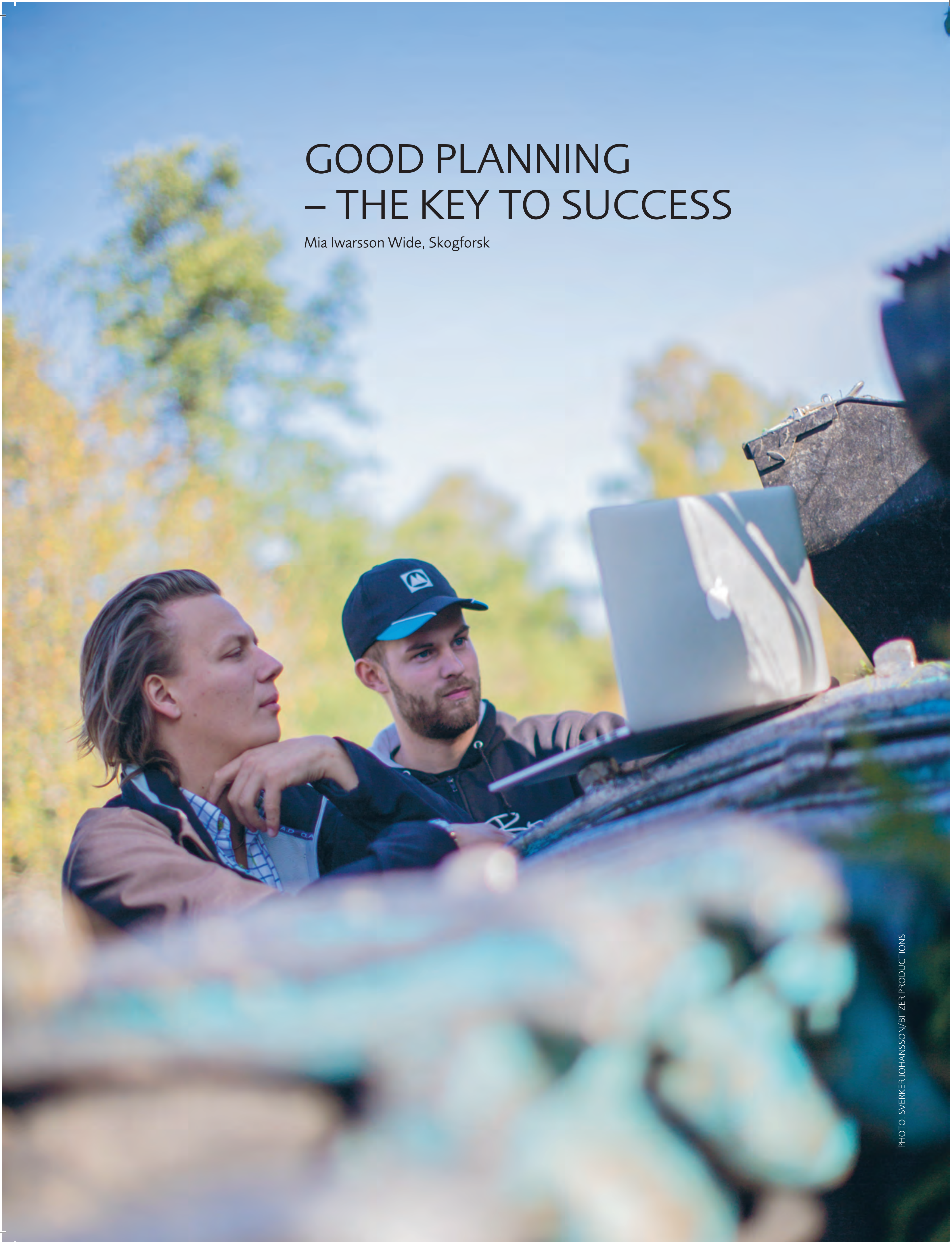
FOREST ENERGY FOR A SUSTAINABLE FUTURE

Composite Report from the R&D Programme

Efficient Forest Fuel Supply Systems 2011-2015

GOOD PLANNING – THE KEY TO SUCCESS

Mia Iwarsson Wide, Skogforsk



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For a successful outcome, in the form of high fuel quality and profitability, detailed and cohesive planning is needed. It is important that all players are aware of how their work affects both the next link in the chain and the end result, and who the customer is.

In order to learn, develop methods, and understand how everything is related, follow-up and feedback procedures must be improved. Simple and reliable systems are needed that relate to customer requirements and that are based on measurement data collected during harvest and handling, historical data, and forecasts.

Unlike roundwood, forest fuel can vary greatly in form and quality. In addition, the forest fuel market is characterised by an imbalance between supply and demand over the year, so biomass must be stored. Carefully planned storage can raise the quality of the fuel, and forest fuel can be stored and comminuted at a landing, a terminal or at the heating plant.

In order to deliver fuel of the right quality and quantity at a competitive price at the agreed time, storage points, comminution technology and transport systems must be carefully planned. All stages, from the planning of felling, harvest, storage, comminution to transport, must be carefully considered, to ensure that delivery specifications are fulfilled and that the entire process is cost-effective.

Planning is also made difficult by the long lead times in combination with uncertain market conditions at the time of the planned delivery. It is difficult for suppliers to adjust volumes retroactively in the event of reduced demand for wood chips, as much of the biomass is already in storage, and it is also difficult to increase delivery capacity without a relatively long period of forward planning.

Simulations – see the whole picture

To optimise management, the entire handling chain must be overviewed. Simulations allow analysis and comparison of different systems, both those in use today and ones that could be used in the future. Simulations can also show what happens if one factor changes, if a machine is replaced, or if the system is transferred to another situation with different conditions.

Simulations of stump supply systems showed that the cost of the best and worst logistical options may differ by a factor of two. Hot systems are sensitive to disturbances, and it can be hard to utilise the full machine capacity of both grinders and trucks in a system. The key to a cost-effective system is to minimise the cost of unutilised machine capacity through carefully considered resource planning in terms of transport distance for the trucks and production capacity of the grinder. Using a less hot system can often be positive, irrespective of transport distance and the number of stumps on the site. For short distances, transport of non-comminuted stumps/stump parts and grinding at the industry is a competitive alternative. The simulations also showed that one key to a cost-effective system is that the machines can work with high productivity and a high level of utilisation.

Simulations of logging residue supply systems are currently being carried out, with the aim of increasing understanding of how the individual processes in the delivery chain affect each other and the supply system as a whole, and how these processes interact with external factors. Important questions include examining how quality and value are affected by 1) whether the material is stored as logging residue or residue chips, 2) the weather during the period of storage, and 3) where the material is stored. The model will also show how these choices affect the costs of comminution and transport.

Another simulation showed that harvest of forest fuel in thinning of small trees could be made considerably more efficient by using new harvesting methods, such as boom-corridor thinning and bundle harvesters. The biggest effects were found in stands where the average volume of the whole tree (including branches and tops) was 0.025 m^3. A system where harvested tree parts were bundled and transported on designated vehicles showed a cost reduction of six percent compared with today's system of harvesting tree parts without bundling.

Reduced ground damage and more efficient forwarding

Harvest of forest fuel must not cause damage to the ground or water. In view of today's often wet autumns and mild winters, good planning and careful selection of forest stands for fuel harvest are needed. Studies of ground damage caused by forest machines have previously shown high frequencies of unacceptable damage. The aim of the STIG project was to develop better maps, combined with more detailed procedures to avoid carrying out forest operations on sensitive ground.

