Knowledge and Technologies for Effective Wood Procurement

Deliverable 2.4

Business tools for improved stand treatment and wood mobilization services

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Table of Contents

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Publishable summary

The report presents results with a particular focus on IT-tools, internet-based applications and other interfaces that enable both the requisition and marketing of silvicultural and harvesting services in three Nordic countries. Research has shown that considerable efficiency differences can exist between apparently similar supply chains, therefore, the task 2.4 focused on selected business processes between forest administrators, service providers, and local Forest Based Industries in Denmark, Finland and Norway.

The Finnish case study showed that the presented model applying an online IT platform required less process interactions than the traditional direct inquiry alternative. With the presented results of the "Online IT platform" being more efficient, the current design of the Finnish tool can be considered an optimal design of a service tool when compared to a common traditional offer inquiry. Through the transfer of the presented design and best-practices, other regions could equally benefit from the efficiency improvement potential offered through the adaptation of such technology and service.

The Norwegian case study provided generalized business process maps for purchase and production planning in a Norwegian farm forestry context. A recent innovation from forest owner associations (FOAs) includes the offer of long-term forest management agreements. For the FOA such agreements ultimately provide the potential to increase planning horizons and the production cover time of the FOA contract bank. The innovation also offers the potential to reduce purchase lead times for initial contact with the forest owner. This can be particularly useful when periodic deviations in demand, production or operating conditions require rapid re-balancing of the contract bank.

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1 Introduction

Most recently, Müller et al. (2019) presented the opportunities if Industry 4.0 and digitalization in wood supply, the authors have shown that that value of Industry 4.0 mainly lies in the interconnection of process steps along the value chain. Digitalization is already transforming the forest industry, with new technologies assisting to better know the forests through the help of modern data and modern technology taking the wood supply into a new era (Metsä Group 2019a,b,c).

According to Haapaniemi et al. (2011), documenting business processes is a first step in the development of an Information System. Furthermore, research has shown that considerable efficiency differences can exist between apparently similar supply chains. Mapping the business processes required in procuring services or forest based products enables them to be systematically analysed, e.g. regarding the number of interactions of participating actors, and redundancies identified and eventually removed. Rauch and Gronalt (2005) showed in their study that the reduction of interaction cost of timber supply is a way to improve the availability of wood as a raw material.

Business process mapping (BPM) has been applied in several studies in the forest sector, although the process mapping potential in forestry is considered to be under-investigated with limited amount of studies (Rauch and Borz 2019). Windisch et al. (2013a) studied the supply chains of forest biomass supply for two cases in Finland and in Germany applying BPM where the authors found out, that the number of processes, in particular data exchange processes, varies substantially in the selected chains (Figure 1).

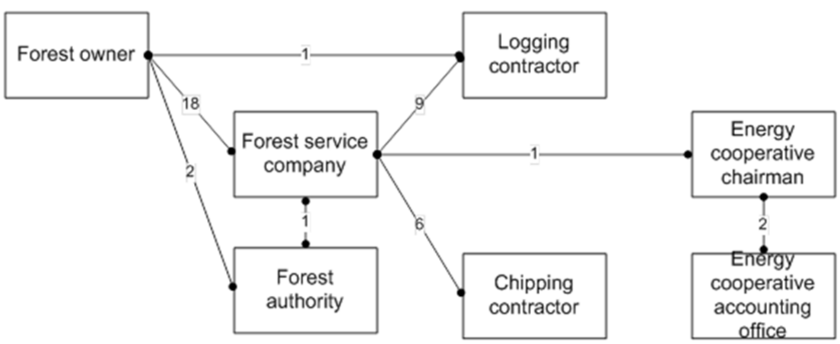

Figure 1. Example of Finnish Process map for a forest energy cooperative with 7 actors and numerous data exchange processes (Source: Windisch et al. 2013)

The objectives of the study were to study IT-tools, internet-based applications and other interfaces that enable both the requisition and marketing of silvicultural and harvesting services in three Nordic countries with a focus on selected business processes between forest administrators, service providers, and local Forest Based Industries in Denmark, Finland and Norway.

