Nordic Forest Research
Cooperation Committee - SNS

Project no: SNS-96 (P2/05)

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FINAL PROJECT REPORT

Please notice that the size of text sections in the form can be adjusted if needed.
The length of the final report should not exceed 5 pages.

1. Projekt titel	Skörd av bioenergi i unga skogar
2. Title of project	Harvesting of bioenergy in young stands
3. Project leader /coordinator (name, address, telephone, telefax. e-mail)	Professor Tomas Nordfjell, SLU, Institutionen för Skoglig Resurshushållning, avd för Planering och teknologi, SE- 901 83 Umeå, Sverige. Tel +46 (0) 90 7868399, Fax +46 (0) 90 7868321 e-mail: Tomas.nordfjell@srh.slu.se (Notera, ändrad institutionstillhörighet pga omorganisationer)
4. Time schedule	The project started 1 / 1 200 5 and ended 31 / 12 200 7
5. Project cost	SNS-grant: 500 000 NOK or ~186 994 Euro Total project cost: ~481 687 Euro Separate document
6. The purpose of the project/main problems/hypotheses addressed	Separate document

7. Brief description of the research plan and of possible larger deviations from the plan	Separate document
8. Results (max 2 pages)	Separate document
9. What advantages has been gained by the Nordic collaboration (i.e. by the cooperating partners, use of the project results)	Separate document

10. Publications and other communication activities (please list scientific reports, more popular reports and other communication activities)	Separate document
11. Project summary (about 1/3 page) with main emphasis on results for possible use in the News & Views section of Scandinavian Journal of Forest Research	Separate document
12. Date and signature	Date: 2008-09-26 Signature of project leader/coordinator

Final project report SNS-96 (P2/05), appendix

6 The purpose of the project/main problems/hypotheses addressed

The overall goal of the project is to conceive and evaluate new operational systems and logistic solutions that allow for an economically feasible and environmentally responsible conversion of biomass from young forests. The hypothesis is that harvesting techniques based on area handling (corridor harvesting) and / or multiple stem handling in combination with bunching, or handling the stems as a bunch in the downstream chain, would contribute considerably to achieving that goal. In Sweden, the project focused on boom-tip technology for corridor harvesting, while in Finland, other concepts of multiple-stem capable harvesting heads, systems productivity and economics, as well as nutrient losses from the harvesting of slash from early thinnings were studied. The Danish part focused on logistics and economics around the dilemma of producing chips in-field, at the roadside, or at the industry. For Norway, emphasis was placed on finding efficient techniques to harvest woodfuel in young stands where tending operations are delayed and in cleaning operations on roadside verges and in former agricultural or grasslands. For Iceland, emphasis was placed on finding the potential for harvesting in young stands, and to get information and experiences from the other countries.

7 Brief descriptions of the research plan and of possible larger deviations from the plan

A number of variations on corridor harvesting with boom-tip technology in young forests were tested with regard to: a) productivity, b) the effect of corridor harvesting on the future development of the stand, and c) the economic potential of the method. In this case, corridor harvesting is defined as the utilisation of a crane mounted harvesting head in felling all the smaller trees in a corridor that is 1-1.5 m wide and up to 10-11 m long. The system was compared with a single-grip harvester. Logistics, productivity and the economic aspects of chip delivery were analysed and compared when comminution takes place in the stand, at roadside or at a conversion plant, respectively. Techniques and logistics associated with multiple stem harvesting and bunching in-stand were analysed with regard to productivity, nutrient depletion relative to whole tree harvesting, as well as the degree of utilisation of the resource.

In the productivity trials on first thinning of pine three different harvesting methods were studied in Finland. The aim was to study the option of leaving the residues in the forest while harvesting pulp wood and energy wood. Methods were as follows: 1. single tree handling (STH) where the assortments and residues accumulated near the strip roads, 2. multi tree handling near the strip roads (MTH1) where the assortments and residues accumulated near the strip roads and multi tree handling at the stump (MTH2) where the aim was to leave the residues spread over the harvested area. In the same trials, location and ground cover of the residues were studied. After harvesting every timber assortment pile and residue heap was located with GPS, the size of the heaps was measured and distances to the center line of strip roads were calculated.