The groundwater model was a key focus in this work. This model calculates which areas have water close to the surface and where the bearing capacity can therefore be assumed to be poor. The calculations are based on data from airborne laser scanning concerning height above sea level, slope, and aspect. An evaluation showed that approximately 70 percent of ground damage occurred in areas classed as wet or waterlogged in the groundwater model.

The groundwater model gives the logging planner and the machine operators a good idea of the ground conditions in the area, and logging can be planned in such a way that machine activity is concentrated to the areas with the greatest bearing capacity.

The decision-support system, BesT Way, combines the above information with a laser scan that describes the forest. The planner decides the location of landings, and BesT Way then calculates the most efficient placement of base roads. No base roads are located in areas marked as wet, but the planning program can suggest suitable sites for crossings of these areas. It also facilitates testing of various base road alternatives with regard to transported volumes and time and costs for forwarding operations.

Harvester data provides valuable information

The harvester continually collects data about felled trees. This harvester data can be used to assess whether and, if so, where on the clear-cut stumps can be harvested, and the volume this can generate.

Since 2012, harvester data has been used to estimate and report the production of logging residue and stump quantities. The calculation module is part of the data standard StanForD 2010. The distribution of forest fuel on a clear-cut can also be visualised through a map layer that can be read in GIS programs in the forwarder that extracts the material.

Stump volumes – potential and actual harvests

With the aim of evaluating existing biomass functions for stumps, calculated and measured quantities were compared. Calculated figures were generated from harvester data, and material lost between the stump and the landing was also quantified. Earlier studies have indicated that the biomass functions produced by Marklund in the 1980s underestimate the actual stump biomass. In the pilot study, actual outcome on some plots was more than 50 percent greater than predicted. The study must be expanded to more locations throughout Sweden with different ground conditions before generally applicable conclusions can be drawn.

The study also examined the scale of wasted biomass in forwarding and grinding of stumps, and the proportion of stumps that were not harvested. The study shows that approximately 5 percent of the material is lost during handling, and that another 10 percent is left in the ground. The stumps are either smaller than the prevailing limit for removal, left for conservation reasons, or quite simply missed by the stump harvester.

Laser scanning to identify suitable stands

Forest-related variables were calculated using data from airborne laser scanning of a large number of experimental plots in unthinned young forest and on roadsides. The results were then compared with field measurements. Clear correlations were apparent for tree height and height distribution, but also for stand density. One conclusion was that laser data can be used to identify areas, or parts of areas, where it would be profitable to harvest forest fuel.

Predicting forest fuel value

In order to plan and manage the supply chains, and to ensure that the customer gets the assortment ordered, accurate inventories of the produced fuels and predictions of future production are needed.

The moisture content of forest fuel is important, because it is one of the most important factors affecting the net calorific energy content. The drying process is complex, and different heating plants have different requirements regarding moisture content. By studying the weight and moisture content of logging residue during storage, and comparing it with weather data for the storage site, functions have been developed to predict moisture content. The aim is to be able to predict the moisture content in a stack of logging residues on the basis of time of storage, storage site, and weather data during the storage. A prediction tool can then be integrated in systems for storage management and trading of forest fuel, which will enable suppliers to predict the moisture content in individual consignments. The work is being carried out in collaboration with the sector and SDC.

The study showed that the gross weight of covered residue stacks and smaller residue piles, resembling those stored on the clear-cut, changed considerably during storage and after rain. The fluctuations were greater in the small residue piles than in the covered stacks. The conclusion is that the degree of remoistening through precipitation is determined by the total volume of the residue stack in relation to its surface area exposed to rain.

Moisture content in the chips is considerably reduced if snow and ice can be removed from the material prior to chipping.

Forest fuel management – trends over five years

For benchmarking purposes, it is important to be aware of trends. Costs and methods in forest fuel supply in Sweden have been followed up over a period of four years. After a peak in 2011, remuneration to forest owners decreased somewhat, largely because the market prices for forest fuels on delivery to the heating plant fell. The proportion of logging residue increased at the expense of defect roundwood up until 2013, after which the assortments returned to the original distribution. The average cost as delivered to the end customer was SEK 175/m3 of chips. Chippers are the most common machines for comminution on the landing and at small terminals, and are increasing their share of the comminution work at the expense of grinders.

Training

Since 2007, Skogforsk has been arranging training courses for forestry professionals and machine operators who work with forest fuel production. Recent courses have also been aimed at buyers of forest fuel at the heating plants. Interview-based surveys have shown that good results are attained in the district or areas that have the most dedicated and interested players in the production chain. Commitment, smooth procedures for internal communication, and feedback are the most crucial factors for production and delivery of high quality fuels.

In view of the personnel turnover in the forestry sector, skills and commitment must always be kept at a high level. It is important to be able to evaluate results from the deliveries received over a period. MORRIS is a tool that shows diagrams of delivery data for certain time periods or specific recipients. If there are major variations in, for example, moisture content, an analysis is needed to examine the causes of the variations, because they have a negative effect on both fuel characteristics and value.

Correct location, careful stacking, and effective covering of the forest fuel stacks are vital for good quality. A decision-support tool has been produced in the form of a simple spreadsheet for comparing various stack locations in terms of forwarding distance, drying conditions, fuel value, and comminution. This decision-support tool has great potential for further development; for example, it could be combined with the prediction functions produced for estimating moisture content in the stack using weather data.


Cranab

SEE THE WHOLE PICTURE

– ANALYSIS OF SUPPLY SYSTEMS

Anders Eriksson & Dan Bergström, SLU

In forestry, machines and systems are constantly under development to increase cost-effectiveness. This work takes place in collaboration with innovators, manufacturers and academia. Theoretical analyses are a more time- and cost-effective way to evaluate new ideas and concepts than building prototypes for testing in the field or conducting time studies of entire machine systems in full scale. Simulations allow analysis and comparison of different systems, both conventional and hypothetical, under the same conditions. Simulations can also show the effects if one factor changes, such as replacement of a machine, or if the system is used in a new setting under different operational conditions.

