demand for energy decreases in Finland. In addition, it is unprofitable to transport by-products long distances, as the financial profits decrease by half in over 60 kilometer distances. However, the long-term predictions are even more difficult to make, because prevailing resource use and energy policies much affect wood flows. For example, due to subsidies payed for small-sized tree harvesting and currently low price of electricity in Finland, it is cheaper for power plants to use forest biomass instead of bark and sawdust.

The weak utilization of by-products goes against the target of European Union to facilitate implementation of circular economy, which means keeping the value added in products for as long as possible by prolonging their lifetime and minimizing waste and disposal. Several new investment purchases have become in progress in a field of pulp and next generation liquid biofuel industries in Finland recently. If those plans are actualized, the use of wood can increase by 6 million cubic meters annually. This opens new opportunities for by-product utilization, as seen in the new bioproduct mill of Metsä Fibre in Äänekoski, Finland. Transforming byproducts to value-adding materials instead of incineration could create more environmental and social benefits. Several modelling studies have shown material production to be more effective than energy generation from a viewpoint of increasing carbon stock and employment. To develop new value adding practices and increase resource efficiency, long-term drivers and barriers as well as possible wood flow changes due to new business solutions should be studied in detail by using scenario analysis or similar foresight methods.

32. Identification of wet areas in forest by using LiDAR based dem **Ivanovs, J.¹, Sietiņa, I.¹, Lazdiņš, A.¹, Skola, U.¹, Zvirgzdiņš, A.¹, Zvaigzne, Z. A.¹**

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Keywords: depressions, fill sink, wet areas, forest management.

Abstract

Water tends to flow and accumulate in response to topographical characteristics of local area and gravitational potential energy. Remote sensing data like LiDAR (Light detecting and ranging) or satellite data can be used to identify local depressions where wet areas may occur. The aim of this study is to evaluate methods that can be used to identify wet depressions in forest landscape and to prepare recommendations for management of forests in Latvia considering distribution and potential impact of the depressions. Study area includes fertile forest stands on wet and drained mineral soils with planted spruce (*Picea abies*) and available LiDAR data. The primary task of the study is to determine correlation between topography of the area, growth conditions and forest regeneration. Map examples has been made to demonstrate methodology for identification of the depressions with potentially hindered run-off. Fill sinks algorithm shown the best results in identifying the depressions and correlation with the field measurement based map of wet areas is 62%. TWI index is not suitable for identification of depressions because of relatively flat landscape. Result of this study reveals that the wet areas have significant effect on tree species composition. In depressions, despite the fact that these areas has been planted spruce, main species are birch (*Betula pendula*) and black alder (*Alnus glutinosa*). Wet areas do not have significant impact on average tree height.

The study approves that landscape have significant role in determination of the water regime, effect of depressions may affect wide areas and wet conditions may persist even to the edges of depressions. It also demonstrates considerable potential of small scale drainage using network of shallow ditches to improve the growth conditions in considerable area.

Further studies are needed to evaluate different algorithms for detection of the depressions, as well as capabilities of different remote sensing data to increase accuracy of the evaluation and to provide more information for the forest management decision making. It is concluded in the study that TWI index cannot detect depressions and potentially wet areas with sufficient accuracy because of relatively flat landscape.

Research was conducted in Latvian State Forest Research Institute “Silava” (LSFRI Silava) within the scope of memorandum between JSC “Latvia state forests” and LSFRI Silava from October 11, 2011 “On cooperation in scientific research”.

33. GIS and remote sensing BASED planning OF FOREST regeneration

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Keywords: forest site preparation, forest management, groundwater, GIS, DEM.

Abstract

The aim of this study is to identify typical characteristics of forest site preparation (FSP) including direction of FSP, number of manoeuvres depending on parcel configuration and forest type and width of manoeuvring track); to evaluate FSP productivity depending on growing conditions; to create schemes of strip roads for commercial thinning; to improve scheme of FSP according to optimized scheme of strip roads in commercial thinning and to evaluate impact on number of manoeuvres and the total distance travelled.

In this study we have developed methods to evaluate quality of FSP. Study shows that there is a significant difference in productivity when machinery of FSP is driving in different angles to the longitudinal axis of parcel. Reduced productivity is justified by prioritizing topography of the ground slope is a decisive factor in groundwater movement and should be considered in FSP planning.