In the productivity studies of the Valmet 801 Combi Bioenergy chipper harvester, the aim was to compare the stands effects for the work time structure. Four different stands were harvested with the machine. Two of the stands were thinnings and two young birch clear cuttings.

In another study, the aim was to test strip debarking as a means to speed up the drying rate and to lower moisture and bark contents. The prerequisite was that debarking had to be integrated into the processing phase of a single grip harvester. The changes made in the harvester head had to be simple, be easily installed and inexpensive. The data was collected on non-frozen and frozen pine wood in spring 2005 and in winter 2006, and on non-frozen birch in spring 2007.

The Norwegian participants had no funding to join this SNS-project, but because they had one project running within the same field they participated in most of the seminars that were held within the SNS project. The research plan was to study harvesting techniques using multi-tree processing equipment on a farm tractor to identify the productivity in such operations. Time studies of a Valmet XM 150 hp using a Nisula 280E cutting grapple were conducted during 2006-2008.

The activities from the Icelandic partners included a study-tour to central Europe together with Finnish colleagues from METLA and NCP, the aim of which being to study methods, technology and markets around wood-fuel. The Icelandic partners also hosted an international symposium together with the Northern Periphery project ‘Northern Wood Heat’ in Hallormsstadur.

The project also sponsored a study on growth and yield modelling on larch in Hallormsstadur and recommendations on future harvesting plans and technology. A thinning trial was carried out using a newly imported 'Menzi Muck' walking excavator – the first mechanised harvesting to be applied in Iceland. The age-class distribution of Icelandic forests is such that thinnings in young forests are likely to be the dominant form of harvesting operations for many years to come.

In total: The research plan has been followed, but a few parts of the project will not be finalized before this project is ended. They are: Norway; Publications will be done later during 2008, Iceland; The trials on mechanized thinning will continue during 2008 and 2009, Denmark, Sweden and Finland; More publications and presentations on conferences will be done during 2008, Sweden; More comparisons with conventional forest regimes will be done during 2008 and 2009 (doctoral thesis).

8 Results

In Sweden, the total forest area constituting harvesting class B3 (mean height over 3m, with the majority of dominant / sub-dominant trees smaller than 10cm at breast height) is 2.9 million ha. Of these, around 678 000 ha have a biomass volume exceeding 30 tonnes dry matter (DM) per ha. Approximately 69% of the forest area with a DM yield exceeding 30 tonnes has a mean height of between 5 and 9 m. The cumulative volume of these areas is 33 million tonnes (DM), or 49 tonnes DM per ha on average. Simulations have shown that productivity in conventional harvesting systems could be improved by up to 40% by utilising a geometric harvesting pattern. A geometric harvesting pattern could be defined here as a series of narrow corridors that are cleared using a boom mounted harvesting head with a long reach. If technology could be developed to utilise the potential that a geometric pattern would imply, it could realise the simulated improvements of doubling productivity in small first thinnings and tripling conventional productivity in neglected pre-commercial cleanings. This would mean 2.8-3.4 tonnes DM / G_0 hour in the latter and 3.0-5.4 tonnes DM / G_0 hour in small first thinnings. Coarse debranching of tree bunches in the prototype rig produced bunches of 5 small pines (dbh 5 cm) with a loose density of 265 kg m^{-3} as against 158 kg m^{-3} for bundles that hadn't been coarsely debranched. Corresponding values for bunches of 2 larger pines (dbh 12-15 cm) were 271 and 107 kg m^{-3} respectively.

Finnish studies have shown that harvesting with a multiple-stem harvesting head increases productivity by between 12% and 25%. Harvesting slash covered 6% of the total area when processing was done near the strip road, and 12% when it is done at the stump, emphasising that the nutrients are better distributed with decentralised processing. Distances between piles of pulpwood and energy wood were however equal for both methods. The strip debarking head removed about 7-9% of the bark on pine and 2-2.5% of the bark on frozen pine. This was only marginally more than for a conventional head (i.e. one that wasn't designed for debarking). The results were similar for birch. A study of a machine designed for combined processing of pulp-wood and small dimensioned timber, as well as chipping of tops and smallwood showed productivity results of 6.9-8.0 m^3 hr^{-1}. In thinnings, felling took 10% longer than in clearfelling, while chipping in clearfellings took 14% longer than in thinnings.