Stumps

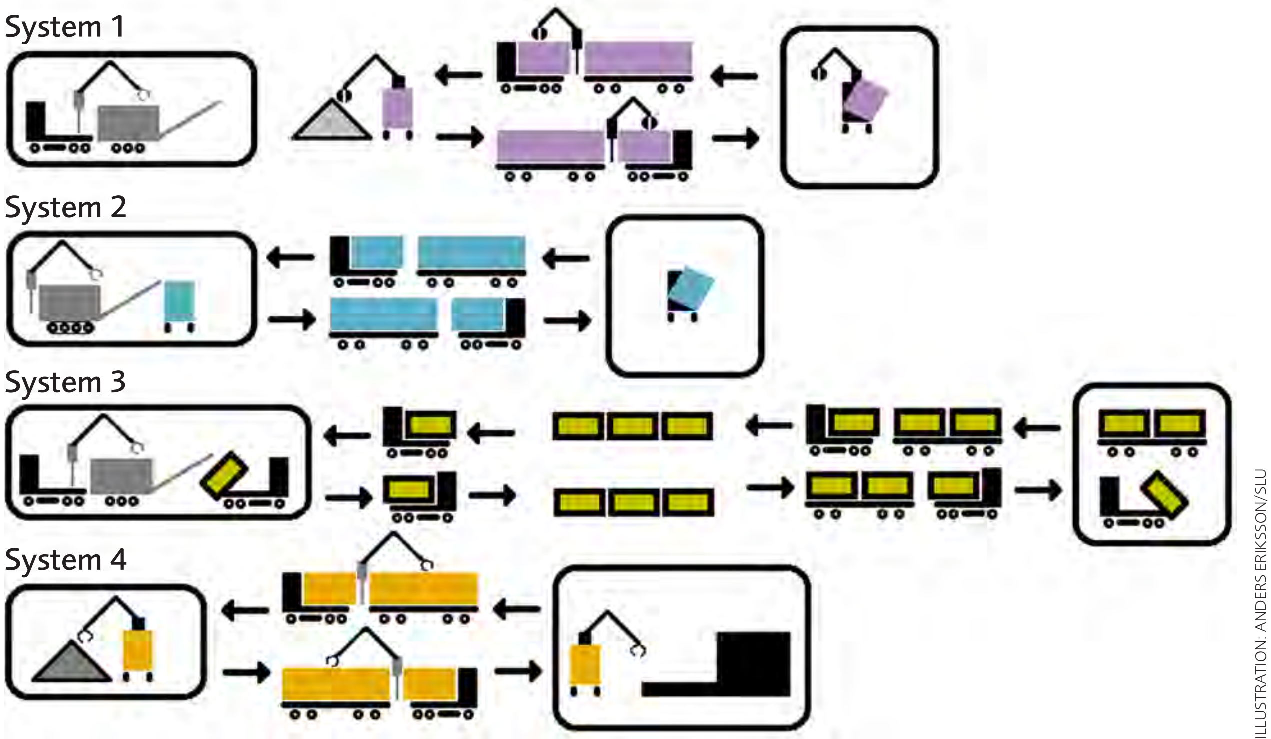
Four supply systems for stump wood were simulated from forest landing to heating plant.

1) Grinding at the landing and self-loading chip truck.
2) Grinding at the landing and direct loading into a waiting chip truck.
3) Grinding at the landing and direct loading into a waiting load-switching truck with containers.
4) Transport of whole stump wood and grinding at the customer's facility.

Systems 1 and 4 are cold, while 2 and 3 are hot, because grinding and trucks are dependent on each other.

The analysis showed that:

- The hot systems are sensitive to unforeseen events. In order to be competitive, the number of trucks must constantly be balanced against the capacity of the grinder and the transport distance in question. Costs of an unbalanced system may be double those of a system in balance. If there are too few trucks, the grinder, which is the most expensive component in the system, must stand idle. If there are too many trucks, they must wait instead.
- Comminution at the landing and transport with self-loading trucks (system 1) is cost-effective, regardless of transport distance and the amount of stump biomass on the landing.
- For short distances, transport of whole stump wood and grinding at the customer's facility is a competitive alternative.



Schematic sketch showing the simulated systems for transport and comminution of stumps from landing to end customer.

The project also examined how 15 different factors affect the cost per delivered MWh for the entire chain, from stump removal to fuel delivery. These factors included fuel quality, biomass losses, machine productivity, machine specification, transport distance, and stump quantity per site. For each factor, a base value was defined, based on earlier studies and previous data, and a 'reasonable' low and high value. Two systems were studied, one with comminution before transport and one after.

Some results from the simulation:

- The base value gave a cost of approximately SEK 156/MWh. When all factors were changed to their lowest values, the cost fell to SEK 97/MWh, and when all factors were set to their highest values, the cost increased to SEK 278/MWh, regardless of system.
- Loss of biomass through, for example, waste, had a greater negative effect the later in the delivery chain it occurred. Missing processed stumpwood at a landing proved, in economic terms, to be nine times worse for the economy in the system than simply leaving the stumps in the ground, assuming the same quantity was lost.
- The cost per delivered MWh could be reduced by 12.5 percent through good storage, which reduced moisture, ash content, and loss of substance.
- Transport distance and stump quantity per site were the two most important factors affecting the system.
- Machine productivity was also important, particularly for the stump harvester and the forwarder. Avoiding sites with poor conditions proved to be important in preventing low productivity of machines.
- In general, sites should be chosen where more than 150 tonnes dry matter of stumps can be harvested, and that are located close to the customer.
- Comminution at the landing is preferable to comminution at the customer's facility if the transport distance is between 30 and 70 km, depending on stump quantity per site.

One conclusion is that stumps can be harvested with a positive net result, assuming appropriate site and delivery system are chosen.

Systems for tree parts from thinning of small trees

National estimates show there is great potential to harvest biomass from unthinned young forests. These forests often have a great diameter distribution, they give relatively low volumes of pulpwood, but they can generate a lot of biomass if small trees, branches and tops are harvested as forest fuel.

Tree parts placed in a stack for drying.

In a project, 14 systems for harvesting and transporting tree parts from thinnings of stands with small trees were analysed. Nine of these were conventional systems and five were innovative systems that potentially could be used in the future.

The cost and energy efficiency of the systems were analysed using variables like mean stem volume, type of assortment, forwarding distance and road transport distance. The effect of introducing load compression of unprocessed tree parts on forest and road transport was also analysed.

The analyses showed that a possible supply system based on boom-corridor thinning and direct bundling in the field can reduce costs by 12 percent and energy use by 32 percent compared with systems currently in use. The effects were greater when mean stem volume was smaller and transport distance greater. This system was suitable for stands with a mean stem volume of less than 0.030 m^3.
Another system, involving a bundling harvester, boom-corridor thinning and optimised bundling, reduced costs by 15 percent and fuel consumption by 22 percent. This system, which was suitable for stands with a mean stem volume exceeding 0.030 m^3, has largely been implemented today by the Finnish company, Fixteri.

Future work

- More system analyses to show possible measures and potentials for reducing the total cost in the supply chains for the various forest fuel assortments.
- Models for stump and logging residue supply, which are still under development, would enable simulation of all activities from forest to heating plant. Simulations based on historical weather data that show how weather affects the customer's fuel needs and the quality of the fuel during storage would enable evaluation of various delivery strategies.
- Future R&D should be aimed at new technologies for felling small trees and examining how these technologies can be integrated with direct bundling. The models developed in the project can be used to carry out further analyses, such as by comparing them with delivery systems

STUMP PREDICTIONS FROM HARVESTER DATA

Maria Nordström, Björn Hannrup, Tomas Johannesson
& Henrik von Hofsten, Skogforsk, Erik Anerud, SLU

Appropriate planning of stump harvest requires prediction tools to assess available and harvested quantities. Biomass functions for estimating stump and root biomass have already been developed in Sweden and Finland. The functions calculate the quantity of biomass for stump cores and, to varying degrees, also for roots, in kg dry weight. For the simpler functions, breast height diameter is sufficient as input variable, so the tree data generated by the harvester can be used.

Previous studies have shown that harvester data can be very useful in generating detailed and precise information about available quantities of logging residue from felling. On the basis of these results, an automated system has been developed that calculates the available quantity of logging residue from felling sites, based on harvester data and existing biomass functions. The calculation system is implemented in SDC's wood management systems and has now been introduced in production reporting of the major forestry companies.

The system is also prepared for handling stump and root biomass in the same way. For this to be meaningful, studies are needed to investigate how well biomass functions for stumps and roots can be used to predict available and harvested quantities, and what adjustments may be needed. In Sweden, smaller follow-up studies have indicated that estimates based on Marklund's biomass functions underestimate the actual quantity of stumps and roots.

The aim of this study was to evaluate existing biomass functions for stumps and roots by comparing calculated and measured quantities of stump harvest. Calculated figures were generated from harvester data. The study also tried to quantify the waste occurring from stump harvesting until the material had been ground on the landing. This was a pilot study with the aim of establishing a work method for a larger-scale study involving nationwide material.