In 41 % of sampled forest stands developed method could be implemented in practice of forest management management.

Before terrain data are used in planning of the FSP, different methods for detection of groundwater movement and wet areas should be analysed for better identification of areas with higher risk to disturbances.

Research was implemented in Latvian State Forest Research Institute “Silava” (LSFRI Silava) within the scope of memorandum between JSC “Latvia state forests” and LSFRI Silava from October 11, 2011 “On cooperation in scientific research”.

34. Diversification of the Finnish forest industries: Role of new products

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Key words: competitiveness; market potential; new wood-based products; structural change

Abstract

The Finnish forest industry has undergone significant hurdles since mid-2000s, with a wave of divestments in pulp, graphic paper and sawmilling capacity and a recent resurgence of investments for example in market pulp and biofuels. Should the current trends continue, loggings are projected to increase to close to 80 million cubic meters in Finland towards 2030. Recent assessments show that such development goes against bioeconomy ambitions, as the production value of the industries is increasing significantly slower than the industrial wood use. However, this picture does not consider the potential impact of emerging wood-based products.

This study aims to remedy this gap by reviewing and analyzing the available literature and data. The specific objectives are to i) define 'new wood-based products', ii) to identify and evaluate the factors affecting the market potential of selected emerging wood-based bioproducts, and eventually iii) to build an understanding, to which extent and on which premises the emerging forest-based products can compensate for the maturing core businesses of the Finnish forest-based industries. This is done by reviewing two 'what if' scenarios for 2050: A) Gaining a 1% market share of the global markets, and B) gaining a 50% share of forest industries' export value from new products.

The most significant emerging markets for forest-based products are typically thought to include construction, textiles, chemicals, polymers, liquid biofuels, as well as a number of small niche markets such as cosmetics, food additives, and pharmaceuticals. The preliminary findings suggest that a 1% market share in each of the five major markets in 2050 could imply a roundwood demand of more than 100 million m³ (incl. side streams and forest residues) and a production value of 37–153 billion €. Consequently, the scenario of Finland achieving a 1% market share in all of the above markets simultaneously seems difficult to reach. Moreover, the analysis of unit values suggests that new products do not self-evidently compensate for the decline of the paper industry in terms of wood use productivity (€/m³), although the data used does not allow making precise assessments on this. One of the largest uncertainties for the conclusions, apart from the data, is whether the industries will mostly produce intermediate bulk products or high value end products in the selected markets. The implications for sustainability and employment remain to be carefully assessed.

35. Economic and climate change mitigation potential of forest fertilization in state forests in Latvia

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Keywords: forest fertilization, wood ash, nitrogen, volume increment, CO₂ removals, internal rate of return

Abstract

The research objective was to assess the potential impact of nitrogen fertilization and wood ash application on wood volume increment in state forests, as well as to determine the economic impact and climate change mitigation potential of this forest management practice. National forest inventory data was used to select forest stands suitable for nitrogen and wood ash application in state forests. Environmental restrictions and other objections of forest management are not considered, therefore the study represents theoretical potential of economic and climate change mitigation. When nitrogen fertilizer is applied at 2.0 thousand ha of forests annually, additional wood volume increment in 10th year reaches 28 thousand m³, but the cumulative increment is 142 thousand m³. When wood ash is applied in 4.3 thousand ha of forests annually, the volume increment after 10 years reach 58 thousand m³, but the cumulative increment is 290 thousand m³. Internal rate of return for nitrogen fertilizer application 20 years from the project start is 11%, but for ash application – 13%. Project influence of gross domestic product reaches its maximum (3.2 million € per year) 11 years after starting the project. Cumulative reduction of greenhouse gas emissions due to forest fertilization corresponds to 635 thousand CO₂ eq. in 10 years. Forest fertilization would contribute to CO₂ sequestration equivalent to 12.7 million € in 10 years. The value of additional CO₂ removal is equal to 156 € ha⁻¹.

Research was implemented in Latvian State Forest Research Institute “Silava” (LSFRI Silava) within the scope of memorandum between JSC “Latvia state forests” and LSFRI Silava from October 11, 2011 “On cooperation in scientific research”.

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