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2 Material and methods

2.1 IT solutions in selected countries

The first step of this task was to conduct a survey of services, IT-tools, internet-based applications and other interfaces that enable both the requisition and marketing of silvicultural and harvesting services, and focuses therefore on business processes between forest administrators, service providers, and local Forest Based Industries.

The special focus was on:

- focus only on services, IT-tools, internet-based applications and other interfaces
- focus on requisition and marketing of silvicultural and harvesting services
- focus on match-making of service need and service provider

An aim of this task was also to identify the data sources behind the services and their updating procedures. Therefore, this chapter includes the brief descriptions of data behind the services and a brief evaluation of the applicability. The selected countries for this task include Denmark, Finland and Norway.

The TECH4EFFECT Working Package 7 report 7.1 “Sustainability Assessment of current and recommended methods report” includes aspects on digitalization in forestry from a broader perspective, but also includes examples of digital applications for forest management and operations control across the value-chain. Some mentioned applications are partly overlapping; however, the focus in presented IT solutions was more specific on the given objectives.

2.2 Business process mapping (BPM)

The main focus of this chapter is the description of material and method used for the development of business process maps within selected cases and countries. Mapping the business processes required in procuring services or forest based products enables them to be systematically analysed. The data sources behind the services and their updating procedures should be identified, described and evaluated for applicability. This provides the grounds for further development of services and platforms and optimal design of wood mobilization tools.

The countries Finland and Norway conducted BPM for this task and focused on relevant issues within their respective operation environment described in more detail below. Precondition for this task was the agreement on common syntax/resolution between concerned countries.

In Finnish conditions, the selected focus is on selected tools/ general level covering the principle of tools (e.g. IT markets) and a comparison between “Online IT platform” vs. “traditional offer inquiry”.

Under Norwegian conditions, the identified bottleneck includes the purchase of wood (most often clear-cutting) and capacity allocation/production planning (done by forest owner associations).

In general, a focus was on requisition and marketing of silvicultural and harvesting services with the deployment flowchart for service processes including “swim lanes” for responsibilities. The software used for building the business processes was Bizagi Modeler (Bizagi Limited 2019).

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2.2.1 Case Finland

The focus of the Finnish case was on the online market(s) and tools available in Finland and the concentration on an increased mobilization of raw material as well as an improvement of the efficiency. Secondary focus was on requisition and marketing of silvicultural and harvesting services including for example activities such as clearing/pre-commercial thinning, establishment of stand/logging site and cutting/operation.

This work utilizes freely available information on the most common tools and the processes from a forest owner perspective when matching with a service provider performing the actual forest operation service, in a simplified way.

This task is building on methods that have been applied in previous research work, e.g. by Windisch et al. (2013a), Windisch et al. (2013b), Rauch and Gronalt (2005) and Rauch and Borz (2019). The selected focus was on available selected tools with a general level covering the principle of tools (e.g. IT markets) and the main emphasis on the comparison between the case "Online IT platform" versus the case "traditional direct offer inquiry", in a simplified way. While the principle of the online IT platform is based on the available service Metsään.fi (provided by the Finnish Forest Centre, Metsäkeskus) from a forest owner´s perspective, the traditional direct offer inquiry assumes a direct contact between the forest owner and a service provider without intermediate actors. While in practice intermediate actors such as forest owner associations or other forest owner cooperations (FOC´s) are quite often involved, they increase the number of actors and processes and therefore were excluded.

Similar to-, and based on the work done by Rauch and Gronalt (2005), interactions were used as an indicator of process efficiency of the alternative business models in the absence of consistent data for time spent on various process by the process owners. The method involved a "As-Is" process mapping aiming to identify general possible improvements through visual observation when utilizing the case "Online IT platform" compared to the "traditional direct offer inquiry".