The study was carried out approximately 50 km north of Strömsund, Jämtland, in central Sweden. The experimental area comprised two felling sites on opposite sides of a small road. Both sites were dominated by spruce, with some pine.

The trees on the plots were felled in May 2011 and harvester data (pri-files) about each individual tree was saved for every plot. Timber and logging residues were forwarded immediately after felling. The stumps were lifted in September 2011 using a tracked excavator (Hyundai, 210LC) with a Biorex 30 stump harvest head. The stumps were forwarded to a landing, and then kept separate in marked piles. After a couple of weeks, the stumps were coarsely ground with a slow-speed grinder, Doppstadt Büffel DW-3060. The ground material was fed directly into marked containers without sieving. The chips were weighed in the container, after which the moisture content and ash content of the material were determined, and the raw weight converted to a dry weight.

From this initial pilot study, we can draw three conclusions:

- The existing functions for calculating quantities of biomass in stumps and roots greatly underestimate the quantities actually harvested, on average by 33 percent.
- At least 5 percent of the material was lost as waste during forwarding and grinding.
- Another approximately 10 percent of the material was left unharvested, i.e. in the ground, because the stumps were too small for harvest or because they were missed during extraction.

The experiments must be expanded to equate to nationwide material to establish whether the results from the pilot study can be regarded as being generally applicable to other sites.

Future work

Issues that could not be tackled within the scope of this study, but which could be investigated, are:

- How is the harvest affected by the time since felling? The pilot study was carried out on fresh stumps, so further studies of how the harvest level is affected by degradation of the stump are needed. A reasonable range would be 0 to 1.5 years.
- How is the harvest affected by the soil?

Stack of stumps at the roadside.

For benchmarking purposes, it is important to be aware of current trends. In 2010, the ESS programme initiated a project in which annual surveys are used to map assortment distribution, costs and methods used in production of primary forest fuel in Sweden. Respondents in the latest survey are mainly the same high-volume suppliers as in previous surveys. Costs to the roadside and to the end customer delivery point are therefore thought to be comparable between the years, but the different cost items to the roadside vary somewhat, along with other activities between roadside and end customer.

FOREST FUEL

– TRENDS OVER 5 YEARS

Torbjörn Brunberg, Skogforsk

Since 2009, the cost of forest fuel has fluctuated (Figure 1). After a peak in 2011, the cost has fallen somewhat, largely because of lower payments to the forest owner.

The proportion of logging residue increased at the expense of energy wood from 2009 until 2013, after which the relative proportions returned to the former level (Table 1).

Table 2 shows the distribution of costs in 2013 across various cost items. The weighted average supply cost to the end customer was SEK 175/m3 of chips.

Generally, wood chip deliveries have increased at the expense of bundles and loose logging residue (Table 3). However, due to investments in centralised large-scale comminution equipment, the proportion of loose logging residue has risen in certain locations, such as around Örebro. If comminution on the landing and at small terminals is considered, the proportion of grinding has fallen in recent years, but grinding still takes place on the wood yards of combined heat and power (CHP) plants and at larger terminals.

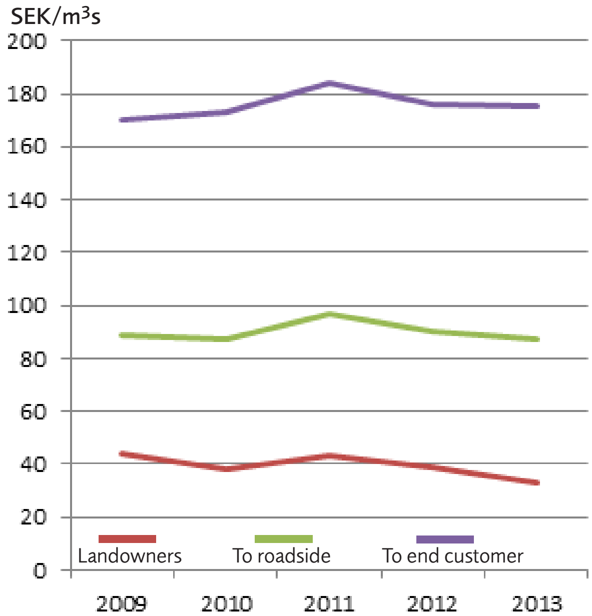


Figure 1. Forest fuel costs, 2009-2013.

Table 1. Reported costs (SEK/m3) of chips for different assortments in 2013, divided into cost items. Note that payment to the landowner is shown as a cost.

	Logging residue from final felling	Small trees from thinning	Energy wood	Stumps from final felling
Payment to landowner	31	8	48	1
Felling/Extraction	0	43	0	52
Forest transport	37	29	18	32
Overheads	8	9	7	6
Cost to roadside 2013	76	89	103	91
Cost to roadside 2012	76	92	117	87
Comminution	48	41	18	49
Terminal costs	3	2	10	6
Road transport	41	41	27	42
Administration	10	9	8	9
Total cost to end customer 2013	178	182	166	197
Total cost to end customer 2012	172	180	181	193

Table 2. Distribution by method (%) per year.

Logging residue

	Bundles	Whole tree residue	Wood chips
2009	4	13	83
2010	1	11	88
2011	0	10	90
2012	0	10	90
2013	0	9	91

Comminution method

	Chipping	Grinding	Other
2009	89	11	0
2010	91	9	0
2011	91	9	0
2012	93	7	0
2013	96	4	0

Small trees

	Harv.head	Shear	Other
2009	46	46	8
2010	59	35	6
2011	74	19	7
2012	73	27	0
2013	82	10	8

Base machine used for the chipper

	Truck	Forwarder	Other
2009	14	83	3
2010	33	65	2
2011	40	58	2
2012	40	60	0
2013	37	59	4

Road transport

	Truck	Railway	Other
2009	84	5	11
2010	88	8	4
2011	95	3	2
2012	96	4	0
2013	96	4	0

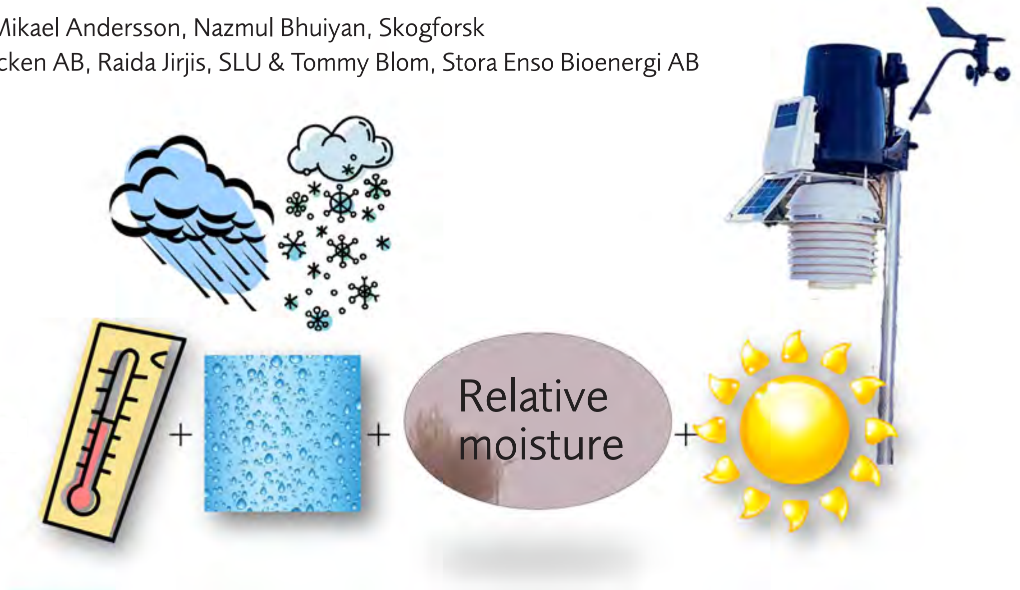
Chipper trucks, i.e. trucks with a chipping unit and a chip bin, have become more common. They are often a cost-effective alternative, particularly on smaller sites and where transport distances are short.

