BIOBORD PLATFORM

FOREST TECHNOLOGY ANALYSIS

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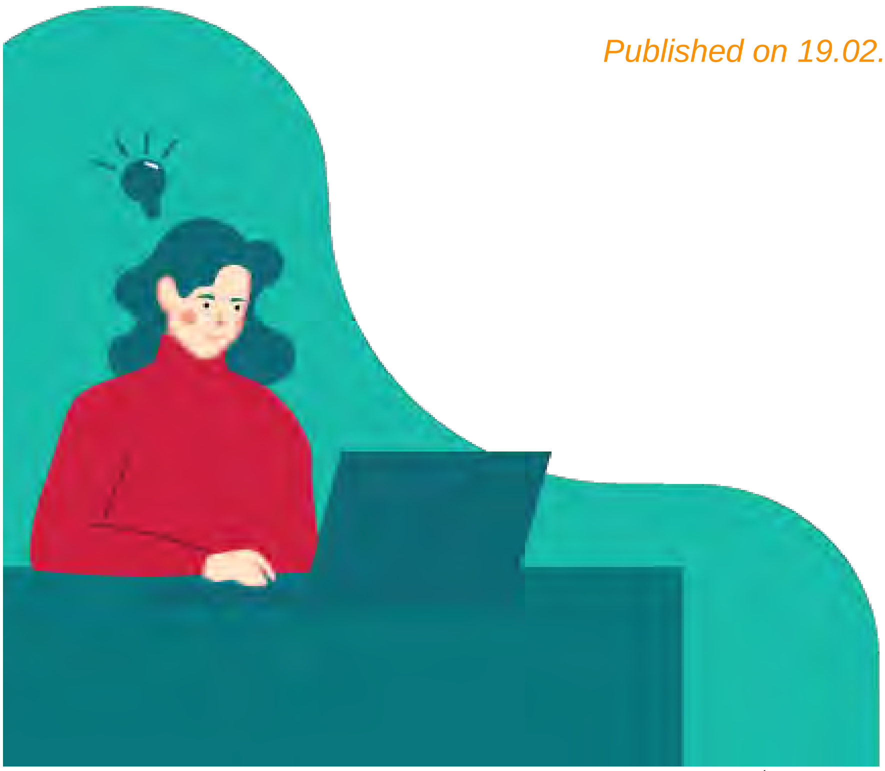

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

Interreg Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

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1. Introduction

1.1 Context

This study is conducted as a part of the Interreg Baltic Sea Region project "ConnectedByBiobord – Biobord open innovation platform connecting bioeconomy developers in BSR", the Forest Innovation Pilot. The project is an extension stage project for the Interreg BSR Flagship project "RDI2CluB – Rural RDI Milieus in transition towards smart bioeconomy clusters and innovation ecosystems", which aimed to support smart, sustainable, and inclusive growth of the bioeconomy in rural areas of the BSR.

The outputs from the RDI2CluB project; Joint Action Plan and Biobord platform for transnational cooperation is the foundation for the ConnectedByBiobord project, which implements transnational innovation pilots from the mentioned Joint Action Plan. There are three innovation pilots in ConnectedByBiobord; Food Innovation Pilot, Forest Innovation Pilot, and Technology Innovation Pilot. The objectives of the Forest Innovation Pilot are to test transnational innovation processes in co-creation between research institutes and business, and to increase and exchange knowledge about bioeconomy to develop higher value-added products, services, and knowledge-based jobs.

The Forest Innovation Pilot Group consists of four partners:

- JAMK University of Applied Sciences, Finland
- Inland Norway University of Applied Sciences, Norway
- Tretorget Ltd, Norway
- Paper Province Business Cluster, Sweden

1.2 Objective of the study

Ever since the origin of mankind, we have been dependent on the forest for food, fuel, and materials. From the first hunter-gatherer societies that lived directly from what the nearby forests could offer them there has been a tremendous development in the society's use of the forest and its resources to today's society where machines, remote sensing and other high technology are at daily use and form the basis of a both profitable and sustainable forestry.

Today, the traditional use of timber for constructions, paper products and energy is still the cornerstone of the forest economy. However, the ongoing climate change and awareness of this and the need for more sustainable solutions and transition from petroleum-based materials to environmentally friendly materials have led to increased research and development of new wood-based products, such as clothing, chemicals, feed for livestock and biofuels. To increase the profitability of the forestry, there is also a requirement for new side stream products, commercialisation of high-quality or special quality wood assortments, and better utilization of the timber. Figure 1 shows the typical timber flow.

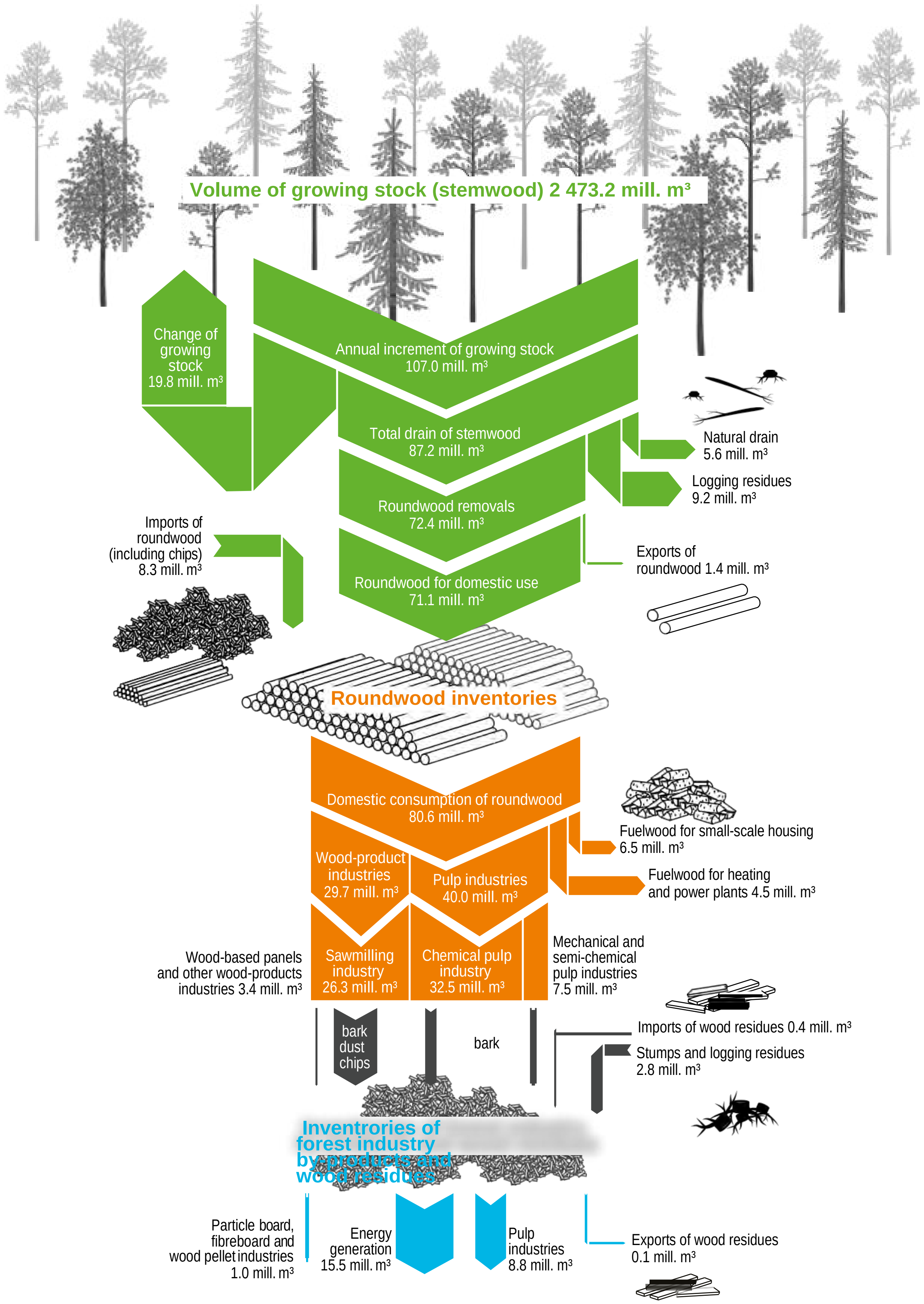


Figure 1 Timber growth, timber flows, roundwood inventories, and inventories of forest industry by-products and wood residues in Finland's forestry in 2017 (Vaahtera 2018)

At the same time, the timber-processing industry requires full-year access to raw material, which is becoming more difficult in an increasingly milder climate where frozen ground on peatland and other soil with poor bearing capacity is no longer guaranteed annually.

Emerging technologies may offer decision support that improves the profitability of the value chain, while safeguarding the environment and sustainability, from forest stands and forest inventory through harvesting to the end-user product. There are great unexplored possibilities in e.g. use of drone-borne multispectral cameras and data gathering by harvesters. However, without a standardised data format and transfer of data from one operator in the value chain to the next, a lot of information is probably lost, and the use of the timber is not optimised.

The objective of this study is to review existing technology throughout the forestry value chain from the forest stand to the end-user product and determine whether there is a transparent data chain following the value chain – and if not; detect the missing links.

1.3 Methodology and structure of the report

This report is co-written by the four partners mentioned above. Each partner has been in charge for specific chapters, which the other partners has commented on. Several online meetings and a workshop have been held to discuss and conclude on the content and conclusions of the report.

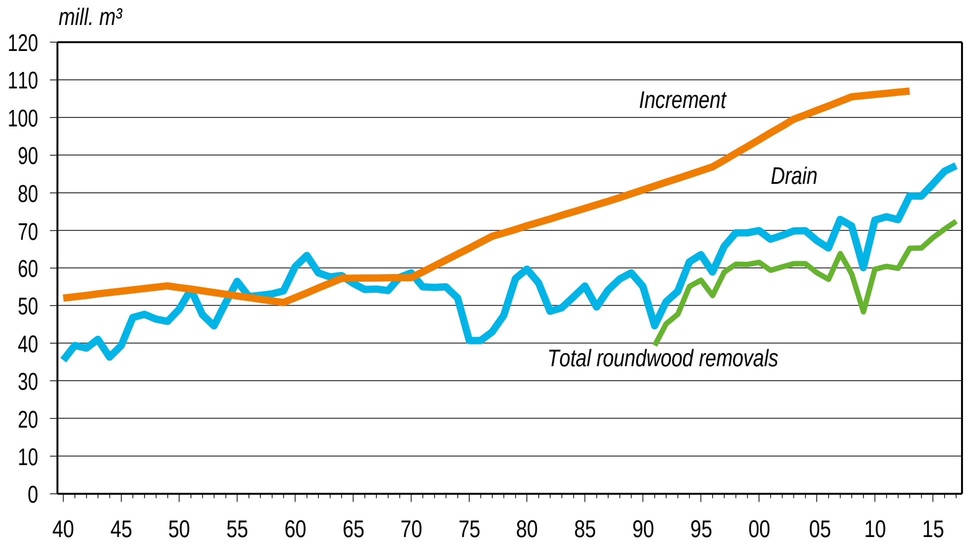
The structure of this report follows the value chain from the forest inventory to the end-user product at the sawmill. Based on our own knowledge, literature studies and discussions with various actors in research and industry, we have been able to describe the current situation for data flow throughout the value chain, with potential and hinders for further development to improve the data transfer for – and thus the knowledge about – the timber that is cut and processed.

2. Forestry in Finland, Norway, and Sweden

2.1 Finland

Finland has extensive forest resources. It is one of the most forested countries in Europe. The total growing stock is over 2473 million solid cubic meters, without tree branches (statistics from the year 2017). The annual increment of growing stock is 107 million cubic meters per year, and the total drain is at the level of 87 mill. m^3, consisting of harvested timber and naturally died trees. Thus, the growing stock is increasing year after year. Of this, 50% is pine, 30% is spruce, 17% is birch and the remaining 3% is made up of other broadleaved trees. In Southern part of Finland, the share of spruce is about equal with pine, when broadleaved trees are in minority share there, too. Annual loggings of roundwood have varied between about 50 mill. m^3 to about 80 mill. m^3, depending on the market trends of the forest industries (Vaahtera 2018).

Forest resources have been increasing almost constantly during the previous 100 years period. The total growing stock has doubled in the past 50 years, while the amount of timber harvested during the same period being equivalent to the present total growing stock. Today, the cap between the increment and the drain is annually about 20 mill. m^3.



Source: Natural Resources Institute Finland

Total roudwood removals, increment and drain of growing stock, 1940-2017

Figure 2 Growing stock increment, drain and roundwood removals in Finland during 1940-2017 (Vaahtera 2018)

Altogether 86% of the total land area of Finland is regarded as forestry land (26.2 million hectares), and three quarters of that is productive forest land (annual growth potential above 1 m^3 per ha). 52% of forestry land is privately owned. The state owns 35% and companies 7%. The rest is owned by municipalities, parishes, and associations. 60% of forestland is privately owned. The state-owned land is mainly located in Northern Finland, so the relative share of the annual growth is higher at the private owned forests. Private family-based forestry is typical for the Finnish society. An average ownership is about 30 hectares, and number of private forest owners is over 600 000 (Vaahtera 2018).

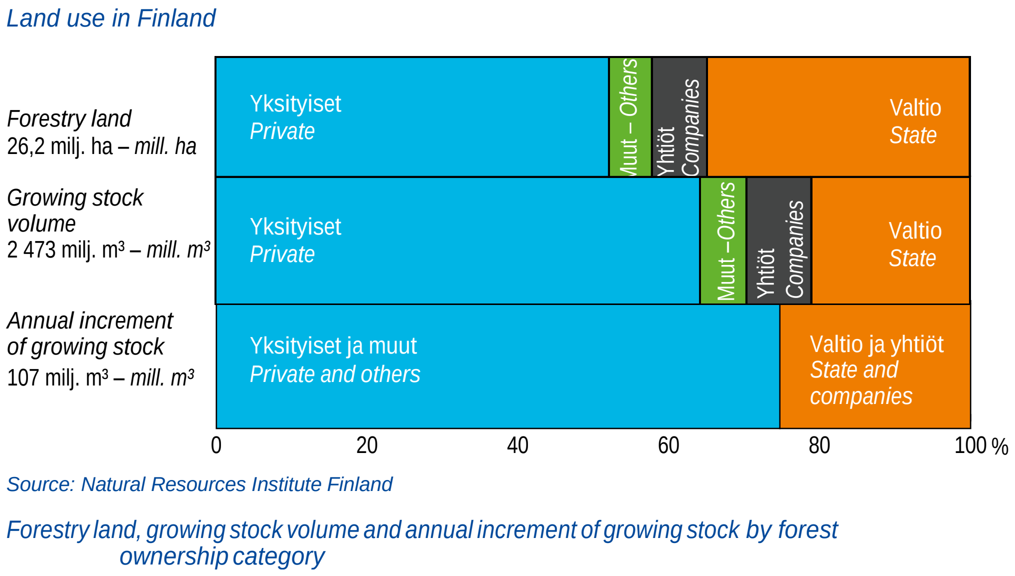


Figure 3 The shares of different landowner groups in forestry land, in growing stock volume, and in annual increment of growing stock (Vaahtera 2018)

2.2 Norway

Almost 38% of the Norwegian land area, or 121,000 km^2 (12.1 million hectares), in Norway is covered by forest (Statistics Norway). Of this, around 82,800 km^2 (8.28 million hectares) is productive forest. The total standing timber volume in the Norwegian forests is 978 million m^3. Of this, 43% is Norwegian Spruce, 30% Scots Pine and the rest is different deciduous trees. The annual harvest is about 12 million m^3, and the annual regrowth is 24,2 million m^3, meaning that as in Finland, the growing stock increases annually.