2.2.2 Case Norway

Industrial wood supply in Norway is managed primarily via regional forest owner associations (FOAs). The mill customers establish supply contracts with the FOAs, who in turn contract wood with their members. Each association offers harvesting and silviculture services to their members via their own contractors. In general, business services for wood supply are well established in Norwegian Forestry. Most farm forests have forestry plans (renewed every 10 years) and the supply chain processes though purchase, harvesting, delivery and payment are supported by a sector-wide IT-infrastructure (Norwegian SkogData with similar architectures to Swedish SDC/Biometria).

Nationally, the annual harvest (10-12 million m^3) is under half of the annual increment (25 million m3). 3-4 million m^3 are exported, primarily because of insufficient industrial capacity for pulpwood processing, but also regional imbalances between sawlog supply and demand. Regionally, the greatest gaps between increment and harvesting are driven primarily by difficult topography (steep mountain terrain) and underdeveloped infrastructure (low forest road density).

Norwegian wood supply situation

In southeast Norway, forestry conditions are more similar to the other Nordic countries, and harvesting levels near annual increment. In these areas there is still a clear pattern of seasonal variation in harvesting with the consequence of uneven capacity utilization and high costs. The current wood supply situation can be characterized as a hot market with consequently short planning horizons for purchase and harvesting.

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The cover time (corresponding number of production days) for a forest owners association's bank of signed FO harvesting contracts may vary from 2 weeks to 3 months. Given the typical size of these farm forests (40 ha), the owners' dependence on income from the forest has decreased with time. Consequently, their involvement in forest management has been reduced. As one measure to maintain active management of these areas, a number of forest owner associations are offering long-term forest management services (AT Skog 2019, Viken Skog 2019). For the FOA, such services have a double-function. First; they avoid a gradual reduction of wood availability due to reduced FO involvement. Second; they also provide a better overview of potential harvesting stands, sites and contracts, ultimately enabling longer planning horizons and increased flexibility for the FOA to fulfil wood supply contracts to mill customers.

Goal – the overall goal of the study was to examine the wood mobilization processes in Norwegian forestry, in terms of potential improvements and future services. The first sub-goal was therefore to provide a general business process mapping of wood purchase and production for Norwegian forest owner associations. The second sub-goal was to provide an initial test of one selected service improvement; long-term management agreements.

2.2.2.1 Business process modeling of purchase and production

Business processes for purchase and production were mapped via personal interviews. Interviews data was collected from three FOAs (including interior and coastal regions).

Two levels are presented here. The first level provides an introductory overview of management activities at market (sales), region (production) and district (purchase) levels (Figure 2). The second level provides the general sequence of purchase and production planning activities done at the district and regional levels. This includes both the business-as-usual variant (Figure 3) and a slight re-configuration to accommodate one selected service development (Figure 4).