When utilisation of energy from small trees began, shear-type felling heads were commonly used. However, because of the flexibility and higher productivity of harvester heads, particularly in taller forest, this technology rapidly became the most commonly used. Today, felling heads are only used locally and mainly on smaller sites, e.g. in felling of unwanted undergrowth in pastures or trees growing on roadsides.

The amount of long-distance transport of forest chips has decreased, due to the declining demand and price levels for forest fuel in central Sweden. This is mainly because of an increasing proportion of imported fuels, such as waste and chips from recycled wood, but also because of milder winters in recent years.

USING WEATHER DATA TO PREDICT MOISTURE CONTENT

Lars Wilhelmsson, Mikael Andersson, Nazmul Bhuiyan, Skogforsk
Erik Persson, Askbacken AB, Raida Jirjis, SLU & Tommy Blom, Stora Enso Bioenergi AB



Heating plants want control over the moisture content of forest fuel in order to optimise incineration. Moisture content varies greatly and there are currently no methods that are fast and able to determine moisture content with sufficient accuracy. Heating plants have to rely on the oven method, which is slow and often the result is not obtained until after incineration. One alternative that can facilitate delivery and production planning is to estimate moisture content, using weather data for the time the logging residue is stored in piles on the clear-cut and in stacks at the landing. A prediction tool is therefore needed for estimating moisture content of stored logging residue, to help improve delivery quality to different fuel customers.

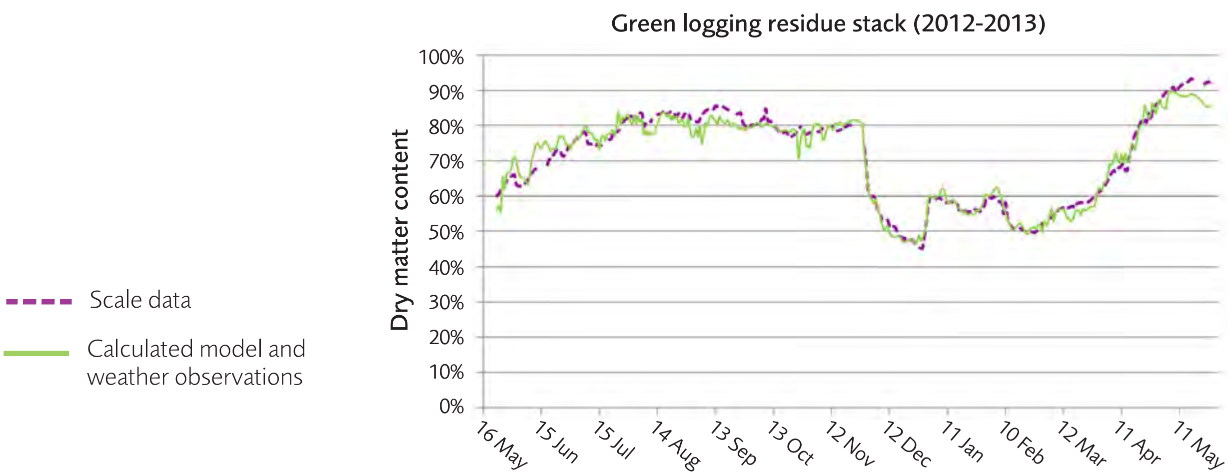
In collaboration with Stora Enso Bioenergi and SLU, Skogforsk carried out an experiment involving continual weighing of stored logging residue in combination with collection of weather data. In May 2012, we placed logging residue from a spruce-dominated final felling stand close to Tierp, in Uppland, on platforms that were placed on electronic scales. The composition of the residue was described using data from the harvester's production files.

Fresh ('green') residues were placed on two small platforms, simulating piles of residue on a clear-cut, and on a large platform, simulating a stack at a landing. At the end of August, the experiment was supplemented with another large platform simulating a stack of summer-stored, dried ('brown') residues that had been forwarded from other residue piles on the clear-cut. The residue was covered immediately after stacking.

The total weight of the residues on each platform was recorded twice per hour. Using the sampled moisture content at the start, and the total weight, the drying and remoistening process could be calculated, along with the quantity of snow accumulated on top of the stacks during the winter period.

In order to link the continual weight changes to the weather, a weather station was set up close to the platforms to record temperature, precipitation (rain and snow), relative humidity, insolation and wind.

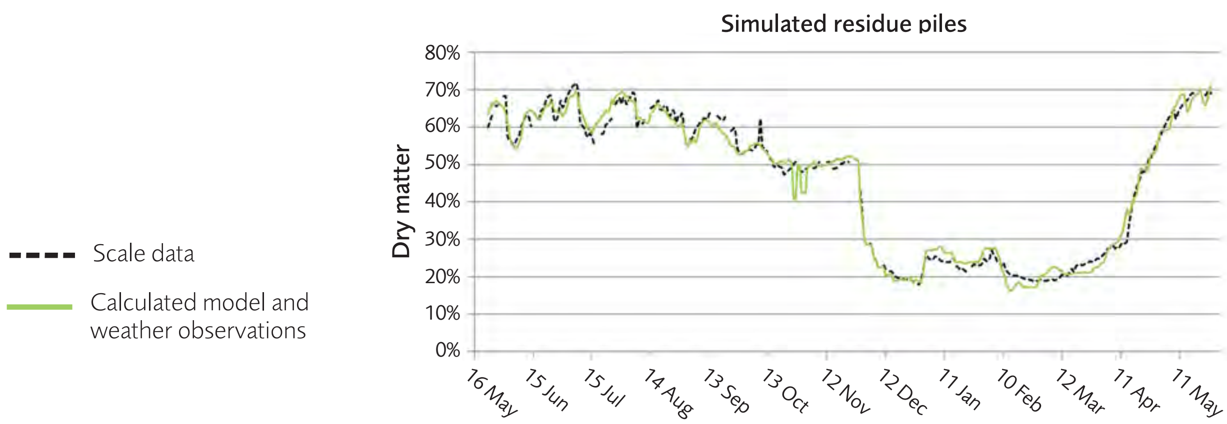
Continual weighing of the residue stacks and piles showed great changes in gross weights, and the changes could largely be explained by weather variables. In periods of rain, the residue piles absorbed considerably more water than the covered stacks. The moisture content in the piles increased by up to 20 percentage points, compared with 5 percentage points for the covered stacks. The difference can



be explained by the covering paper, and also by the residue piles having a considerably greater surface area exposed to the rain in relation to volume, compared with the stacks. Snow gave a maximum weight increase of 75 percent for the stacks and 180 percent for the residue piles.

The weight changes in the two residue stacks were similar but, in particular, the green stack had lost so much weight by the end of the summer that we suspected that some of the weight loss could be due to substance loss. We conducted visual and scent checks of the green residue stack on several occasions in summer 2012, and when the stack was chipped in May 2013, but found no visible signs of microbial growth. Our continual measurement of temperature and air humidity in the stacks did not show any signs of heat development compared with the surrounding air.