There are more than 125,000 separate forest properties in Norway, and 77% of the area is owned by private individuals, mainly farmers. 60% of the properties are 25 hectares or smaller. Each year, there is conducted harvesting on about 14,000 of the properties. While forestry is a traditional and important industry in Norway over most of the country, the largest forest county is Inland county. Around 25,000 persons are employed in the forest-based value-chain in Norway (Regjeringen 2018). Almost all the Norwegian forests are PEFC- or FSC-certified (Skogeierforbundet, s.a.).

2.3 Sweden

Two thirds of the country’s land surface – or some 28 million hectares - is covered by different types of forests, and 80% of this is in active use. Of this, some 23 million hectares is considered productive forests. The largest landowner in Sweden is state-owned Sveaskog Ltd, which owns 3.1 million hectares of forest land, or almost 14%, of the country's forest land. The Swedish Church are also a large forest owner 990 000 ha. Family-owned forests represent around 50% of the total forest area and some 60% of the total annual yield, and more than 300 000 private individuals own forest land themselves.

The total volume in the Swedish forest is 3533 million m^3, and the annual growth is 120 million m^3. The annual felling is 80 million m^3, which means that also in Sweden, the amount of timber standing in the forests are increasing. Over the past 100 years, Sweden's forest volume has increased by 100 %. Every year, at least 380 million trees are planted in Sweden.

3. Description of the technology throughout the production chain

3.1 Forest inventory

3.1.1 Data input: sources, format, IPR, use of the data

National Forest Inventory - Finland

Forest resource data is collected mainly at three levels in Finland; at national level, regional level, and forest estate level. In addition, data is collected when harvested timber is measured for timber trade and harvesting and transportation contract purposes. Forest inventories in Finland have already a long track record. They have been implemented systematically and border-to-border since 1920's in 5 – 10 years cycles. These National Forest Inventories (NFI) have provided comprehensive and fairly precise information about the forest resources and their trends in the country. The results were presented at national, province and municipal level.

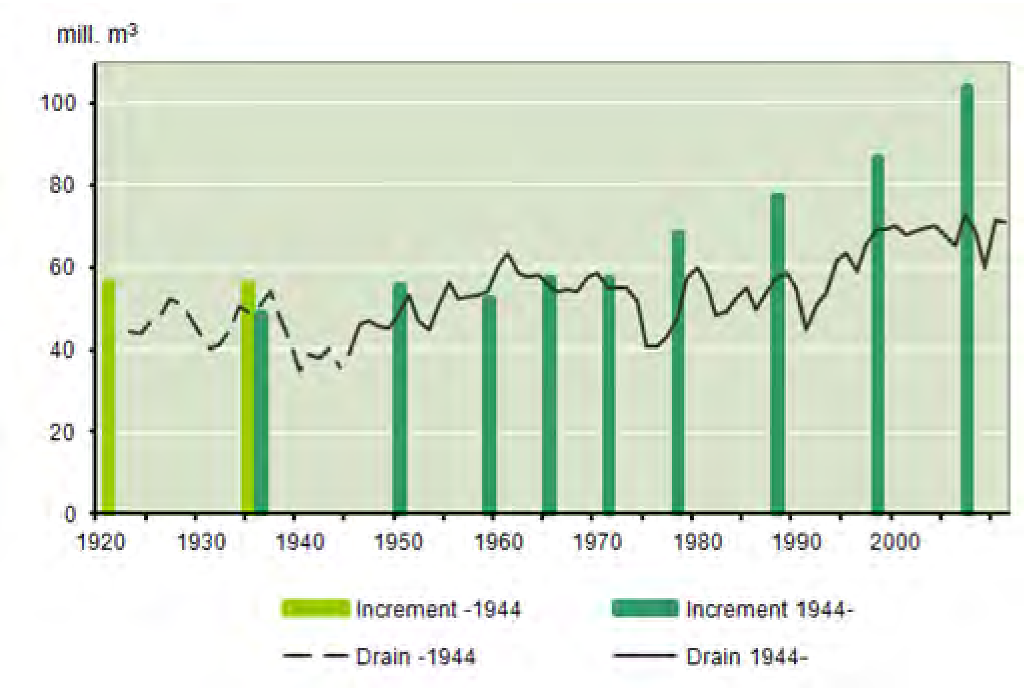


Figure 4 National forest inventory rounds 1920-2009, and annual stem wood increment and drain according to the NFI (Paananen 2019)

NFIs based on only field measurements until the last round. The inventories were started by drawing representative sample lines through the country, and they were surveyed. But in recent inventories systematic sampling and field plot measurements have been used. The field plots are located in a regular network of clusters over the whole country. Field data is measured from the plots, and forest statistics are calculated for the whole country and for large areas of over 200 000 hectares. (Metla.fi)

At the last round, the multi-source NFI utilizes several data sources, like field measurements, satellite images and digital maps. With this method, forest statistics and thematic maps can be produced for any given area, e.g. Forest Centre regions and municipality areas.

The NFI inventory results are used for large area forest resource assessment and monitoring statistics. The results provide information about:

- forest resources - volume, growth, and quality of growing stock,
- land use structure and forest ownership,
- forest health,
- biodiversity of forests and forest carbon stocks and their changes.

(Metla.fi)

The Natural Resource Institute of Finland (LUKE) is responsible to carry out NFI –inventories and management of the database. The government finance the work. Inventory results for large areas are open information for the public.

National Forest Inventory - Norway

Breidenbach et al. 2019: *The current NFI grid was implemented in the 6th NFI from 1986 to 1993, when permanent plots on a 3 km × 3 km grid were established below the coniferous tree line. As of the 7th inventory in 1994, the NFI is continuous, and 1/5 of the plots are measured annually. All trees with a diameter ≥ 5 cm are recorded on circular, 250 m2 plots. The NFI grid was expanded in 2005 to cover alpine regions with 3 km × 9 km and 9 km × 9 km grids. In 2012, the NFI grid within forest reserves was doubled along the cardinal directions. Clustered temporary plots are used periodically to facilitate county-level estimates. As of today, more than 120 variables are recorded in the NFI including bilberry cover, drainage status, deadwood, and forest health. Landuse changes are monitored and trees outside forests are recorded.*

Data is used for reporting (I.e., Carbon sequestration), basis for policy, and forecasting.

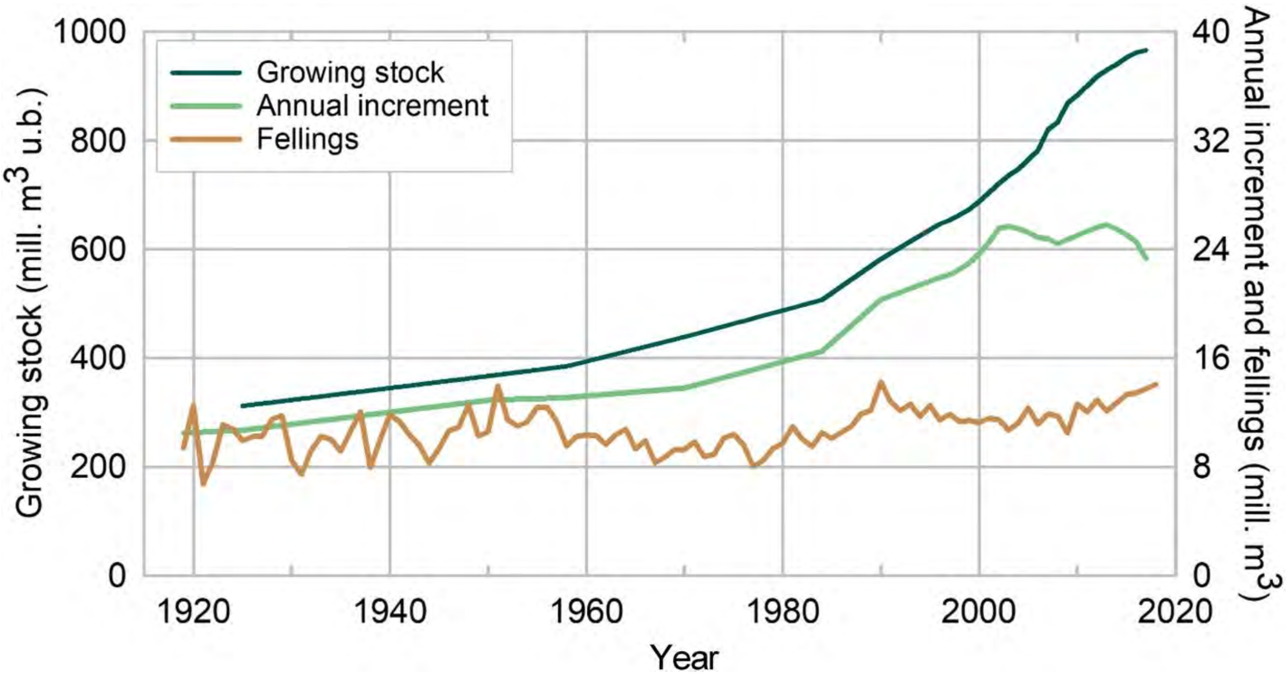


Figure 5 Timber resources and felling in Norway

NFI map product

SR16 is developed using photogrammetric point cloud data (and now mainly Lidar data (my comment)) *with ground plots from the Norwegian National Forest Inventory (NFI). First, an existing forest mask was updated with object-based image analysis methods. Within the updated forest mask, a 16×16 m raster map was developed with Lorey's height, volume, biomass, and tree species as attributes (SR16-raster). All attributes were predicted with generalized linear models that explained about 70% of the observed variation and had relative RMSEs of about 50%. SR16-raster was segmented into stand-like polygons that are relatively homogenous in respect to tree species, volume, site index, and Lorey's height (SR16- vector). When SR16 was utilized in a combination with the NFI plots and a model assisted estimator, the precision was on average 2-3 times higher than estimates based on field data only. In conclusion, SR16 is useful for improved estimates from the Norwegian NFI at various scales. The mapped products may be useful as additional information in Forest Management Inventories.*

The SR16 product is under development and now includes variables such as: biomass, harvested volumes/biomass per year, and others. The data is freely available. The map does not provide information on property-level without further processing.

Regional Forest Inventory - Finland

Regional level forest inventories (RFI) are implemented by the Finnish Forest Centre. This work is also financed by the government. The RFI information contains stand wise information about the core attributes of the forest, like total stem volume, share of tree species, medium height of the dominating canopy class, and DBH. It also shows information about habitats of special interest and the use of forests. Majority of the data is openly available in digital format. (Metsään.fi)

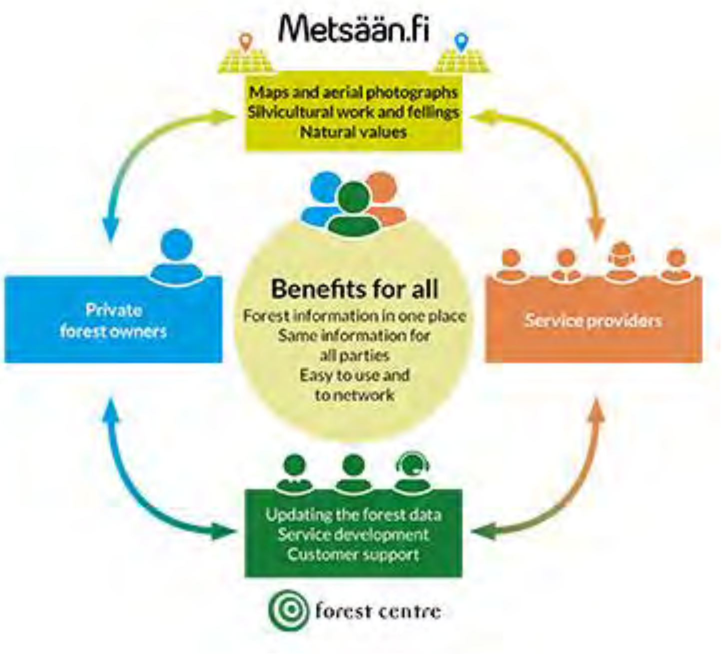


Figure 6 Forest information services of the Finnish Forest Centre (Metsään.fi)

Open forest data is available through three different channels:

- map services,
- file packages based on spatial data,
- and data interfaces

No personal data or contact details of forest owners are disclosed in connection with open forest data available through the Metsään.fi website. (Metsään.fi)

Data is collected and updated in stand wise form (a stand or forest compartment is homogenous forest area with average size 1,5 hectares)

- Soil and site type,
- Growing stock
- Silvicultural needs and cutting possibilities
- biodiversity information

Product description can be found here: [Open forest data - Product description (metsaan.fi)]

Map services:

- Habitats of special importance in accordance with the Forest Act
- Grid cell data

- Forest use declarations
- Compensations for damage caused by deer
- Remote sensing sample plot

(Metsään.fi)

Open forest data is also available in various data packages. The datasets are grouped by data content and region. Spatial datasets are particularly useful, for example, for performing analyses at the level of regions.

Data packages are introduced here: Spatial datasets | Metsään.fi (metsaan.fi) (Metsään.fi)

Inventory is based on laser scanning, but aerial photos are also useful especially in tree species recognition. The remote sensing data is combined with the field data so that each field sample plot gets corresponding characteristics of laser point data and pixel values of aerial photos. After that, modelling between the forest measurements and remote sensing data can be done and utilised in the estimation of the whole inventory area. Laser techniques do not provide accurate estimates of seedling stands and they must be measured in the field if other sufficient information is not available. (Paananen 2019)

Lidar (light detection and ranging) system sends pulses of laser light and measures the distance from the ground or vegetation according to the returning pulses. In forest inventory 0.5-1.0 observations (pulses) / m^2 is currently used. This means flying altitude of 2 km and about 1 km scanning line width. Because laser scanning does not need sun light, it can be done also during the night. However, rain drops scatter the laser beams. (Paananen 2019)

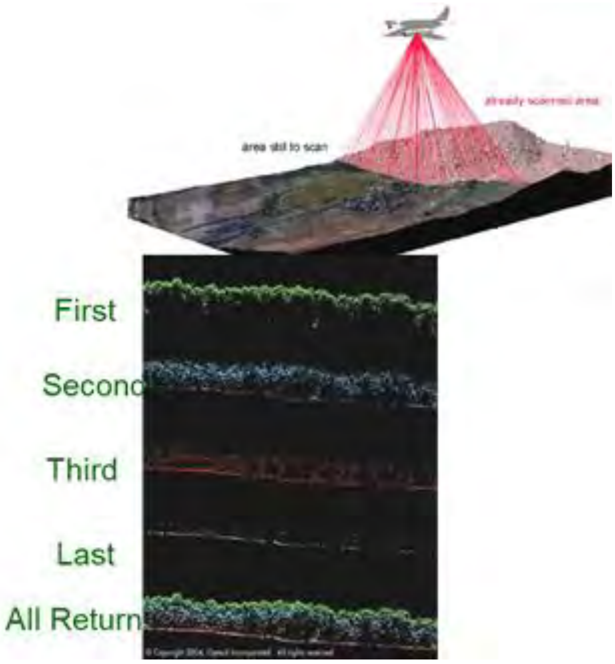


Figure 7 Airborne laser scanning method (Paananen 2019)

Lidar Canopy Height Model (CHM) can be used in automatic stand delineation. In addition, semi-automatic process has been developed to combine micro stands to larger treatment compartments (size 0.5-5 ha).