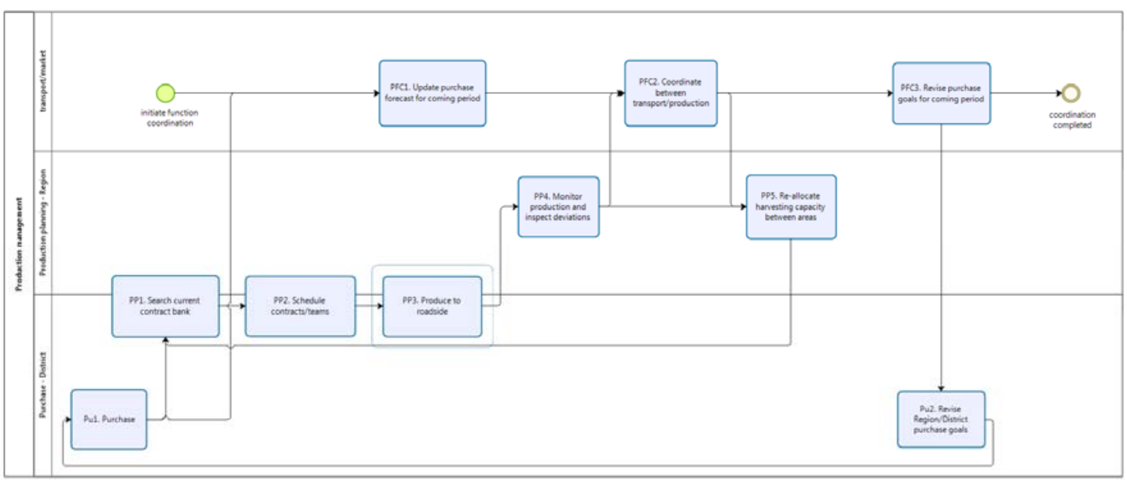

Figure 2. A typical configuration for periodic coordination activities between purchase (lower), production (middle) and market (upper) functions.

Periodic coordination between functions (Figure 2) involves three general steps; updating the purchase forecast for the coming period (PFC1), coordination between transport and production functions (PFC2) and subsequent revision of purchase goals for the coming period (PFC3). Production

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management can be aggregated to a loop of 5 general activities; searching the contract bank for suitable sites (PP1), scheduling the selected contracts and harvesting teams (PP2), production to roadside (PP3) and subsequent monitoring of production/deviations from plan (PP4) and eventual re-allocation of harvesting capacity between regions/districs (PP5). At this level purchase management is limited to the setting of region/district purchase goals which are presented in more detail below.

At the region/district level, the purchase and production planning process starts with monitoring of to which degree the current bank of contracts meet the purchase goals (Figure 3). If the current bank does not meet the defined goals, 4 general purchase activities are initiated: contact with forest owners (Pu1.1), estimation of a production prognosis and suitable conditions at the site with the harvesting contractor (Pu1.2), confirmation of the contract and suitable operating conditions with the forest owner (Pu1.3), before entry of the signed contract (FOA-FO) in the FOA contract bank (Pu1.4). Signed contracts are entered into the SkogData VSYS VH module to receive a contract number and production planning can be initiated. Once the contract is registered, FOA harvesting instructions can be uploaded to the harvesting contractor web (EntrWeb) and followed up via contractor production reporting to the FOA manager web (SBLweb). Deviations between contractor production and FOA production goals (Pp4) can then re-initiate the purchase process if deviations cannot be solved within the current contract bank.

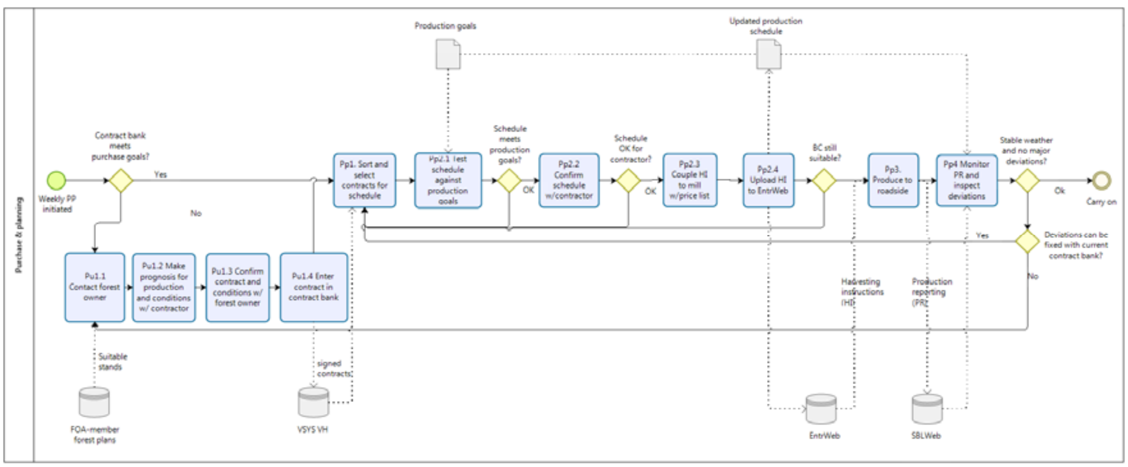

Figure 3. Detailing of BAU activities between FOA purchase (Pu1.1-1.4) and production planning (Pp1-4t).