When the residue from the stacks was chipped at the end of May 2013, a large number of samples were taken to determine moisture content. Both the green and the brown residue stacks had an average moisture content of 16.5 percent, with a standard deviation within the stacks of only 1.2 percentage points for the green stack and 1.4 for the brown stack. The conclusion is that substance losses were not abnormal, and were at the same level for both green and brown logging residue. Moisture content in the small residue



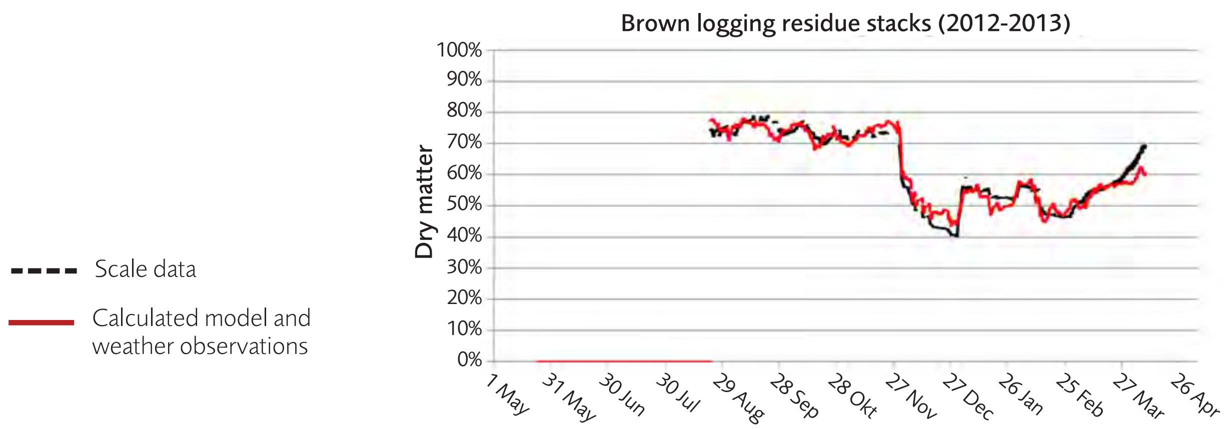
piles was much higher, nearly 40 percent, and with a standard deviation between samples within piles of 5 percentage points.

Using collected data, functions were developed that describe the moisture content of logging residue on the basis of storage time and weather data. After validation, the functions can be incorporated into a planning tool where the user, on the basis of continual weather data from e.g. the Swedish Meteorological and Hydrological Institute (SMHI), can predict the day-by-day moisture content in residues stored in piles on the clear-cut and in stacks at roadside. It will also be possible to forecast future moisture content using weather forecasts or weather scenarios. Such information can be used to plan the supply so that customers get material with the desired moisture content, and to describe the expected moisture content in future deliveries.

Snow is a problem. If a method can be developed to avoid including snow in comminution, the moisture content in the logging residue will be considerably lower. The Finnish research institute, VTT, has successfully tested using rotating brushes fitted on the crane to remove snow.

Storage trials using similar experimental setups, with different forms of stored materials and storage periods, have been carried out within the scope of the INFRES project, in both Finland and Austria

PHOTO: TOMMY BLOM/SEBAB



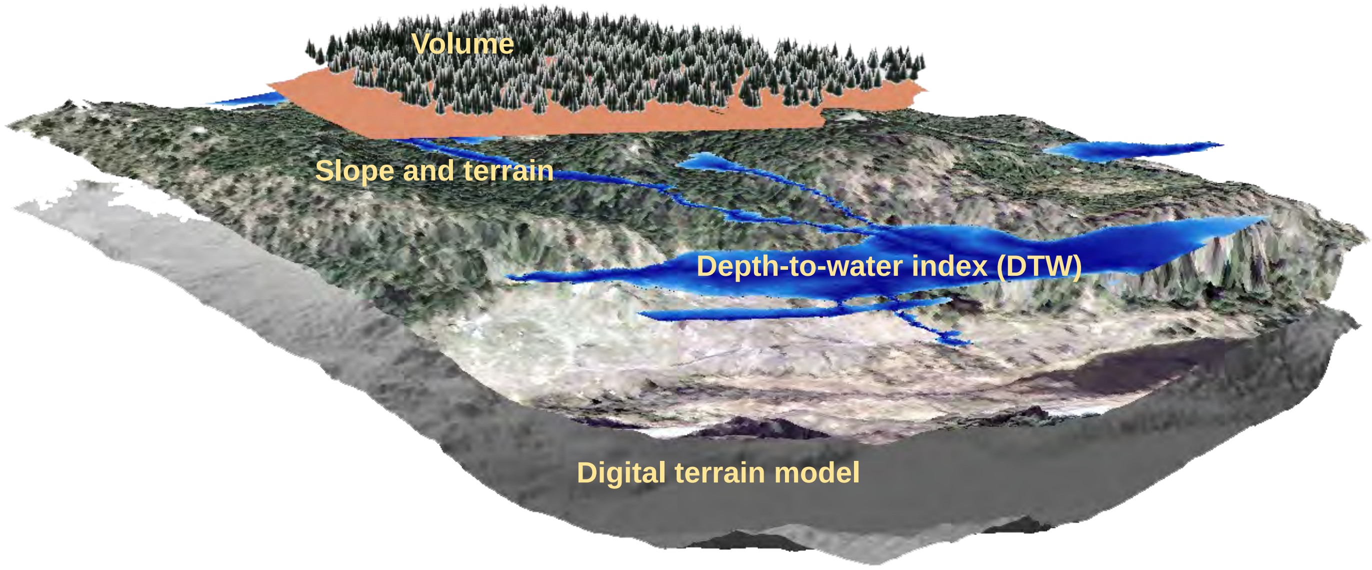
Future work

In order to improve control, management and feedback, prediction instruments and models for moisture content must be developed and validated. Data can be retrieved from measurements or historical data in the supply chain and/or meteorological and geographical data from practical experiments or documented experienc.

"There is a move towards commodification of biofuels, where moisture content is the single most important variable. The customers want to know what will be delivered, rather than see what they get. The prediction tool will therefore be interesting for the supplier, who can use it to direct the right material to the right customer, so that they can supply a cost-effective and competitive biofuel.".

Tommy Blom, Stora Enso Bioenergi.

Forestry activities always involve a risk of damage to ground and water. The problems can be reduced by planning operations carefully, by building crossings over streams and wet areas, and by using tops and branches to strengthen and protect the ground in areas with low bearing capacity.



BETTER PLANNING REDUCES GROUND DAMAGE

Gustav Friberg, Karin Westlund, Sima Mohtashami, Isabelle Bergkvist & Gert Andersson, Skogforsk

The STIG project

In the STIG project, Skogforsk, has worked with the forestry sector to develop the use of depth-to-water (DTW) maps, generated from airborne laser scanning data, in forestry operations. The laser point cloud generated in scanning enables models of the terrain to be produced in the form of height above sea level, slope and aspect. This in turn makes it possible to identify areas that are wet and waterlogged, and insert them on a map. This material also gives the logging planner a good idea of conditions on the site already in the office.

The depth-to-water index map method used was developed in Canada by the University of New Brunswick. To investigate whether DTW maps could work in Sweden, such maps were made for an area in eastern Uppland. Ten test quadrats with sides of 1 km were laid out, and sampling points were placed at 50-metre intervals along each side. Each point was surveyed in the field, and ground moisture was recorded in one of four classes, depending on the estimated depth to the water table.