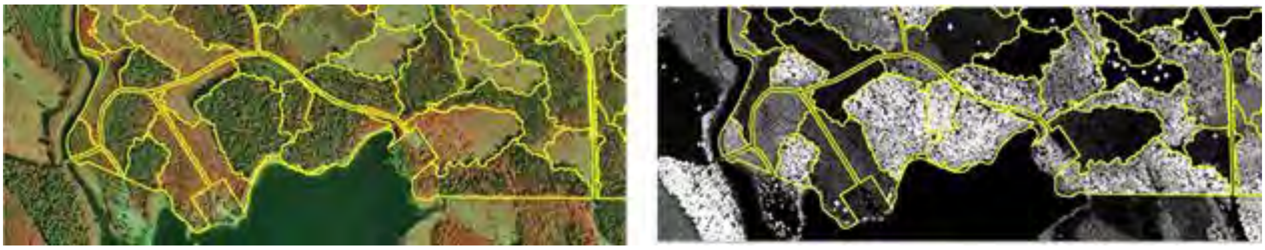


Figure 8 Automatic stand delineation (Paananen 2019)

Forest inventory primary unit is a 16x16m (on-going round 0,5x0,5m) grid cell. In the next phase the systematic grid data is generalized and calculated to the forest compartments. In addition, silvicultural treatments and cutting proposals are simulated according to the forest management recommendations. (Paananen 2019)

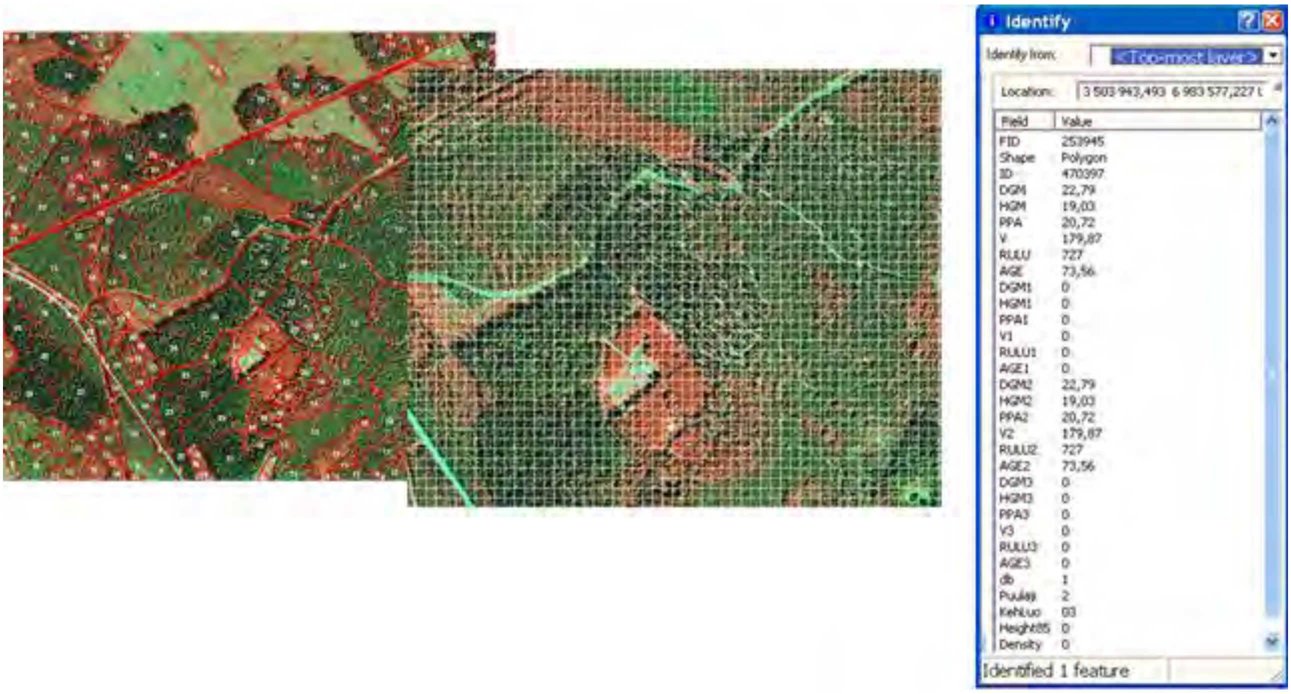


Figure 9 Forest inventory primary unit (Paananen 2019)

Metsään.fi is a portal through which people who own forest property in Finland can conduct business related to their forests. The portal connects owners with related third parties, including providers of forestry services. Metsään.fi is a portal which offers the latest information to forest owners on their properties. The forest owner decides which external parties may access his estate wise forest data. Forest owners can see what should be done in their forests right now. (Paananen 2019)

Information is displayed for each forest compartment, including soil type, growing stock, possible logging or forestry actions are suggested, including income and cost estimates. Maps and aerial photographs clearly show where properties are located and what they look like. Users log in securely using their online banking codes. (Paananen 2019)

The forest owner decides which external parties may access his forest data. Forest owners, companies and the Forest Centre can use the same information. Forest owners can easily share the information with companies and inform the needs for forest work and use the data in planning timber sales agreements in the new e-service (Kuutio). Forest owners and companies can also inform Forest Centre about work done and submit forest use declarations or applications for state financial support to silvicultural works. (Paananen 2019)

Figure 10 Metsään.fi is a forest owner's tool for managing his/her forest resources (Paananen 2019)

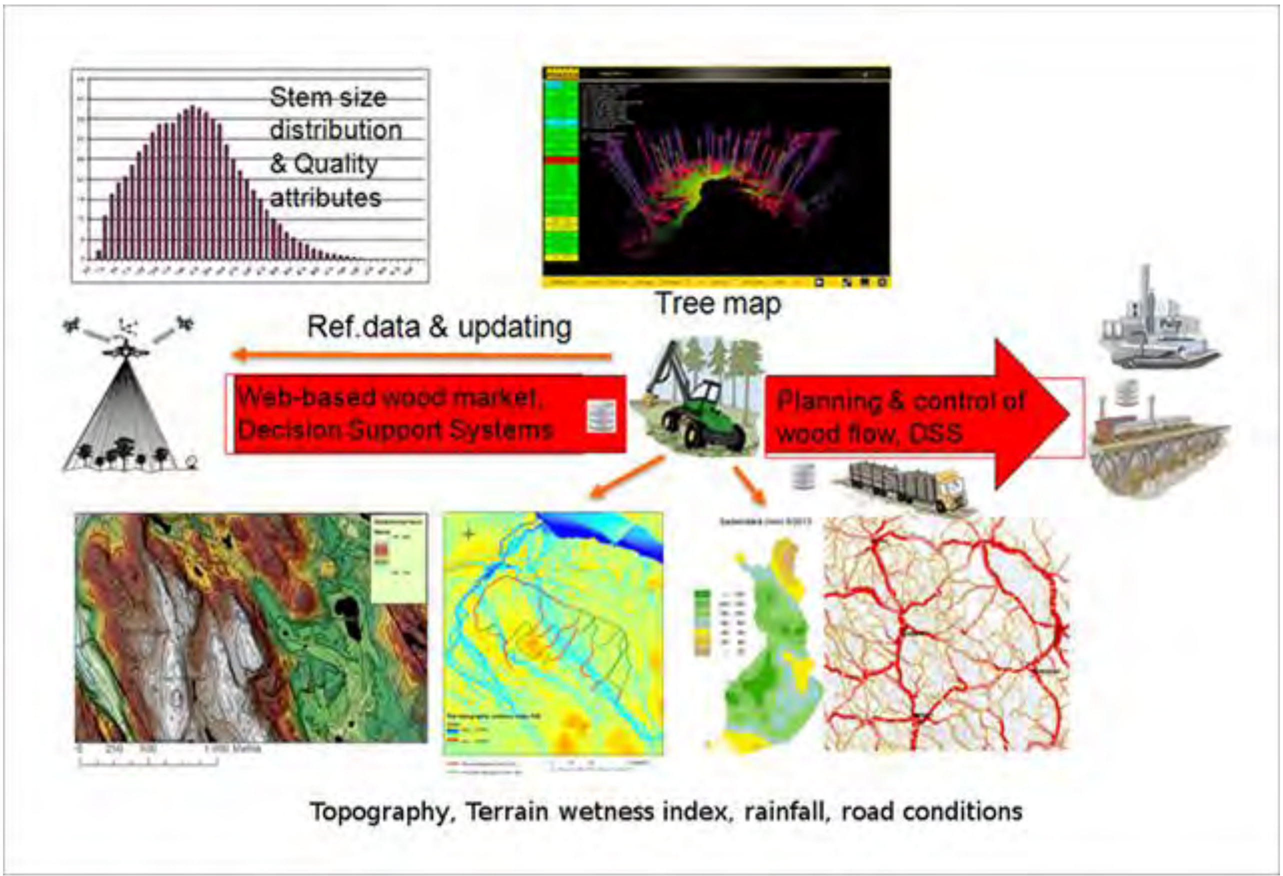


Figure 11 Metsään.fi tool enables connection with various databases and different kind analysis based on them (Paananen 2019)

Forest estate level information management

From the early days up till the first decade of this century the Forest Centre and Forest Owners associations carried the main responsibility to produce forest management plans for the private forest owners, municipalities etc. Work was based on field level manual inventories and recommendations for measures given by forestry experts. At the same time forest inventory data was collected for authority use. Invention method was different than used in NFI inventories. Every forest compartment of the estate was visited, and light measurements were performed. Main forest attributes, soil properties, recommendations for measures, and some other information was recorded.

Compartment maps over the estates were drawn. The final result was a printed booklet that introduced information about the resources, recommendations for measures, other additional information, and economical calculations about the forestry for the next 10 years period. In addition to forest management purposes, the forest management plans were used for real estate transactions and timber sales. Planning work was partly financed by the government, partly by the forest owners themselves.

Gradually private service companies took over the business and started to develop their forest management planning tools. It has become an open business, and hence it is the most flexible and development-oriented sector among forest inventory parties. Competition makes them to seek for new competitiveness factors. Forest industries timber procurement departments have their versions of forest management plans their offer to forest owners. Purpose is to create continuous and committed relationship with timber sellers. Forest Owners Associations have their versions, like various private service companies.

As an example of a private forest management plan product, an advanced and high technical level representing product is provided by the Mosaicmill Oy company. Please see: [MosaicMill home]

This Helsinki based company introduces themselves: *MosaicMill Ltd is Finland based technology company established in 2009. The company is one of the leading companies applying drone data in forestry and new methodology enables forestry planning without traditional field work. MosaicMill is the developer of Cessna class EnsoMOSAIC aerial survey system. Product portfolio includes also hyperspectral sensor and reflectance field targets for agriculture and forestry. (mosaicmill.com)*

The forest planning system is introduced in a slideshow: Microsoft PowerPoint - MosaicMill-Drone-Forest_Inventory_08_2020

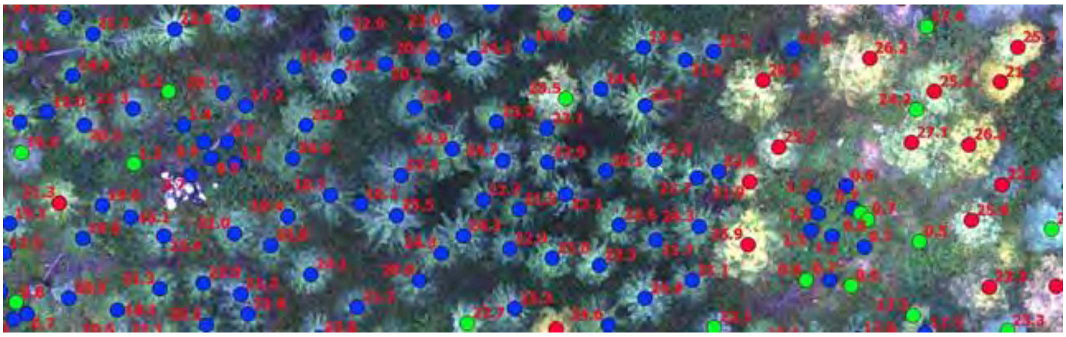


Figure 12 An example of tree mapping picture of the Mosaicmill Oy's inventory system (mosaicmill.com)

The Finnish-German company CollectiveCrunch has also applied AI methodology to analyse forest "to evaluate the tending needs of seedling stands, create harvesting proposals and to predict the timber grades of a harvested area". Source: https://www.collectivecrunch.com/ai-forest-planning-article-customer-metsahallitus/

The Finnish company Bitcomp provides also geographic information systems and forest change predictions related to forest resource management. Source: https://bitcomp.com/foresta/

In addition to these examples, several other forest management planning products are available.

3.1.2 Potential and hinders for more input/more efficient data exchange

Potential:

- Frequent updated information on forest area status, yield, growth, costs, management activities etc.
- Raised awareness and more knowledge on the value of information in order of making decisions.

- Access to guidance and advice on forest management.
- Practical and tailored advice on management adapted to forest owners' preferences and management targets.

New technology-based forest inventory methods are replacing traditional field work-based labour-intensive methods. Despite of rapid development of the inventory methods, especially remote sensing-based inventories, accuracy, and timeliness are still a bit questionable, and hunger for better inventory data is growing all the time (Kangas 2018).

Information about the forest stands is expressed as stand level features, like volume by tree species groups, above-ground tree biomass, basal area, basal area weighted mean diameter, and basal area weighted mean tree height etc. Single trees with their individual properties are lost in the sums. On the other hand, stand level average information provides only poor picture about the quality variations inside the tree population, which can lead to wrong timber-log qualities to sawmills.

In addition to enhanced collection techniques, that produce better quality sensing data, direction is towards single tree level data, where every tree, or valuable tree, have location and some quality information. 3D data produced by remote sensing methods can be enhanced and updated by terrestrial level sensing methods. This kind of data would enable many improvements in forest management and timber harvesting. It would provide much better information about timber qualities of different tree species at the stand, when special timber assortments tend to get lost in the timber mass flow in cuttings. Thus, forest owner might lose timber sales incomes, and wood processing companies interested in minor timber assortments, have difficulties to acquire raw material.

Single tree level data would enable more accurate thinning plans, also in advance. Trees to be removed / left can be pointed on a digital map, or selection can be generated automatically by some algorithm. Accurate information about the yield and the growing stock after harvesting can be gained. This way forest owners' ideas about the harvesting program can be realized, including variable densities of growing trees in different parts of the forest. Forest owner and other interest groups can utilize virtual reality for creating various scenarios of the future of the stand. It might be also a way to more automatic harvester work at thinning, when the cutting machine knows exactly which trees are dedicated for harvesting.