2.2.2.2 Testing the effect of a new service option; long-term management agreements

Ultimately, forest management agreements may enable the FOA to directly select forest owners' stands for purchase and production planning. This effectively increases the planning horizon and the degree of freedom (flexibility) in production management. Figure 4 shows a revised sequence of activities for FOA purchase and production planning for forest owners who have entered such as agreement.

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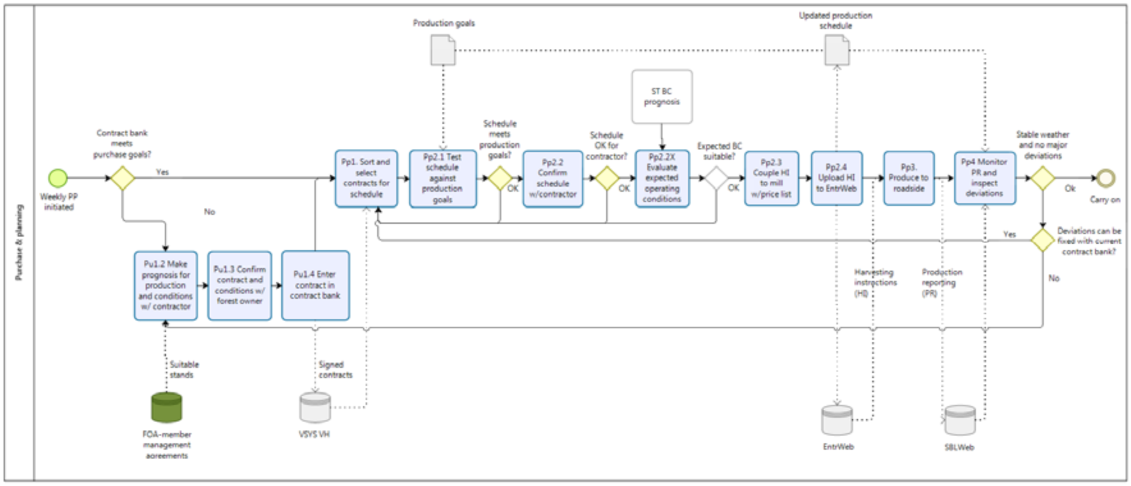

Figure 4. Detailing of FOA activities in wood purchase (Pu1.2-1.4) and production planning (Pp1-4) when purchase is included in long-term management agreements with FOs.

Comparing the purchase activities between figure 3 (Pu1.1-Pu1.4) and figure 4 (Pu1.2-1.4), the only difference is one less step (Pu1.1) in the purchase process, and with this, a reduced lead time for initiation of purchase. While this will save time for FOA purchasing, in general, the reduction in lead time would be most useful when deviations between reported production and production goals (Pp4) require rapid additions to the contract bank.

2.2.2.3 Potential effects of long term management agreements on production KPIs

A simple quantitative model used to map the effects of the increased planning horizon on key performance indicators (KPIs) for the production phase. The test was based on data for three harvesting teams in south-eastern Norway. The data was partitioned into 3 alternative contract banks, equivalent to 3, 6, and 9 months of harvesting work. A mixed-integer programming (MIP) model was used to compare optimal production solutions for the 3 planning horizons.