Waterlogged 0 m

Wet < 1 meter

Moist 1 – 2 meter

Dry > 2 meter

The surveyor's assessment corresponded to the DTW map in 68 percent of the points. For 25 percent of the points, the map had indicated too wet conditions, while in the remaining 7 percent the map indicated too dry conditions.

Ground damage, defined as ruts penetrating the humus layer where mineral soil was exposed for a distance exceeding one metre, was evaluated after harvesting on 36 sites. All damage was recorded and mapped, and the result compared with a DTW map and the recorded operational paths of

The DTW map can serve as a useful tool, both in the office and in the field.

Better planning of crossings reduces damage caused by forestry activities.

the harvester and forwarder. Damage was found on approximately 50 percent of the length of strip and base roads situated on wet ground; for roads on waterlogged ground the figure was almost 20 percent, and on dry ground less than 10 percent. The lower damage rate on waterlogged ground compared to wet ground is correlated to a higher rate of road reinforcement with slash and fewer passages on these sections.

Skogforsk has also evaluated Stora Enso's harvesting instruction 'The Right Method'. In brief, this method means that logging is to be planned so that timber is transported efficiently, high-intensity base roads and strip roads with poor soil bearing capacity are covered with branches and tops, and extra care is taken in wet and waterlogged areas. Most forestry companies have developed similar instructions to reduce ground damage. The study examined 36 sites, where 18 had been harvested using 'The Right Method' and 18 had been harvested with no special directives.

After harvesting, the sites were surveyed in detail using the same definition of ground damage as above. For each occurrence of damage, coordinates, length, width and depth of damage, proximity to water or conservation area, and whether any ground protection measures had been made (e.g. reinforcement of base and strip road with tops and branches, logs or log mats) were recorded. The damage was also classified in accordance with the common ground damage policy applied by the forestry sector.

The study involved a total of 433 hectares. On this area, 3400 occurrences of ground damage were recorded, giving an average of 7.8 occurrences of damage per hectare. The number of damaged tracks per hectare was less than half on the sites where 'The Best Method' had been used. The occurrence of serious (unacceptable) damage was only a quarter of that on the sites that had been harvested with no special directives.

The results indicate that ground damage can be reduced considerably if clear directives are given about logging procedures on sensitive ground. There were also indications that quality and volume of tops and branches available for extraction as logging residues could be increased with better planning of operational routes and effective reinforcement of base and strip roads.

BesT Way

The STIG project has been the starting point for the development of a decision-support tool for operational planning of harvesting site that combines the information in the digital terrain model, the DTW map, with route optimisation for forwarding. The tool is called **BesT Way** (Decision Support for Site Planning).

Approximately ten years ago, Skogforsk started to develop a route optimisation program for forwarding of roundwood, logging residue and stumps. This forerunner of BesT Way was able to present alternative forwarding route options on the basis of the harvester's production files, which gave information about how much had been felled and where the timber was located on the clear-cut. The program then calculated the best route for the forwarder to minimise the transport distance.

BesT Way is based on the same idea but, instead of harvester data, data from the laser scanning is used to describe the forest. This technology gives a good estimate of the timber supply at pixel level, small areas of just over 100 square metres. Accessibility in the terrain is described by factors such as slope, ground wetness, soil, and height above sea level.

In the basic version, BesT Way calculates the most efficient placement of the base roads in relation to the position of the landing. BesT Way places no base roads in areas marked as wet or waterlogged on the DTW map. However, it can indicate one or more suitable sites for reinforced crossings of wet areas, and calculate a new optimal road placement based on these new conditions. The program can then test various sites for landings and crossings, and see how these affect, for example, forwarding distance and time consumption for forwarding, total cost, extractable volumes of roundwood and logging residues, number of passages at a certain point in the road network.

Field planning is expected to be more efficient with BesT Way, as a preliminary plan proposal can be drawn up in the office and the subsequent field visit can focus on confirming and modifying this proposal.

A graduate student compared the actual forwarding distance on two sites to the forwarding distance using the optimal route placement suggested by BesT Way. In both cases, BesT Way shortened forwarding distance by more than 20 percent.

In a first step, we believe that general calculations of base road patterns, forwarding distance and volumes of logging residue can be very interesting. In the longer term, more advanced applications can be discussed, such as time and cost calculations, navigation support for forwarder operators, and flow calculations at stand level.

Future work

- Decision support to find the best placement of base roads to minimise risk of ground damage needs to be developed further, and implemented in forest operations.

EFFICIENT PLANNING IN YOUNG STANDS

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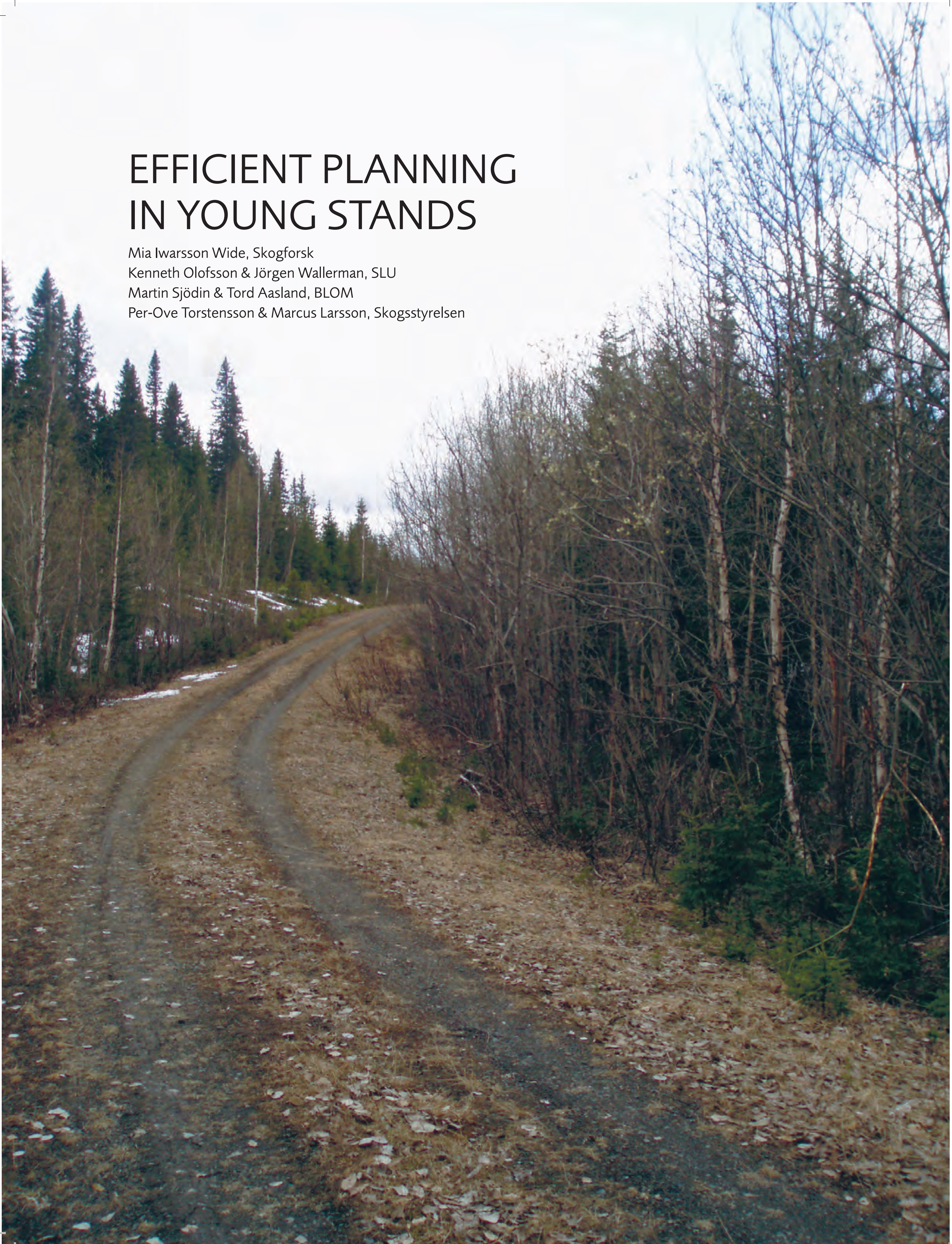

Identifying young forests that fulfil requirements for profitable forest fuel harvest using traditional field surveys is expensive and difficult. A study shows that laser scanning may be an effective tool.