Hinders:

- Limited access to data, and possibilities to move data from different sources and owners. This can be both technical hinders and limited rights to data.
- Technical competence with regards to service providers (providing forest inventory and management plans), and data collection and data exchange from harvester operators.
- Age and maintenance of harvesting machines and their capacity to collect and share data.
- Small owners are reluctant to invest in updated inventory data.
- Lack of knowledge of the value of data and the value of decision making.

When inventing forest resources, the question is always costing versus benefits. Very detailed and accurate data is possible, but collection and management cost of such data is seldom justified from economical point of view. New remote sensing techniques have decreased the costs by decreasing manual work in collection and handling of the data. But they have still their limits. Various weather and tree sphere conditions cause blurriness and misreading in sensing process. Essential tree-specific properties, if any, are calculated based on tree-species, height, and canopy width information (Kangas 2018). Still, production of tree maps with identification of tree species is already available with technology where each tree is located and measured from UAV data (mosaicmill.com).

Hence, a crucial challenge is to get accurate measured information from single trees at acceptable costs. In Nordic countries, it seems to be the case for the on-going decade that national and areal inventories will produce just stand level information. It is seen detailed enough for the most needs among forest stakeholders. Can rapidly developing technologies and open-minded new concepts for data collection bring solutions that enable establishment of tree-level forest inventory database?

3.1.3 Data production: what are the sources, format, IPR

As explained before, tree maps and stand level information are available for reasonable price from airborne sensing processes supported by some field level sampling plots (Kangas 2018). Some tree-specific data could be collected, as well, from clear targets, and especially with UAV –based methods.

Regional forest inventory data is open and accessible for the public in Finland. All datasets are accessible through WMS and WFS spatial data interfaces. In addition, forest stand data is also accessible through a REST interface, which returns data in the form of XML messages in accordance with the Forest Information Standards. At a later stage, a corresponding REST interface will also be implemented for the grid cell data. The data is owned and managed by the Finnish Forest Centre. (Metsään.fi)

Field level measuring techniques based on scanning with portable scanners, even with a smartphone, are available. E.g. a Finnish company Trestima Oy has developed smartphone-based applications for field level forest inventories. Pl. see: https://www.trestima.com/w/en/

Figure 12. A smartphone application for forest inventory by Trestima Oy (Trestima.com)

Field work can be speeded up by measuring stand characteristics with pictures. TRESTIMA® application also works as a nifty field data logger and is compatible with several forest information standards. This means you can type in you forest management and harvesting plans in the field with ease. All inputted data is also geotagged and can be later edited in the cloud service or coupled with editable stand borders. (pl. See Forest inventory system - Trestima Oy)

Laser-scanning-radars are developed for forest machines in order to collect data from the forest when the machine operates at the stand. The target is to increase automatic action of the machine, but at the same time further inventory information from the forest is gained.

Point cloud technologies and applications are evaluated and tested for example in a large co-operation project in Finland between the land survey authorities and some universities (pl. See In English | Pointcloud.fi). Similar R&D work can be assumed existing in other countries, as well.

Figure 12. Example of a point cloud picture from a forest and an electric line (Pointcloud.fi)

The above-mentioned source also includes a prominent list of publications. Liang et al. forecast development of the technology in their publication "Terrestrial laser scanning in forest inventories" as follows:

Terrestrial laser scanning (TLS) provides a measurement technique that can acquire millimetre-level of detail from the surrounding area, which allows rapid, automatic, and periodical estimates of many important forest inventory attributes. It is expected that TLS will be operationally used in forest inventories as soon as the appropriate software becomes available, best practices become known and general knowledge of these findings becomes more widespread. Meanwhile, mobile laser scanning, personal laser scanning, and image-based point clouds became capable of capturing similar terrestrial point cloud data as TLS. (Liang et al. 2016)

In addition to portable terrestrial laser scanning technologies, under interest there are also methods based on under canopy UAV scanning. The preliminary test results have been gained. (Hyyppä et al. 2020)

Ownership of data, data transition protocols, data collection concepts and practical applications are questions needed to be answered before the practices can become business as usual. It can be evaluated that the easiest way to proceed in early phase is within the forest management planning for the private forest owners.

3.2 Harvesting area and stand

3.2.1 Potential and hinders for more input/more efficient data exchange

Potential:

- Automatic registration and development from remotely sensed data, supported by data collected by harvesters.
- Automatic registration of harvested area from harvester registration.
- More detailed information on stand level, e.g.: variation in species, age, site index, stems, diameter distribution, harvesting and management costs, terrain, soil.

Hinders:

- Limited access to data, and possibilities to move data from different sources and owners. This can be both technical hinders and limited rights to data.
- Technical competence with regards to service providers (providing forest inventory and management plans), and data collection and data exchange from harvester operators.
- Age and maintenance of harvesting machines and their capacity to collect and share data.
- Development and knowledge in statistical methods to provide stand-wise estimates.
- Lacking motive to invest and take to use new applications – no value-add to harvesting company

3.3 Stem

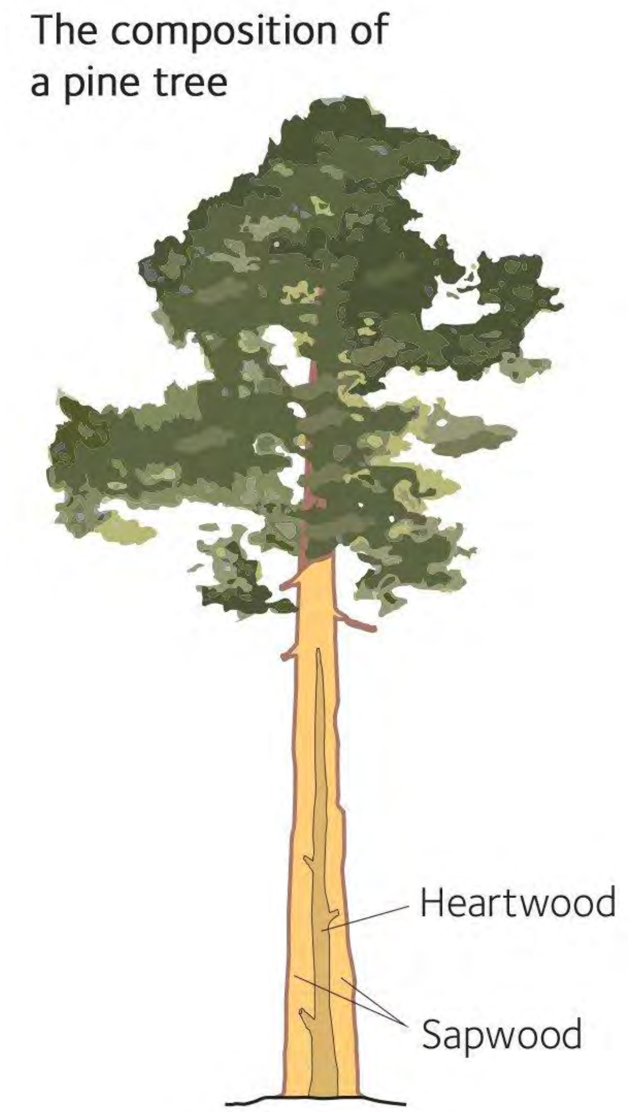


Figure 13 Picture: Origin Swedish Wood

- Stems can be described in several ways with data from Forest Stand, Drones, Synthetic with algorithms, harvesters and possible from log scanners in the future.
- From forest stand it is possible to inherit data which is possible to use to do enhancement on existing stem data from e.g. harvesters or drones or be input in algorithm that construct virtual stems.
- Drones with cameras can be used to measure enough parameters on a tree/stem so it can be reconstructed and further calculated, with help from forest stand data.
- Stems profiles from harvesters are measured above bark on every 10 cm from the root cut to the last cut at approximative 5 cm. Also are all the cuts which represents produced logs and pulpwood with an estimated grade depending on active pricelists and assortments. Also estimated damages are registered on the stem

- Synthetic stems are calculated with the help of Forest stand and eventual drone data, these two sources are complements to each other in stem constructions. One of the stem generation algorithms is Edgren Nylinder which is based on Species, Diameter, height, and form.

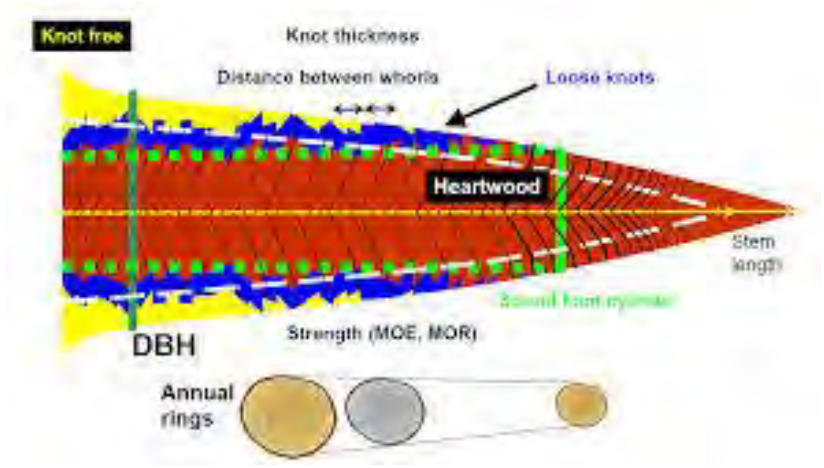


Figure 14 Picture virtual Stem (Stem profile) source Biometria, SLU

3.3.1 Physical production; suppliers, producers, and customers

- Stems are produced either from calculations or through harvesting stems
- Suppliers and producers are forest administrators for syngenetic stem calculation and harvesters such as Komatsu, Ponsse, John Deere, Rottne etc
- Customers of stem profiles are Forest Owners, Sawmills and harvesting companies.

3.3.2 Data input: sources, format, IPR, use of the data

Input from Forest Stand are in the standard Forest Standard and for example:

- Site Index
- Altitude
- Stand Age
- Diameter distribution in breast height or Average diameter (Dbh)
- Average Height

Input from drones is also in the format of Forest Stand and for example:

- Tree Height
- Diameter in breast height (Dbh)
- Crown height

Input for the harvesters to be able to operate is:

- Price list in StanForD format
- Root diameter when felling
- Running diameter from deliming knifes
- Grade or damage input from operator

Input for calculations of synthetic stem profiles examples:

- Diameter in Breast Hight Dbh
- Tree height
- Form or Crown height
- Site index
- Stand age
- Latitude
- These parameters are depending on which property to be calculated

The IPR is owned by the producer otherwise there are agreements handling this.

3.3.3 Potential and hinders for more input/more efficient data exchange

Potential:

There are possibilities to enhance the estimation on stems for potential products and values using wood properties such as heartwood diameter, knot sizes, knot angles, knot types (sound, dry etc), distance between knots (lims), fibre length /width, fibre direction, density etc. By using these parameters there can be calculation of wood characteristics such as Module of Rupture (MOR) and Module of Elasticity (MOE) for possible construction products. Also there can be estimation on heartwood products such as outdoor panel and decking products with no additives. Interior panels and furniture products can be estimated using calculation around knot structures. Also fibre properties such as fibre wall width/length can be estimated for the pulp industry. To be able to estimate these parameters on standing trees/stems can be sharp tool in how to cut, destinate and estimate price on harvested logs and can enhance the planning process both for forest owners and the sawmill/pulp industry. Enhanced possibilities to do better business a win-win situation. Block Chain technology would suit these issues well.

Hinders:

Limited possibilities in the common ERP for estimations on standing forest using wood properties, and on harvesters' algorithm to optimize the stem according to wood properties. New ways of calculations are required to enhance the results and fully find the possible products. There are several algorithms from projects that has addressed these kind of issues, Indisputable Key is one example of where algorithms been established. There are gaps in the digital chain from the harvested log to when it arrives at the industry, the origin of the log based on the cutting area is known but the harvesters' data is lost. The data of the log after it has been measured is lost when it gets sorted and stacked. At that point, we only know specie and diameter class. To connect data from harvesters and Log Scanners and the construct useful algorithms and AI processes would be a start to solve the problem, also individual identification through the whole process from harvesting to log scanning, sorting, stacking and log consumption would be a part to solve this problem.

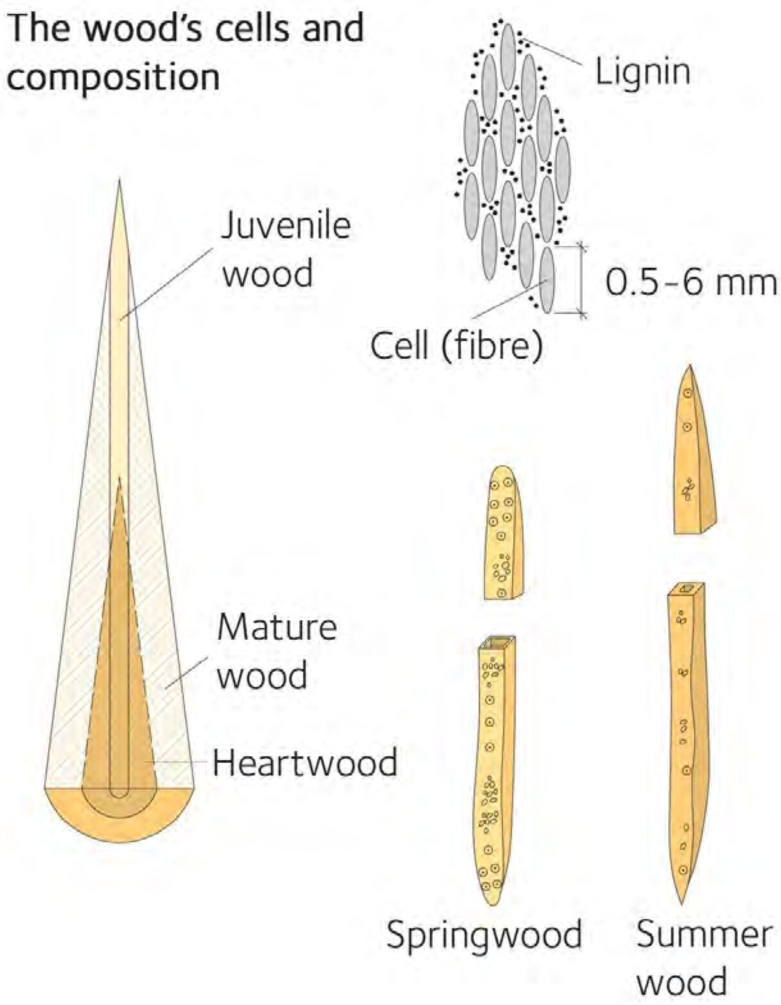


Figure 15 Illustration of different zones in a stem (Träguiden, 2012)

3.3.4 Data production: what are the sources, format, IPR

On harvested stems the data is in Stanford Format and are produced in a harvester's computer and read out to a software compatible with Stanford standard such as SilviA. Output stem wise is:

- Stem with diameter on every 10 cm up to last cut
- Every cut for log or pulpwood with grade
- Position on damages

On a synthetic stem there is the same as the above except for the logs and the damages, it is a pure stem. A synthetic stem can apply the same attributes as a StanForD stem, and it can also be in a Stanford format and be used as a calculation base.