Storage trials show that moisture content in piles with young wood is halved (to 30%) under favourable conditions. Norwegian studies show that the productivity is approximately 10m^3 hr^{-1} when dense young forest is clearfelled on agricultural lands, whereas it is about 8 m^3hr^{-1} in a thinning.

In Denmark work focused on the development of models that could be used in illustrating the most appropriate pathway for handling, transporting and processing fuelwood from pre-commercial thinnings. The models were based on a network analysis / dynamic programming algorithm, which is fed with a number of variables on the forest stand which in turn determine productivity rates and therewith influence the pathway. The model, which was not fully developed in 2007, will be expanded to include a simulation component in the final project phase, or the initial phase of the WoodWisdom project 'WoodValue' which will ensure full implementation. Work was also started on looking at methods for thinning in naturally regenerated young hardwood (Beech) stands (< 1.5 m). The rationale is to provide enough growing space in these heavily stocked stands to allow the saplings to develop to a size that can justify their utilisation for energy. A system using a crane mounted hedge trimmer, where some of the teeth are removed from the cutter bar, meaning that the young trees would be 'thinned', was decided upon for testing. This work culminated in the additional funding being

received from the Danish Forest and Nature Agency for further testing. These tests will be carried out in April 2008.

9 What advantages has been gained by Nordic collaboration

During the project, 4 project meetings, and one larger conference has been conducted (Sweden 2 times, Iceland and Denmark). The exchange of ideas and results and discussions about future topics, research techniques, trends within the field and future collaboration are the biggest advantages. Most importantly the project has familiarized partners to each other. It has promoted further project work in a form of new proposals/plans and consortiums e.g.. EU-Bothnia-Atlantica and OSCAR.

10 Publications and other communication activities

Scientific reports with a referee system

Bergström, D., Bergsten, U., Nordfjell, T. & Lundmark, T. 2007. Simulation of thinning systems and their time requirements for young forests. Silva Fennica 41(1): 123-133.

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

Nurmi, J. 2007. Recovery of logging residues for energy from spruce (Picea abies) dominated stands. Biomass & Bioenergy 31(6): 375-380.

Talbot, B. & Suadicani, K. 2006. Road Transport of forest chips: Containers vs. Bulk Trailers. Forestry Studies / Metsanduskilud Uurimused 45, 11-22.

Submitted scientific reports

Bergström, D., Nordfjell, T. & Bergsten. U. 200x. Compression of tree bunches in early thinnings. *Submitted*

Lehtimäki, J., Nurmi, J. Energywood Harvesting Productivity of Three Harvesting Methods in First Thinning of Scots Pine (*Pinus sylvestris* L.). *Submitted*

Nurmi, J., Lehtimäki, J. Debarking and seasoning characteristics of downy birch (*Betula pubescence*) and Scots pine (*Pinus sylvestris*) feed stocks in conjunction with multi-tree harvesting. *Submitted*

Other scientific reports

Ersson, T. B. 2007. Produktivitet vid selektiv mekaniserad bioenergiröjning. Inst. f Skoglig Resurshushållning. Master Thesis. Arbetsrapport nr 166.

Pesonen, A. 2006. Modelling the Growth and Yield of Larch in Hallormsstaður, Iceland
Faculty of Forestry University of Joensuu. Master's thesis in Forest Planning and Economics

More popular reports

Dominik Röser, Lauri Sikanen, Antti Ala-Fossi, Karri Pasanen, Loftur Jonsson and Asko Puhakka 2007. Small and medium scale district heating plants and supply of forest fuel in Central Europe – A travel report. METLA Finland.

The "NorthernWood Heat Symposium" 2006 in Hallormsstadur Iceland includet a booklet produced by Heradsskogar 2006, Iceland.

Manuscript to more popular reports

Bergström, Dan. 200x. Sammanställning av ackumulerande skördaraggregat för skörd av klena stammar (Energiskördare). Skogsteknologi, Skoglig Resurshushållning och Geomatik, SLU, Umeå.

Norway: The results are scheduled to be published nationally and perhaps internationally during 2008.

Scientific proceedings

Nordfjell, T., Bergsten, U., Bergström, D. & Lundmark, T. 2006. Boom-tip corridor harvesting techniques for young forest stands with high biomass: future possibilities. Proceedings: World Bioenergy conference, Jönköping, Sweden. 30 May – 1 June, 2006.