Stands of small trees are a large potential source of forest fuel. Sweden has large areas of dense or very dense young forests with small trees in need of thinning, where only some of the harvested trees are of pulpwood dimensions. Calculations show that the potential harvest of forest fuel in thinnings of small trees lies between 5 and 7 TWh per year, taking into account technical and economic limitations.

Vegetation along roadsides is also a relatively unutilised forest fuel resource. In Sweden today, there are approxi-mately 213,000 km of roads without state funding, and the energy potential along these roads is estimated to be approximately 1.5-2 TWh per year.

Calculation tools

Previously, Skogforsk has developed a calculation tool for estimating volumes and economy relating to harvest of forest fuel in stands of small trees based on the age of the forest, site index, number of stems per hectare, and mean diameter or mean height. The assortments to be extracted are also specified, and how many stems are to be left in the stand after thinning. The tool calculates extractable volume and the cost of felling and forwarding. The results are first presented as a net cost to the roadside, but the tool can also calculate costs for various types of comminution, storage and transport, and thereby calculate a net cost for the fuel delivered to the heating plant.

A problem for users of the calculation tool is that the accuracy of the input data is usually poor, because field surveys of young forests and roadsides are expensive. The effect is that the results are very unreliable.

Laser scanning – an alternative?

Data from airborne laser scanning allows accurate estimation of forest height and density in middle-aged and older forests. A large study was carried out to investigate whether laser scanning could be used to assess the potential for forest fuel harvest in younger forests and along roadsides.

Stand data for 250 reference plots representing forests with small trees was recorded in a field study. A further 96 reference plots were placed along roadsides. Measurement data from the plots was then compared with national laser scanning (NNH) data from Lantmäteriet (The Swedish Mapping, Cadastral and Land Registration Authority) for the same plots. The analyses were carried out using the area method, which is based on multiple linear regression. Vegetation indices were calculated by comparing the relationship between the laser hits that reach vegetation compared with all hits, including those that reach the ground. A high vegetation index indicates dense vegetation, while a low vegetation index indicates sparser vegetation, because many laser hits reach bare ground.

Regression models were used to calculate five basic forest-related variables: basal area weighted mean height, basal area weighted mean diameter, arithmetic mean diameter, total biomass and total number of stems. The direct estimates of forest variables and vegetation density showed relatively high accuracy, particularly for the range of heights, but also for density of the vegetation.

On the basis of the laser scan information about mean diameter and total number of stems, the profitability of harvesting tree parts was calculated. The results were compared with the same calculation based on field-measured data from the reference plots. In 76 percent of the cases, the model using laser scanning provided a correct answer to the question: Is harvesting of forest fuel viable on this plot?

Calculating stem density and profitability of harvest along roadsides proved more difficult. There was a large variability, with a standard deviation of 27 percentage points for estimates of biomass. For roadsides, the calculation of whether harvest of forest fuels would be viable or not was correct in 64 percent of the cases.

Conclusion

Laser scanning allows identification of stands or parts of stands where it would be viable to harvest biofuel in young forest, but roadsides are rather more difficult. The method can probably be improved by combining NNH data with other data sources, such as aerial photos or satellite images that give information about the mix of tree species (the proportion of deciduous trees has a considerable influence on the profitability of biofuel harvest).

It would also be interesting to investigate whether a higher point density in the laser data would improve the accuracy.

Lantmäteriet's laser scanning means that there is now a comprehensive ground model for Sweden. In the future, tree height can be calculated using an automatic stereo matching of aerial photos, which gives the height of the forest canopy. In other studies, this has been shown to give almost as good an estimate of forest variables as laser scanning.

PROCESS MAPPING OF SUPPLY CHAINS

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Production and deliveries of forest fuel, and in particular logging residue, are characterised by long lead times and many different players involved in handling the material. This entails a risk of sub-optimal activities, duplication of work, and/or information disappearing in the supply chains.

In Germany and Finland, process mappings of forest fuel handling have indicated large potentials for streamlining business processes by systematically describing the work carried out to avoid duplication. It should be possible to adapt the method used in these process mappings to Swedish conditions, while also harmonising it with other methods for describing supply chains, e.g. skogs-SCOR.

Process mapping can increase players' awareness of the whole process, their respective roles in the process, and the possibility to influence both the end result and other parties' work situation. It can also identify which tasks need to be done, who should do them, and how information should be handled to make it available to parties that need it. Process mapping can also clarify the potential for rationalisation of the work, both for the company responsible for the forest fuel chain and for the contractors who perform the physical work.

In autumn 2013, a project was started with the aim of using the Finnish study method to develop and apply a method for mapping all processes in a supply chain for forest fuel, from planning of the harvesting operation to delivery of fuel to the end customer. The method was developed during a pilot study producing a process map of the biomass supply chain of a forest owner association. It was then used for a detailed process mapping of the biomass supply chain at a major forest company. While the forest owner association bought all the forest they felled, a significant proportion of the timber catchment of the forest company was from their own forest lands.

The work began with an introductory interview to create an outline process map of the business, and to map which players were active in the supply chain. Interviews were then held with the various players in the chain. After the interviews, the process map was drawn up in detail, and the interview responses compiled, compared and analysed. During the analysis, notes were made regarding each activity or element in the process chain:

- that, according to one or more respondents, cause irritation, generate unnecessary costs, or that could be performed better or more efficiently
- where the respondents had different views on how the activity is carried out, and/or who should carry out the activity
- where the analysis shows that there are, or that there is a clear risk of, sub-optimal activities, duplication of work and/or information losses.

Results show that, in the first mapping, many different problems and causes of irritation were noted in the supply chain studied, such as shortcomings in procedures, poorly and/or wrongly placed landings, and insufficient information transfer between the different players. In the second mapping, the respondents recognised some of these problems, but felt that most of the problems had been resolved. However, there were still work processes, procedures, etc. that could be improved upon.

There are many reasons for the differences between the surveys. The process is more complicated in the first mapping, because the forest owner association harvests and produces the forest fuel on behalf of many small private forest owners; in the second mapping, the company mainly works on its own land and only a small proportion of the volumes handled are purchased from other owners. The people and companies involved in the second mapping also have more extensive experience of handling logging residue than those who took part in the first mapping. One contractor company in the second mapping provides several services in the supply chain, i.e. harvesting, forwarding of both roundwood and residues, chipping and transport of chips. This contractor has worked actively to improve internal communications and has a comprehensive view of the services provided, so disruptions and problems occurring within its part of the chain have already been identified and minimised or eliminated.

Future work

The process mapping project shows that information can disappear in Swedish supply chains and that work descriptions are not always adequate, causing irritation and extra work. What remains is to examine the scale of the savings potential if the chain is streamlined, and how this can be done in the best way.