To stems it is possible to manual calculate and estimate wood properties which can base development of different wood component such as windows or furniture example of wood properties:

- Continuous heartwood diameter
- Sound knot cylinder
- Knot angle, distance, size, and type
- Fibre angle

- Fibre properties
- Basic Density
- Module of Rupture (MOR)
- Module of Elasticy (MOE)
- etc

IPR is due to agreement between parts

The usage of stems from harvesters and in some way synthetic stems (in StanForD format) is very helpful both in estimations and feedback after silviculture treatments such as thinning example of usage:

- Calculate new pricelists for harvesters
- As input in estimations of standing forest
- Update Forest stand registers after treatments such as cut or thinning
- Misc Development

3.3.5 Data output: who are the receivers, format, IPR, potential and hinders for deliverance of more/the right data

The usage of stems from harvesters and in some way synthetic stems (in StanForD format) is very helpful both in estimations and feedback after silviculture treatments such as thinning example of usage:

- Calculate new pricelists for harvesters
- As input in estimations of standing forest
- Update Forest stand registers after treatments such as cut or thinning
- Develop new wood products
- Misc Development

Potential:

Today, data from harvesters – especially stems – are used as above. If these data could be combined in a good way with data from especially 3d X-Ray scanners at the sawmill, the stems generated in the harvesters could be «dressed» with the measured properties from the log scanner. Also, if a system to recognise logs from the harvester was possible, the reconstruction of stems would be really powerful. Further development of products etc would be very useful.

Hinders:

Technology is not there fully yet, and a standard for data output from the log scanners must be in place.

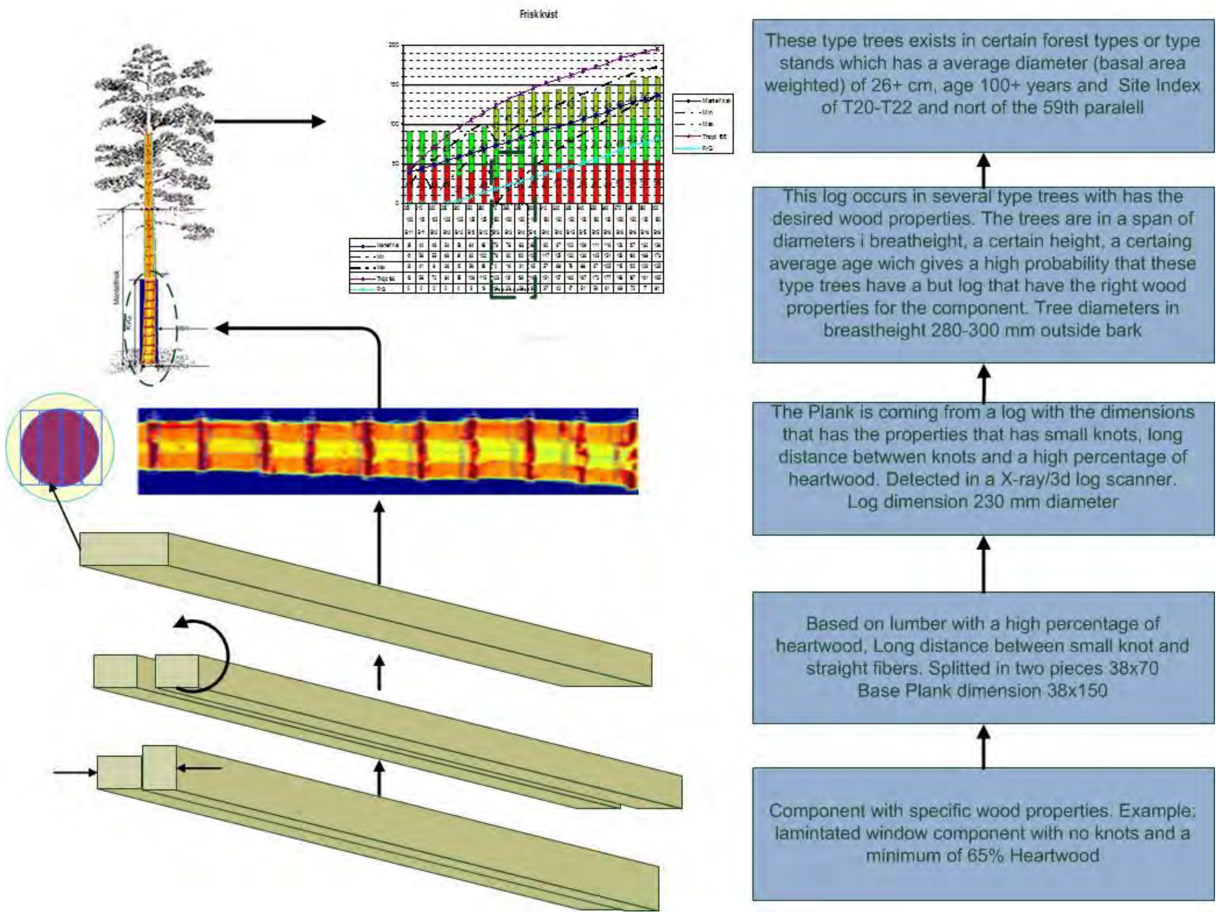


Figure 16 Picture Component Modelling with wood properties (Source: Silviforum AS)

3.4 Logs – Harvesting, Forwarding and Transport

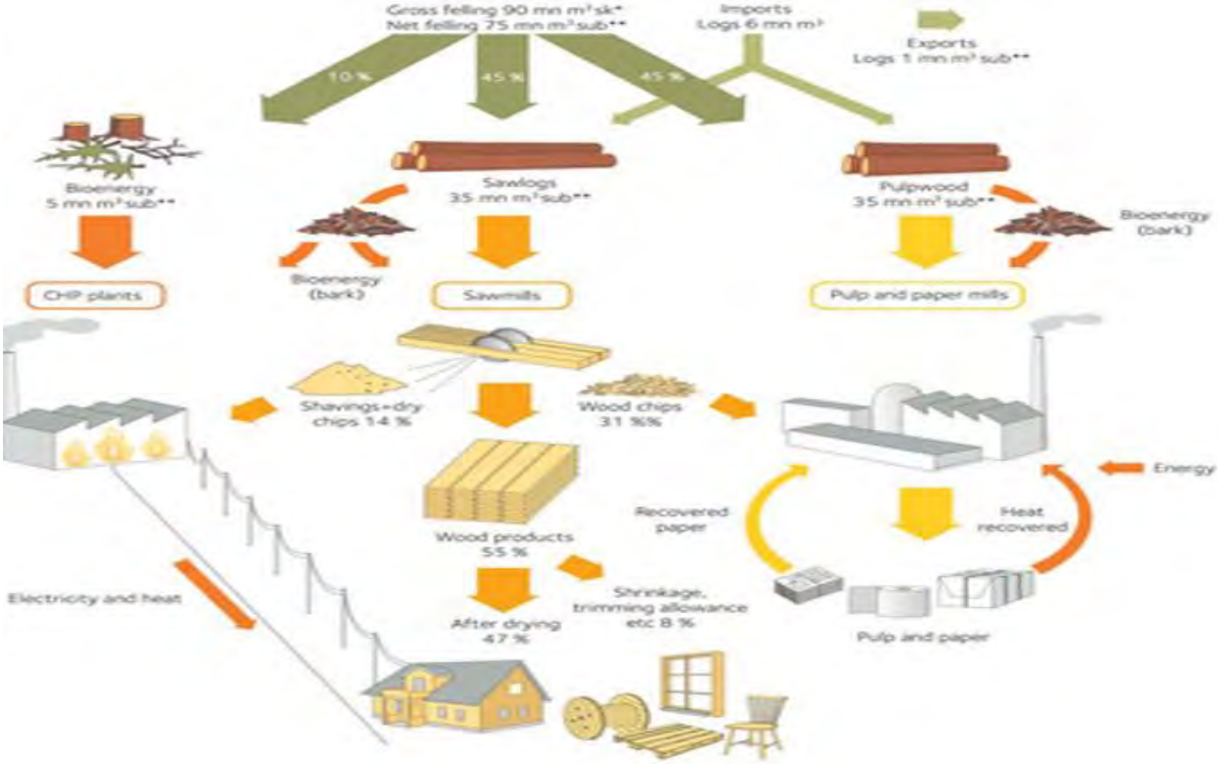


Figure 17 The value chain, numbers from Sweden (source: Swedish Wood, CGI)

3.4.1 Physical production; suppliers, producers, and customers

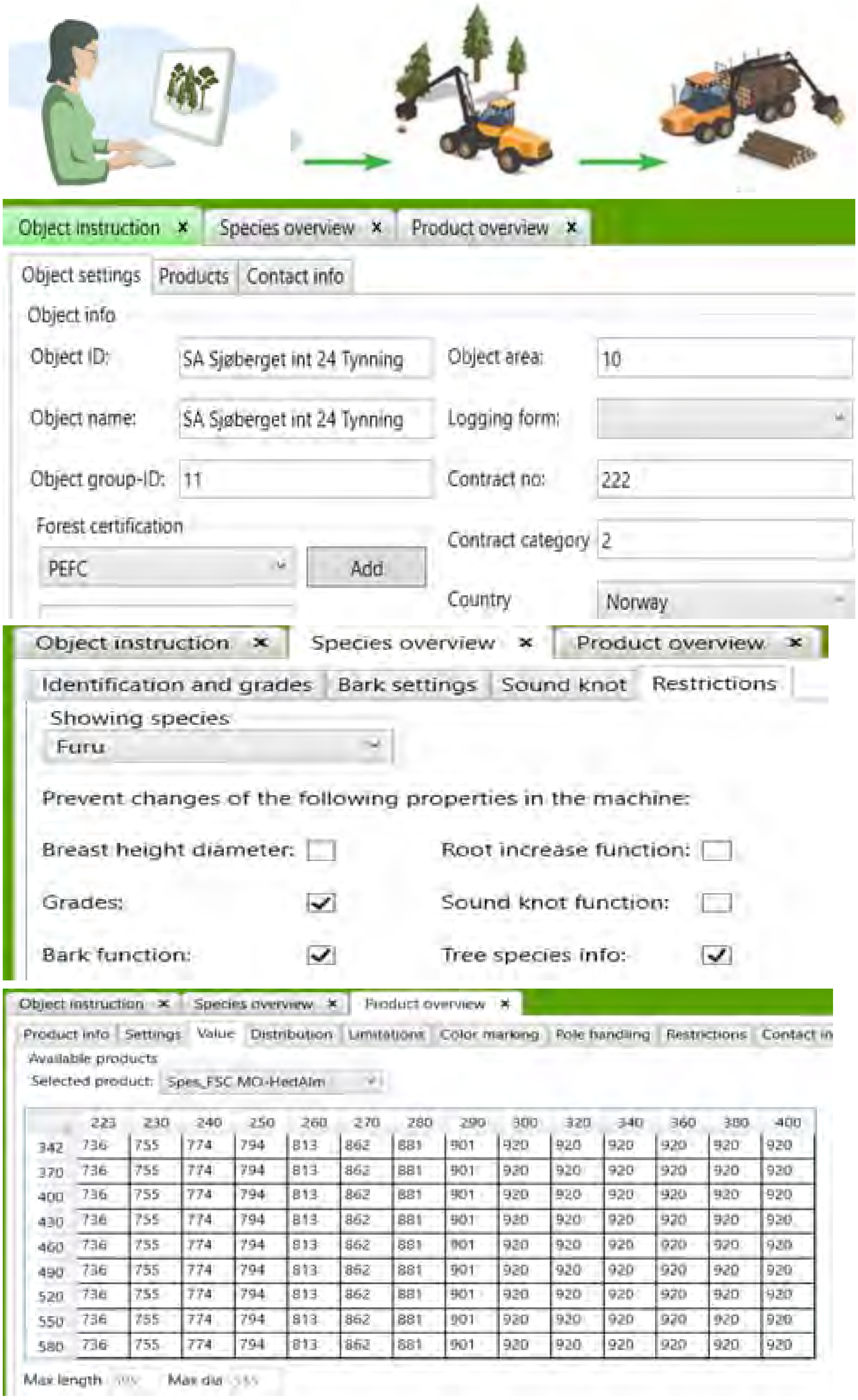
- Suppliers can be forest owners by themselves or companies buying/selling wood.
- Producers are owners of harvesters and forwarders
- Customers are the sawmills, paper and pulp mills, users for production energy and other fibre consuming industry.

3.4.2 Data input: sources, format, IPR, use of the data

- The forest industry is making long terms orders of different products – species, characteristics converted to class of quality, length, diameter, distribution of length and diameter. Out of these parameters the industry makes bucking instruction
- StanForD is an abbreviation for Standard for Forest machine Data and Communication. Today StanForD is used in several countries and constitutes a de-facto standard even though it has not been afforded any official status. The application of the standard extends to all types of data communications with forest machines.

StanForD 2010 introduces a concept for giving identities for machines, objects, stems, logs, etc. with Keys and User Ids. A Key is set automatically in the machine (usually a consecutive number) and a User Id is allocated by, for example, the logging organisation. The system makes it theoretically possible to isolate each log that is produced globally and provides traceability for each modification of the settings in the machine. www.skogforsk.se/english/projects/stanford

- IPR is regulated in contracts between owner of forest machines and buyer of wood.