Nordfjell, T. 2006. Harvesting techniques for young forest stands with high biomass: Productivity of simulated corridor thinning. Proceedings: The Northern Woodheat symposium, Hallormsstadur, Iceland. August 21st- 23rd, 2006.

Gjølsjø, S. 2006. Biofuel from regenerating forest and thinnings: a case study. Proceedings: The Northern Woodheat symposium, Hallormsstadur, Iceland. August 21st- 23rd, 2006.

Jónsson, L. 2006. Introduction of the symposium. Proceedings: The Northern Woodheat symposium, Hallormsstadur, Iceland. August 21st- 23rd, 2006.

Nurmi, J. 2006. Multi tree-harvesting (MTH) in small diameter stands: methods, productivity and fuel stock characteristics. Proceedings: The Northern Woodheat symposium, Hallormsstadur, Iceland. August 21st- 23rd, 2006.
Talbot, B. 2006. Purpose Built vs. Tractor-mounted Chippers: A techno-economic appraisal. NSR conference in Estonia.
Talbot, B. 2006.Road Transport of forest chips: A relook at containers vs. bulk trailers. NSR conference in Estonia.
Nordfjell, T., Nilsson, P., Henningssson, M. & Wästerlund, I. 2008. Unutilized biomass resources in Swedish young dense forests. Proceedings: World Bioenergy conference & exhibition on biomass for energy. Jönköping, Sweden. 27-29 May, 2008.

Interviews or summary in newspapers or elsewhere
Land, Skogsland nr 43, 2005. ”Ny teknik stärker skogsbränslet”
Land, Skogsland nr 33, 2006. ”Tomas tror på bioskörd i korridorer”
Skogen nr 11, 2006. ”Minikorridorer lönsamt”
Landsbygd i Västerbotten, hushållningssällskapets medlemstidsskrift nr 1, 2006. (Nordfjell, Bergström, Bergsten, Lundmark) ”Teknikutveckling för skörd i unga skogar”
Medlemstidskrift nr 1 – Mars 2006. (Nordfjell, Bergström, Bergsten, Lundmark) ”Teknikutveckling för skörd i unga skogar”. Hushållningssällskapet Jämtland.

The project has been presented at the Forest exhibition ”SkogsNolia” nead Umeå 15-17 June, 2006 and at ”World bio-energy conference” Jönköping 30 May – 1 June, 2006. A seminar was held in Ullava (Finland) 7 sept, 2006 about ”energivedsbarkning, avverkningsteknik och bränslekvalitet”, and another seminar was held in Kannus (Finland) 25 oct, 2006 about ”energikooperativ, energivedsbarkning och bränslepotentialer”.

The web address for the project: http://www.bionordic.net

11 Project summary

Even today, there are large areas of young forest with considerable volumes of biomass. It is partially possible to increase the volume of available biomass through improved silviculture and maintenance of existing stands through a longer period. The technology available today offers an economically feasible solution to this providing that there is sufficient density (60-70 tonnes DM ha^{-1}) and that the trees are sufficiently large (dbh >9 cm). The technology that needs to be developed should be able to achieve break-even conditions (i.e. non-profitable) on stands with densities of over 30 tonnes ha^{-1} (with a 50% harvest), irrespective of the size of trees. Theoretically, the corridor harvesting concept and technology could achieve this once they are developed. The problems are similar for forest areas and agricultural lands that are undergoing a natural transition to forest.

Apart from harvesting, the transport of small whole trees also needs to be carried out efficiently. An initial step in the right direction is coarse debranching. If the trees can be roughly debranched already in the felling head, a considerable increase in the density of tree bunches is achieved, and if this bunch can be handled as such further down the chain, then substantial efficiency increases can be made. Subsequent compacting, e.g. during loading, further increases the density. Providing the coarse debranching can be carried out at felling, other issues such as leaving some bark and some of the finer fractions reduce nutrient loss and the ash content of the fuel.

At least 50% of the volume in young dense forests can be removed without negative consequences on stand development. This implies that large volumes are already available for utilisation, and that available volumes could be increased substantially if and when suitable technology is developed in simultaneously with appropriate new harvesting models.

Presently, there is no machine that integrates technology for producing pulpwood, small-dimensioned timber and chipping biomass in an effective manner. It is questionable whether this would ever be possible without becoming too complicated and expensive.