	223	230	240	250	260	270	280	290	300	320	340	360	380	400
342	736	755	774	794	813	862	881	901	920	920	920	920	920	920
370	736	755	774	794	813	862	881	901	920	920	920	920	920	920
400	736	755	774	794	813	862	881	901	920	920	920	920	920	920
430	736	755	774	794	813	862	881	901	920	920	920	920	920	920
460	736	755	774	794	813	862	881	901	920	920	920	920	920	920
490	736	755	774	794	813	862	881	901	920	920	920	920	920	920
520	736	755	774	794	813	862	881	901	920	920	920	920	920	920
550	736	755	774	794	813	862	881	901	920	920	920	920	920	920
580	736	755	774	794	813	862	881	901	920	920	920	920	920	920

Figure 18 Example of a bucking instruction (Source; CGI)

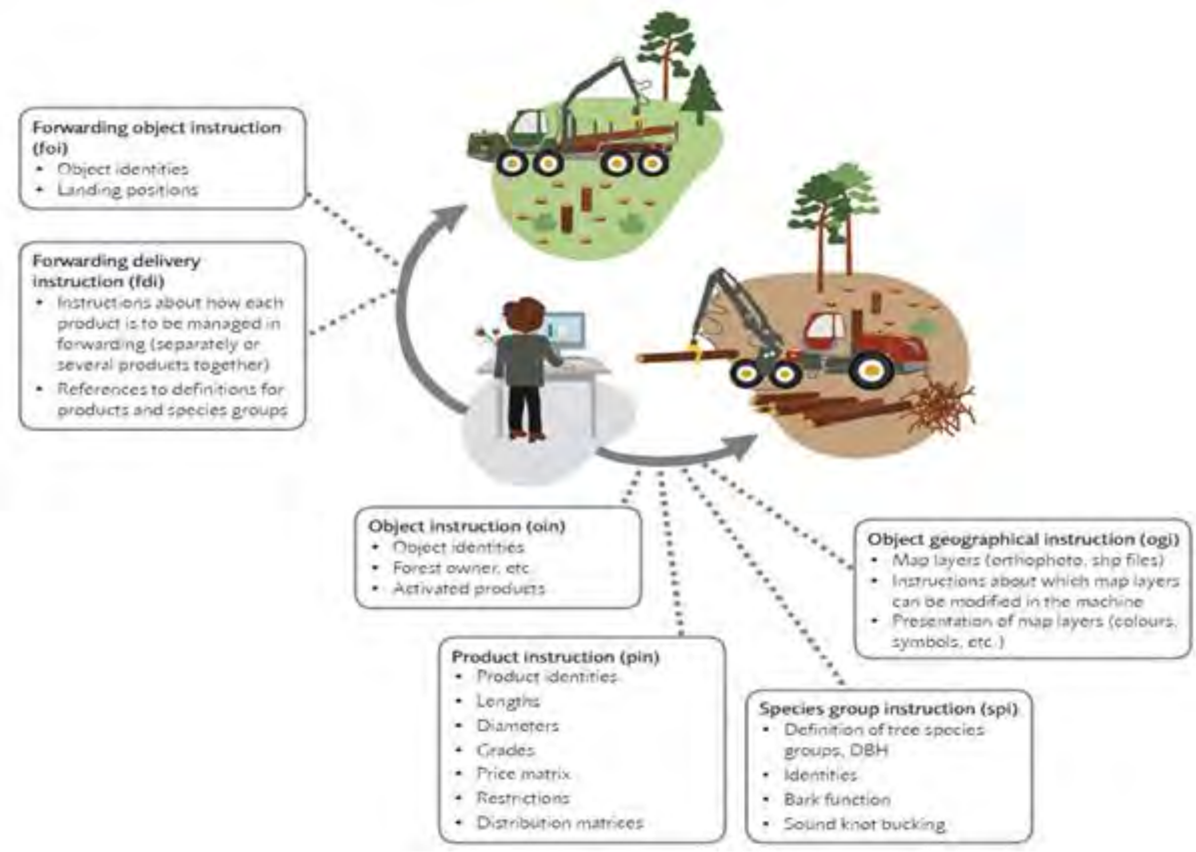


Figure 19 Diagram showing the various messages in StanForD 2010 that are used for controlling harvesters and forwarders (source: Skogforsk)

3.4.3 Potential and hinders for more input/more efficient data exchange

Dataflow Map

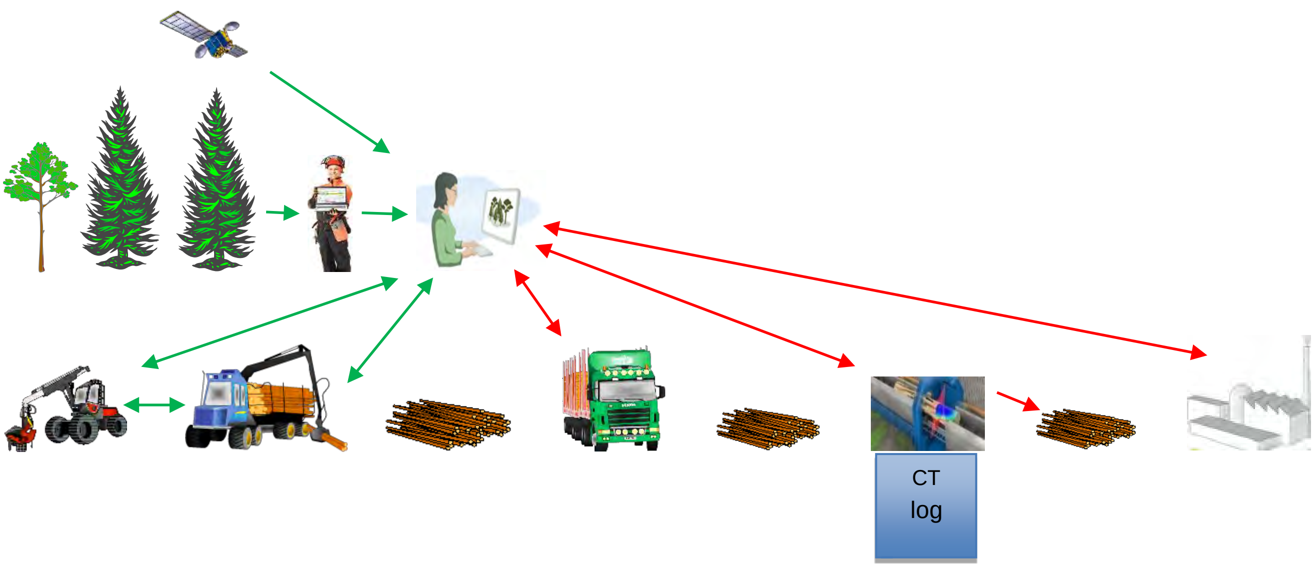
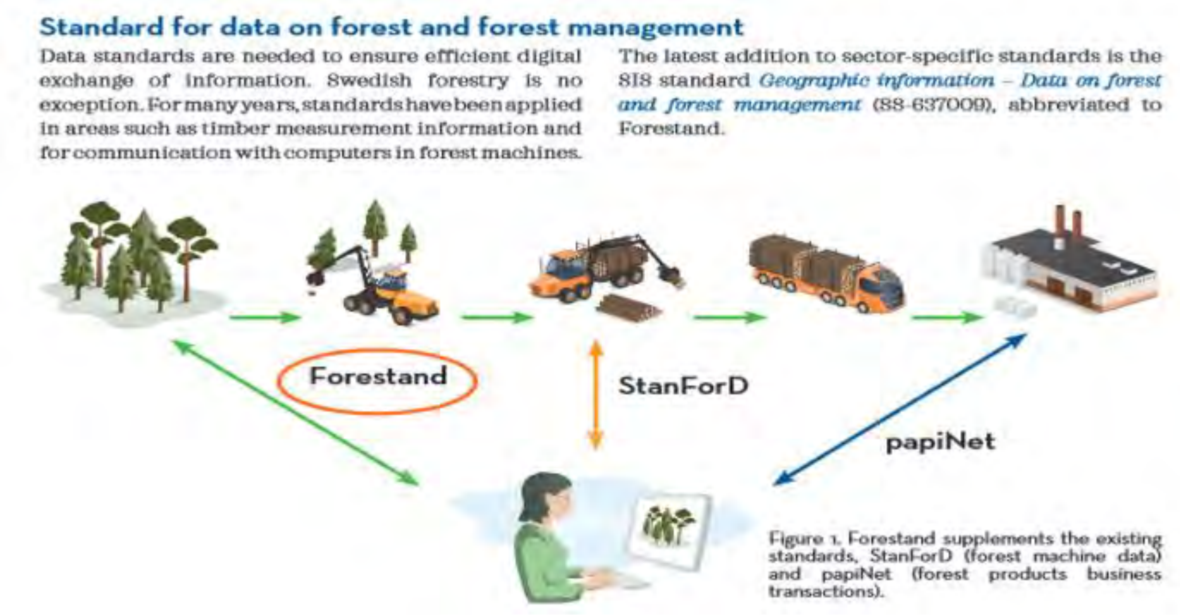


Figure 20 The current data flow. Green arrows are communication by ForeStand and StandForD. Red arrows are not standardised data



Potential:
Single tree and log information from remotely sensed data.
Detailed information on log level from harvester data (StanForD).
Better and more updated bucking instructions adapted to stand conditions.

Hinders:
Limited access to data, and possibilities to move data from different sources and owners. This can be both technical hinders and limited rights to data.
Technical competence with regards to service providers (providing forest inventory and management plans), and data collection and data exchange from harvester operators.
Age and maintenance of harvesting machines and their capacity to collect and share data.
Knowledge in the value-chain regarding what data and information can be provided from the forest.
Knowledge in construction and implementation of bucking instructions. This applies for buyer, seller, and operator.
Development and knowledge in statistical methods to provide steam and log-wise estimates.

3.4.4 Data production: what are the sources, format, IPR

- The software in the forest machine computer generates a lot of data and helps the operator cut the wood that industrial customers then process into sawn timber products, pulp, or energy. Most of the data flows to, from and between forest machines are managed according to StanForD, the forestry sector’s own standard, which supports operational control, production reporting, quality assurance, and operational monitoring.
- With StanForD 2010, the forestry sector now has a standard that is adapted to modern IT solutions and information needs, allowing detailed and flexible control, and monitoring of harvester and forwarder.
- IPR is regulated in contracts between owner of forest machines and buyer of wood and others.

3.4.5 Data output: who are the receivers, format, IPR, potential and hinders for deliverance of more/the right data

- Receivers of data is industry, forest association, transport organization, public authority
- The new format and structure in StanForD 2010 give the forestry sector a very powerful tool for close control and in-depth analysis of logging. StanForD uses the well-established XML format
- Production reporting from the harvester is per log, so production can be reported and analysed according to very specific requests from, for example, the logging organisation or industrial customer. In the future, the structure will also allow every log to be reported online. The detailed harvester information can also be used as a basis for forecasts of forest fuel extraction and calculation of such product properties as density, heartwood content and knot structure. StanForD 2010 also introduces a message for reporting geographical information.
- Operational monitoring is done by registering each individual work process for the operator and machine separately. The cause of various types of disruption can be registered. The system is independent of the logging object on which the machine is operating at the time. One advantage of separating operational monitoring from the object is that, for example, time gaps are avoided when a machine is moved from one object to another and then back again. Relevant key performance indicators can later be calculated, and different machine systems and logging teams can be compared, by analysing production and standstill in different time series.
- To ensure that the harvester and forwarder systems for measuring length, diameter and weight are accurate, there are procedures for assuring measurement quality. For the harvester measurement, quality assurance includes making random control measurements of sample of stems and comparing the results with the machine data. An independent auditor making regular follow-ups can also be linked into the system. For the forwarder, quality assurance includes checking any load-weighing equip-ment. The StanForD 2010 messages for harvesting and forwarding quality assurance also include calibration data for the measuring systems.

Production reporting

StanForD 2010 is based on the principle that data is registered in the machine computer at high resolution, and then aggregated or further processed in the companies' own data management systems. The main option for production reporting from harvesters is therefore the hpr message where production is reported for each individual log. For the forwarder, every single load or part-load (when several products are coloaded) is reported as the smallest unit.

Harvested production - hpr

In production reporting for the harvester, detailed information is stored about every single processed log and stem in a structure similar to the older pri file type. All length and diameter measure-ments along a stem, and the quality, can be sent in the same way as an stm file. Every log is given a unique identity so that production from several machines on the same object can be reported in the same message, while retaining the possibility to trace every log to a certain stem and machine.

Multi-tree handled stems can also be reported in the same structure because every bunch (and every stem in the bunch) is given its own identity (StemBunchKey). Even unclassed logs are stored in the message, although with a smaller number of variables.

Forwarded production - fpr

Production reporting for the forwarder comprises a description of what has been forwarded (number of logs/bunches, volume, weight) and where every load (or part-load) has been unloaded. The production reporting also includes time stamps (start/stop) for each load and references to operator and logging object. The message also allows the reporting of current status, e.g. that forwarding has been completed for all or parts of the object.

Object geographical report - ogr

The ogr is largely similar to the object geographical instruction (ogi). In this message, information is stored about which map layer has been modified in the machine, how the map layer has changed, and who made the change.

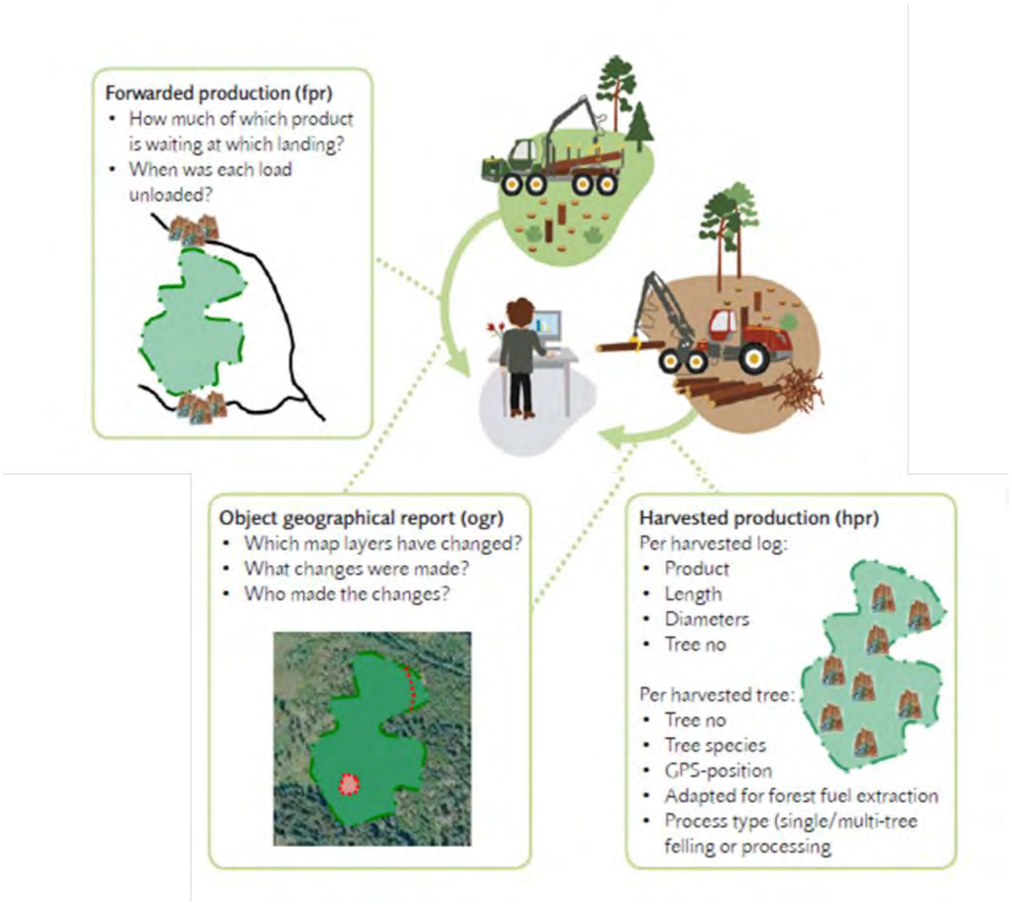
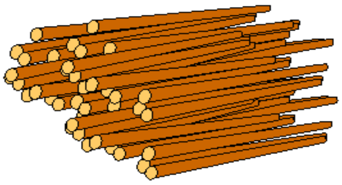


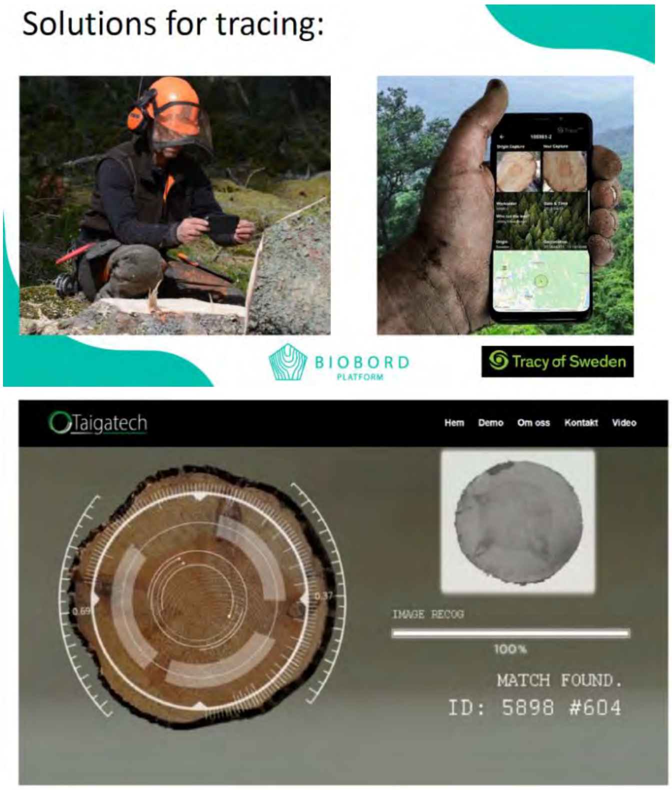
Figure 21 Picture from StanForD (Skogforsk)

3.5 Bundle

3.5.1 Physical production; suppliers, producers, and customers



- Today, there is not technology in place to identify single logs so we cannot trace it back to the harvested production, the only thing is that we can trace on the log is the forest stand when it arrives at the industry, the reason is «bundling»:
- The harvester produces and sort logs of the same assortment/quality in smaller log piles to facilitate and make forwarding of logs easier.
- The forwarder is loading the logs from the same assortment when forwarding the logs to the landing, the logs get mixed during loading.
- When the forwarder is unloading and piling the logs in bigger log piles at the landing, the logs get even more mixed.
- When the timber truck is loading for transportation to the industry it gets mixed again.
- When unloading at mill site the logs get mixed again.
- When the log scaling and sorting process start, logs from several cutting sites/suppliers and the newly scaled logs are mixed with earlier scaled and sorted logs.
- When a log is on its way to the sawing process its origin is long lost
- This is the same for other assortments of logs and pulpwood.
- Some pulpwood is getting sorted on rough parameters such as altitude of origin, parallel, freshness (cutting date/week) this is hardly handled by the logistic processes.
- Summarize: possibilities to trace = lack of competence in daily production.



Source: www.tracyofsweden.se and www.taigatech.se (tracyofsweden.com)

3.6 Sawn goods / sawn timber (PP6 with help from PP8)

3.6.1 Physical production; suppliers, producers, and customers

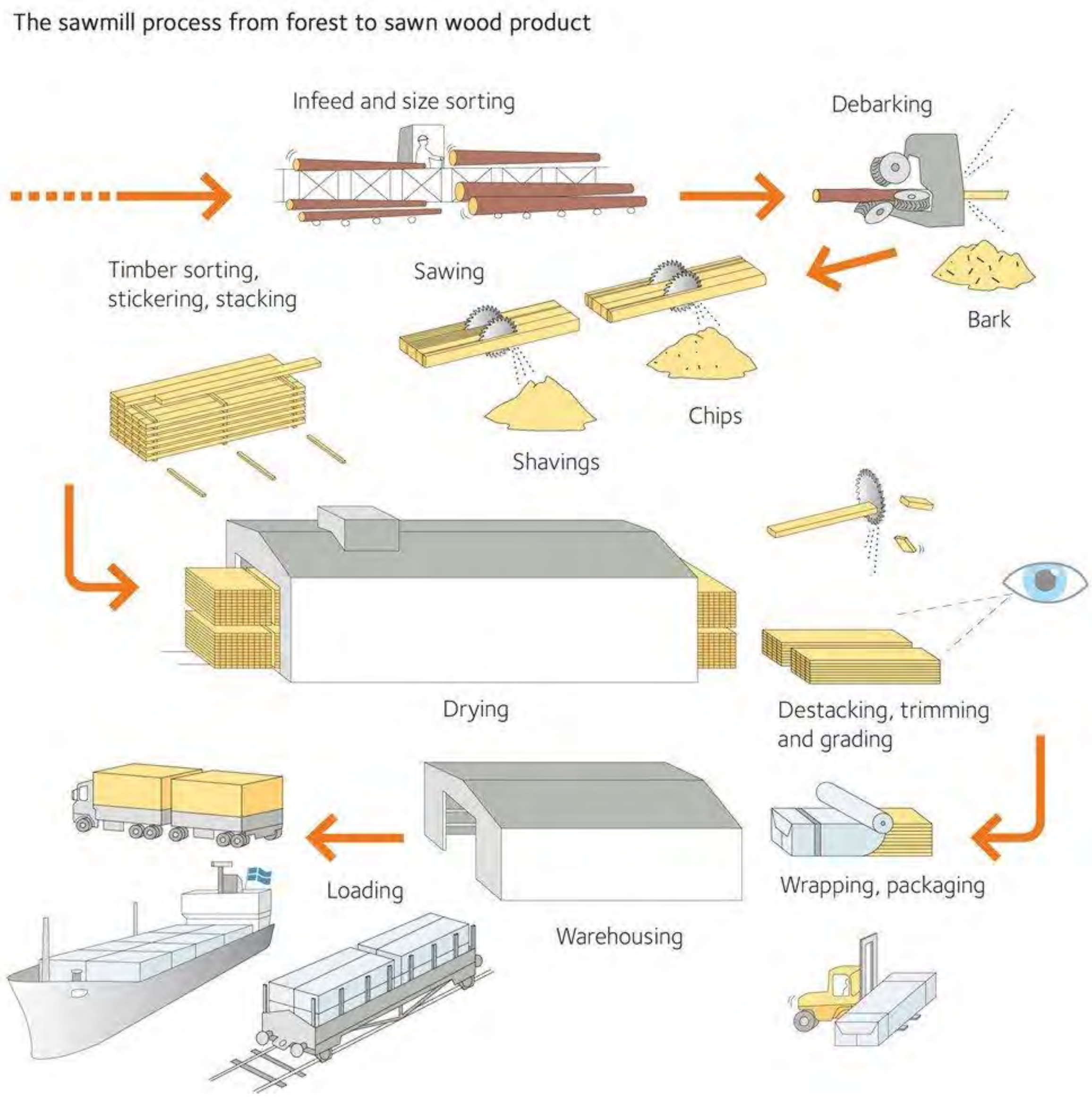


Figure 22 Picture Swedish Wood

- Sawing logs to different sawn goods using different sawn patterns depending on market, wood species, log diameter & length and estimated or measured wood properties.
- Mostly are the logs sorted in different diameter classes for each species. Sawtimber yielding sixth quality will not go to the sawmill but will be delivered as pulp wood. Scaling and grading done by measuring teams. The measurement/scaling & grading is the last point of change in ownership between forest owner and industry. Change of ownership can also be done earlier (e.g., standing forest for sale). Suppliers can be forest owners by themselves or companies buying/selling wood.

- Logs are scaled by using diameter and length and a quality based on market price list and the forest owners are being paid for their supplied logs, rejects are being paid by using current pulp wood prices.
- Mixing logs between measurement and sawing = loss of information since logs are not traceable.
- Debarking between the measurement and sawing = diameter without bark can vary between calculated during measuring and actual after debarking.
- Parallel at the log scanning logs are being sorted in to saw classes based on specie, diameter and sometimes length and if possible, wood properties depending on the log scaling equipment, and current saw pattern for that saw class. By using X-ray technologies, the wood properties such as, knot structures, heartwood diameter, density, fibre angles etc can be measured and be powerful parameters for matching logs to how to be produced and the final product / order. Logs are then stored in log piles based on established log classes and the sorted logs inventory is updated with current updated stock.

Figure 23 Source: LOAB/Microtec

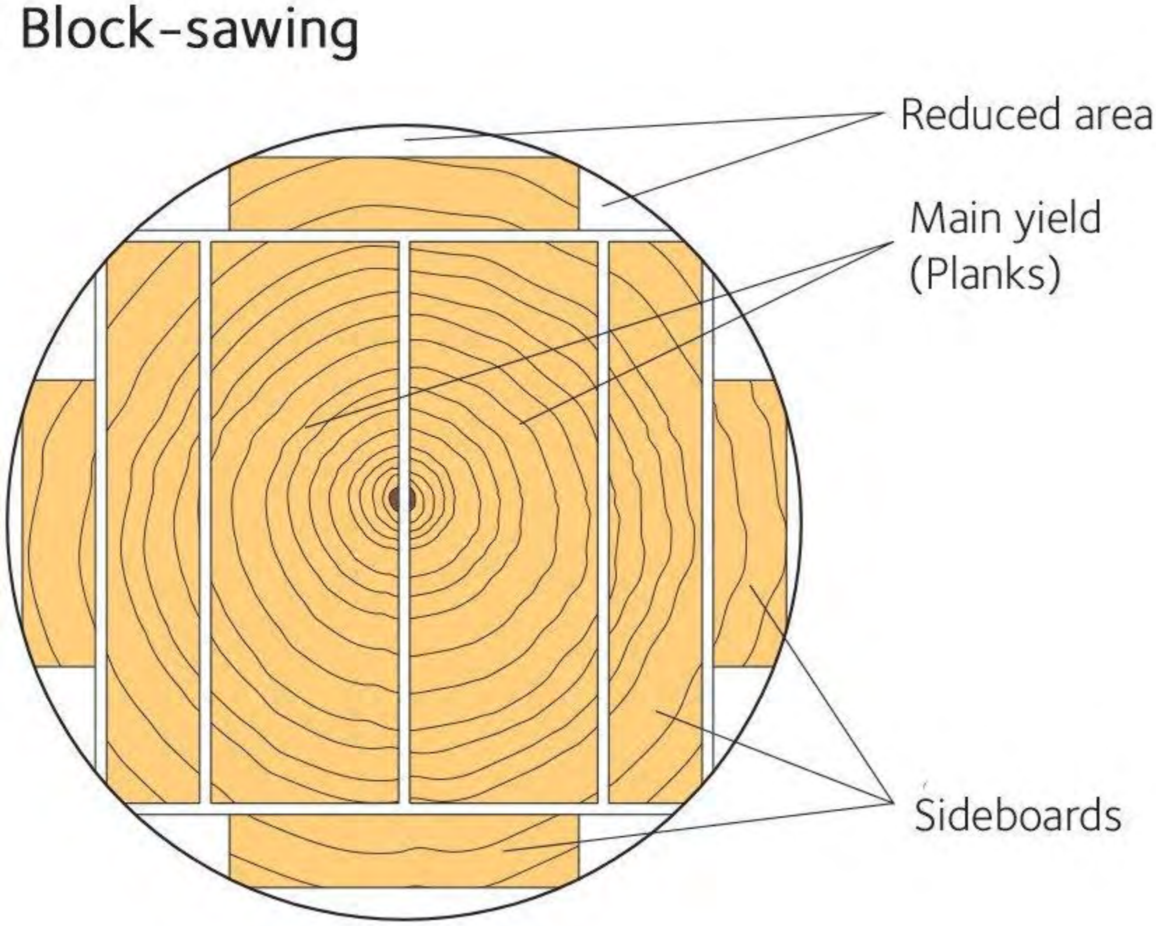


Figure 24 Source: Swedish wood

Next operation is the actual saw operation which is based on the log class and its saw pattern, the consumed logs is decreasing the inventory on stored logs in current log class. The logs are being debarked and are measured by a log scanner which is optimizing the logs position into the saw, when passing the scanner, the sorted logs inventory is consumed and updated. The output is centre planks, sideboards, cellulose chips, and sawdust. At the saw process there can be several scanners to support the sawing process, also other sensors such as saw precision, heart wood detection, fibre angle detectors etc.

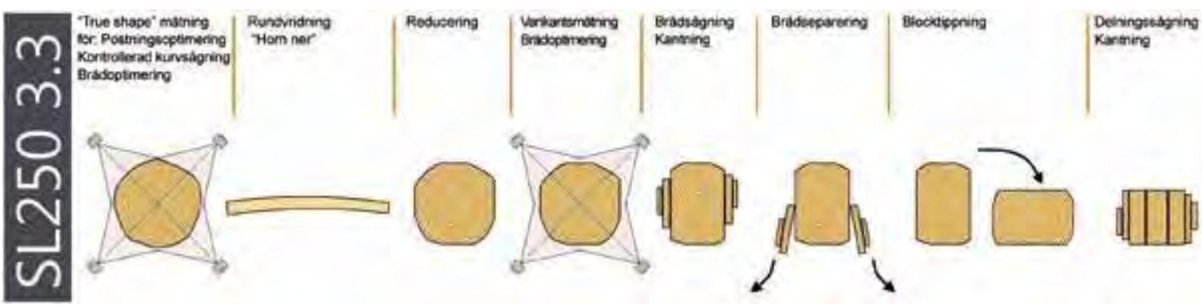


Figure 25 Picture: Hesaw

After the saw process there is a first sorting which can include a Scanner which can sort the sawn products based on matching on product specification and demands on final moist content so the kiln drying process can be optimised. Several sawmills have no scanner supporting this process, so the sawn products go directly to stacking before kiln drying. Inventory before kiln drying is updated.

Figure 26 Raw lumber LTU Luleå Technical University

Kiln Drying is planned from the order situation and the stock on raw lumber. Depending on the end product and the clients' specification on the product different drying program is used to establish the right moisture content on the product. There are Progressive drying systems or compartment system available. There are sensors to measure moisture in the air flow (wet, dry) and also energy and the moisture content in the lumber. This process will decrease the stock on raw lumber and update the stock on dry not finalized lumber.

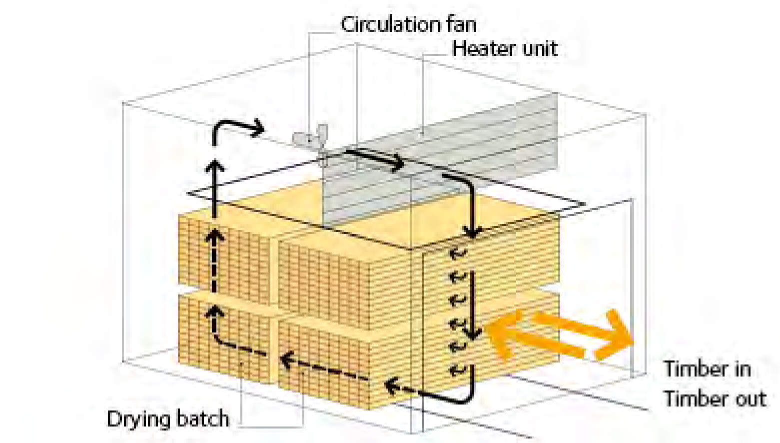


Figure 27 Compartment Kiln, Swedish wood

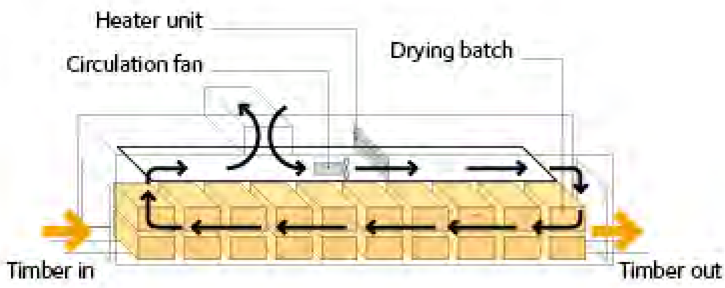


Figure 28 Progressive Kiln, Swedish wood

Destacking, Grading and trimming uses the dried lumber stacks, consuming from the ungraded stock and perform grading of the lumber. This is performed with uniform dimensions and sometimes based on wood properties. After destacking there are one or several scanners which optimises cut and automatically sorting the lumber in the right grade or/and order based on the grades established properties. In a combination grading /plaining mill there are also a plaining process before grading, the lumber is packed in packages ready to be delivered. This operation will update the stock and orders on lumber ready to be shipped or be transferred to other product processes such as plaining or gluing for example.

Figure 29 SCA and Skog Supply

Figure 30 Source: From and Martinssons

Internal Logistics Measured Logs and Produced Lumber are being visualized through MES and/or ERP Systems, order information is also if available visible, this establishes that forklifts and has available information in truck terminals so they can manage the total stock and do the required deliveries based on orders.

Figure 31 Sawinfo Datapolarna

3.6.2 Data input: sources, format, IPR, use of the data

- Results from 3D (or 2D) measuring frame are controlling the sawn patterns that are allowed
- 2D: Length (in mm) and diameter (each 1-10 cm) in 1/10 mm

- Format differs between different producers of measuring frame and different producers of saws. But can be delivered to different platforms (e.g. http://digiwood.se/) by API-format.

  Log Scanners /Log Scaling 2D/3D/X-Ray are measuring the logs geometry, grade, or properties (X-Ray) such as

  - Log Geometry
  - Bark
  - Density
  - Heartwood
  - Knot structures
  - Bends
  - Damages
  - Fibre properties
  - Moisture
  - Estimated Grade
  - Etc

  And attach the data to the delivery id / forest supplier possible to combine with forest data. The current saw pattern and log class is attached.

  - Log Scanners 2D/3D/X-Ray for optimize saw position due to geometric properties and bends, collecting the same data as the Log Scaling Process except Bark. There can be several scanners through the whole saw line. There are test going on to use the data/picture from the log scaling scanner and recognize and match it to the Log Scanner for optimizing the saw process.
  - Log position measuring devices, block size and block position (by order and Saw pattern)
  - Saw HMI, production per hour, stop, reason for stop, timestamp (by order and Saw pattern)
  - Board Scanners on raw boards knot structure, fibre angles, damages, heartwood, adjusted cuts etc (Not on all sawmills) (by order and Saw pattern)
  - Drying information, such as energy consumption, moist content, time in, time out etc (By order, lumber dimensions)
  - Board Scanners grading plant, knot structure, assigned grade, fibre angles, damages, heartwood, adjusted cuts etc, production per hour, stop, reason for stop, timestamp (By order, lumber dimensions), stops.
  - Order and production data is normally collected by ERP and MES functions, either manually from the Machine HMI or automatically.
  - Format differs between different producers of measuring frame and different producers of saws. But can be delivered to different platforms (e.g. http://digiwood.se/) by digiwood API-format/integration platform.
  - All IPR belongs to sawmill.
  - Sawmill use data. Probably are the also in use by the suppliers of saw-equipment

3.6.3 Potential and hinders for more input/more efficient data exchange

- Currently, it is not possible to trace data from forest to the sawing equipment due to mixing on the forwarder, in the stack at the roadside, on the trucks, in the stack at the industry, in the measuring/sorting and in new stacks before sawing.
- No standard for formats = market for platforms/indexators like DigiWood.
- No tracing inside the sawmill either but can be traced some stages with use of modelling (like DigiWood)

Potential:
To certify the origin of the delivered logs and have a possibility to trace logs and keep individual information about the log through the process. Connect forest data and log information through the Stanford standard with the data from log scanners, especially the first log scanner and then establish a better estimation for standing forest and forest planning, which could give the sawmill a better production and order planning and enhance sales and productivity. The Digiwood platform with time stamp Index is a great possibility to get a start on trace boards within the sawmill,

Hinders:
Today there are not possible to have traceability individual on logs from the forest to the sawmill. There are possibilities to trace on forest stand level by using scale ticket information and forest stand ID. There are no standards for collection of data from log and board scanners that could enhance both traceability and algorithms. Not all sawmills using MES or enhanced ERP functions to collect production data in the process.

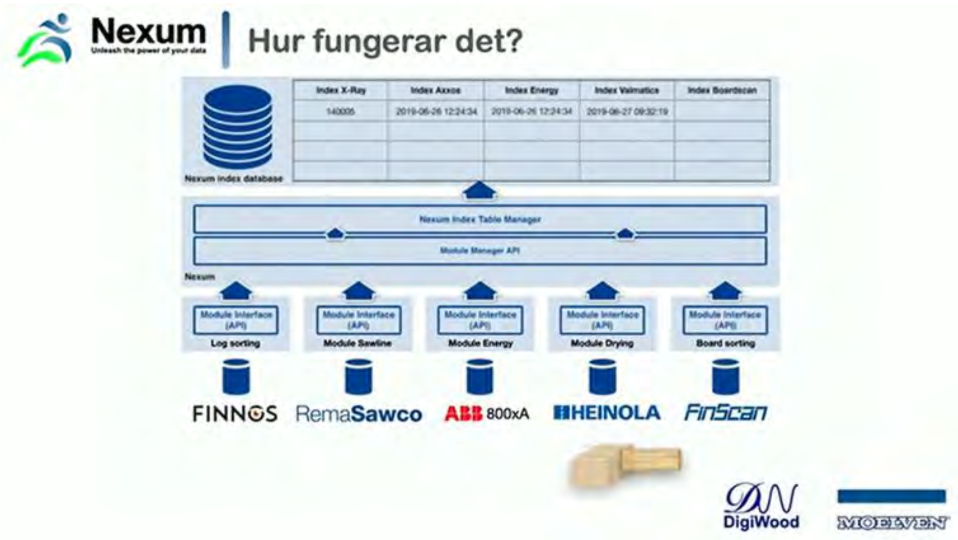


Figure: DigiWood/Moelven

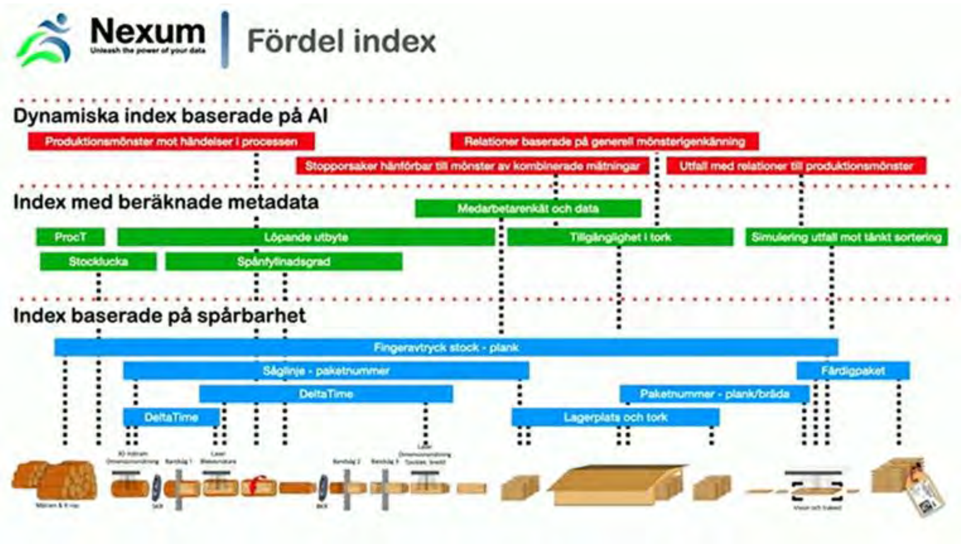


Figure 32 Source: DigiWood/Moelven

3.6.4 Data production: what are the sources, format, IPR

- Massive production of data from the machines within the sawmill often is the machine with like an isolated island in the production chain and data is limited used. Some sawmills are building in ERP/MES function to put the Sawmill "Online" and collect data which is not fully used. Potentials for Digitalisation and use of AI is possible. There is not any standard for data Collection and use within the sawmill production except for deliveries of products using papiNET, which is also used for logs delivered.
- Today data use only within the sawmill and not available neither for forest owner nor end market

3.6.5 Data output: who are the receivers, format, IPR, potential and hinders for deliverance of more/the right data

- Sawmills produce a lot of data in different formats. They use very little by themselves and keep the data for themselves.
- Due to lack of traceability data cannot be linked to forest owners.
- Some proposals for tracing are available from the project INDISPUTABLE KEY https://cordis.europa.eu/project/id/034732
- New solutions are also available using photos of annual rings from trees (from harvester to sawmill)

Potential:
To have a label on all delivered products of its origin so the customer can see that the product is produced with sound methods. To give the sawmill a better way of buying logs from the forest owner by establish new algorithms (AI, Digitalisation) so the whole process from the buying and planning process to the sales of products are better connected and gives a market driven operation.

Hinders:
Not using current available data due to standard issues, no MES functions in place, no individual identification on logs. Indexation from Digiwood is not established. Need new and different competence in the organisation.

3.7 Stack

3.7.1 Physical production; suppliers, producers, and customers

- After sawing the sawn goods are sorted. Sixth quality go to the chipper. Sawn goods with same width and height go to the same stack. Sometimes they are also sorted by length. The sawn goods are then dried in stacks. Then sorted again in different qualities. Stacked again in stacks with similar quality/qualities (and lengths).
- All internal processes in the sawmill.
- Stacks of dried sawn goods are the end product for sawmill. Mostly sold to planing or to producers of CLT, glulam, doors, windows and/or furniture.

3.7.2 Data input: sources, format, IPR, use of the data

- Control measuring is done by scanners, cameras, lasers etc and gives data for dimensions and quality.
- Format differs between the different producers but can be collected by tools like DigiWood.
- All IPR and data is internal for the sawmill. Probably data are also available for the companies producing some of the equipment.

3.7.3 Potential and hinders for more input/more efficient data exchange

- Products from different sources are mixed during the process. No tracing.
- Tracing could be available using year rings and later in the process by barcode or similar.

3.7.4 Data production: what are the sources, format, IPR

See above and for the production of sawn goods.

3.7.5 Data output: who are the receivers, format, IPR, potential and hinders for deliverance of more/the right data

Data is only for the sawmill and are not available either for suppliers nor for customers others than dimension and quality (e.g. strength = T21).

3.8 End user product

3.8.1 Physical production; suppliers, producers, and customers

- Can be hard to define who are the real customers, but here we choose those producing products (planed timber, CLT, glulam, doors, windows and/or furniture) out of it. Other producers can combine these in new products (bridges, modules etc.) before it meets the consumers.
- Planing gives end product, but planed wood also goes into different industrial productions.
- Most end products can be described with a BIM-model (3D model). At this stage, the data starts coming from the opposite position – from the architects and designers.
- New challenges occur since the DAC (data assisted constructions – BIM models) can be used to DAP (data assisted production or Computer-aided manufacturing CAM) – but the production equipment does not understand the format from DAC.

3.8.2 Data input: sources, format, IPR, use of the data

- BIM models are IFC-files (Industry Foundation Classes) based on the standard ISO 16739
- Different programs for designers and architects seem to have different formats for IFC-files and this are a challenge for use in automated production.
- There are multiple standards linked to IFC like Information Delivery Manual (IDM), BIM Collaboration Format (BCF), Information Delivery Specification (IDS) and standardizing interfaces to access data - open Connected Data Environments Interfaces (family of APIs)

3.8.3 Potential and hinders for more input/more efficient data exchange

- Lack of universal standards hinder use of data from BIM in production. The planning phase becomes more efficient and precise, and these data will be available for purchasing and later use of the building / the product – but can be hard to use for production of CLT, elements, pre-cut etc.

3.8.4 Data production: what are the sources, format, IPR

See above.

3.8.5 Data output: who are the receivers, format, IPR, potential and hinders for deliverance of more/the right data

See illustration. Data here mostly comes from the market (customers and their designers):

Picture from Internal report for Trehus Innlandet/Tretorget.

4. Conclusions and recommendations

4.1 Technological opportunities

Forestry has become a high-tech industry, where technology is used and data produced throughout the value chain; from inventory based on laser scanning to generate information on the standing trees in the forest stands, via the harvesters that collect information about the timber they cut, to x-ray scanning of the timber at the sawmill and various sensors that measure and control the end product.

However, information about forest resources is shown at stand level as cumulative and average attributes, instead of individual data of single trees. Thus, lot of quality information is lost into the big timber mass. In addition, the data is lost several times through the value chain, and there is no possibility to trace the end product back to a specific tree in the forest. This loss of data occurs mainly by stacking and reloading the timber. The first time this happens is already in the forest, when the harvester stacks the timber, and the forwarder transports it. Thus, when the timber arrives the sawmill, there is no longer any information about each individual log, and they must be measured again – and this information is also lost during processing and restacking. Another challenge for the data flow is the lack of a common data format throughout the value chain; when the data changes format, it is no longer readable for the receiver and the information is lost.

By standardising the data format, the transfer of data is made much easier. This is partly done by the StanForD standard, but this does not last throughout the value chain, and still, the data cannot be traced to a specific log – only to a batch of timber. The data from the harvesters are today used to update forestry management plans, and we see an opportunity to increase this use of the data, it would e.g. be of interest to study whether this data can be used to calibrate LIDAR data for forest inventory.

4.2 Challenges to work on

We have discovered several issues to work further on. Many of them are not feasible in this project but may be relevant for later studies and projects.

4.2.1 Forest inventory

- Data on individual tree level
  - Better forest inventory. What is needed to achieve this, and what is already out there?
  - How to store and utilise data from single tree detection based on multiple sources (terrestrial laser scanning, airborne laser scanning, etc.)
  - How can we make single tree information add enough value to cover the costs? What are the costs? What is the experience from companies/forest owners which have invested in single tree data?
  - Information (location, quality) about minor and rare / special timber qualities
- Combination of data
  - Combination of ground level measurements with aerial photography. New applications built upon combined data
- Use of data from harvesters
  - Can data from harvesters be used to calibrate LIDAR-data and other remote sensing data?
  - Can this improve the forest management plans?
- Future management plans
  - Multipurpose and stand free planning or traditional stand-wise?
  - Resource mapping and management advice – a public service or private property/investment?

4.2.2 Management planning

- Planning for forest owners
  - Simulations of thinning options / programs showing management of each single tree
  - Calculations of economic effects of various treatments
- Utilising forest inventory data in harvesting

- What data is needed for this? How could the data be stored, and should they be open access?
- Automatic harvest planning
    - What data is needed for this?
    - How to estimate the value?
    - Other goals?

4.2.3 Data management in industry/sawmill

- Connecting data from sawmill to data from harvesting
    - How to trace the data?
    - How can we improve the harvesting/deliver more of the correct type of raw material to the sawmill?

4.2.4 Other issues

- Answering to special demand on certain types of trees
- New technology adaption
    - How to show the value of data utilisation?
- Tracking of logs through the value chain
    - Can fingerprint technology (image recognition/AI) make it possible to follow each log from the forest and through the sawmill?
- Standardisation of data and open-source access to databank
    - How to pass on StanForD into the internal sawmill dataflow, provide feedback mechanisms, and optimise simulations?

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