The goal function maximized net profit for the FOA. The net profit function included three levels of production bonus (NOK/m^3) for meeting monthly production intervals (within for each of 6 assortments) and utilization penalties for not fulfilling agreed monthly machine hours (deviations exceeding 10 % for each of the 6 machines). Production was simulated for three consecutive months (March, April and May) with the each of the three contracts banks. Each set of simulations was run with two different levels of production bonus (1 and 10 NOK/m^3). The primary KPIs for comparison of the 27 monthly results include:

- deviation from production goals per assortment

- variation in machine utilization per team and machine

In addition, maximum distance between monthly harvested sites was tracked per machine team.

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3 Results

3.1 IT solutions in selected countries

3.1.1 Denmark

In Denmark, data on forest resources is collected and processed by the University of Copenhagen providing valuable information on important characteristics. Several decision support tools then provide useful instruments for the Danish forest management.

The University of Copenhagen collects the forest resource data using the following techniques:

- laser scanning
- aerial photography
- field visits/NFI plots

The collected data is then processed and applied to show the following important forest characteristics:

- Forest area
- Timber volume
- Carbon storage
- Growth and harvest
- Forest health
- Biodiversity in the Danish forests
- Forest ownership demographics

Applied in various decision support tools, the data is then utilized in forest management for practical applications, for modelling, for growth, yield and economic simulations, for economic accounting etc. on different levels.

In Denmark, several interest services are then available in the forest sector providing maps, tables and various services to their users. Available tools and services are presented in the following sub-chapters.

3.1.1.1 Examples of decision support tools in Danish forest management

Data collected by the _University of Copenhagen is utilized in forest management for practical applications. These applications include: modelling, methods, growth-, yield- and economic simulations, economic accounting and other aspects applied on various levels (Table 1).

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Table 1. Decision support tool examples in Danish forest management.

Computerized tool/DSS	Models and methods
PROTEUS	GIS, Stand level growth and yield models, Economic accounting, Simulations
PEB	Stand level growth and yield models, Economic accounting, Simulations, Optimisation,Multi-criteria decision analysis
PC-KORT	GIS, Stand list information
TAURON	Stand level growth and yield models, Economic accounting, Simulations
PLANKAT	Stand level growth and yield models, Economic accounting, Simulations
LANDINFO	GIS, Stand list data, Regeneration models
SØK	Stand level simulation of growth, yield and economic
TAURON	Stand level growth and yield models, Economic accounting, Simulations
PLANKAT	Stand level growth and yield models, Economic accounting, Simulations
PLANKAT	Stand level growth and yield models, Economic accounting, Simulations
RODPOST	Optimisation of harvest assortments
KUBIK	Sorting and simulations

3.1.1.2 Examples of internet services for the forest sector in Denmark

In the Danish forest sector, several interest services are available to their users. These services provide maps, tables and various other services as listed below:

- Interactive forest maps: https://ign.ku.dk/samarbejde-raadgivning/myndighedsbetjening/skovovervaagning/kort-over-skovressourcer/
- Seeds and plant sources: plantevalg.dk
- Forest accounting tables: https://www.skovforeningen.dk/udgivelser/skovokonomisk-tabelvaerk/
- Environmental portal: http://www.miljoeportal.dk/borger/Sider/Borger.aspx

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- Consultancy work from a range of private organisations [main actors]
  - Skovdyrkerne.dk [Forest Extension Service]
  - Skovforeningen.dk [Danish Forest Owners Association]
  - Hedeselskabet.dk [Danish Heathland Company]
  - Kwplan.dk [KW-Plan aps]

3.1.2 Finland

The Finnish National Forest Inventory (NFI) produces information on national and regional forest resources and their changes in regular 5 to 10-year cycles. Field data provide statistics on a country level and for large areas, satellite images allow for information also on smaller areas; the multi-source NFI thereby utilizes several data sources including satellite images, field measurements and digital maps. The Finnish Forest Centre (Metsäkeskus) as a state-funded organization is tasked with promoting forestry and related livelihoods, advising landowners, collecting and sharing Finland´s forest data and enforcing forestry legislation (Ministry of Agriculture and Forestry 2020).

"The Finnish Forest Centre is responsible for collecting and sharing information about Finnish forests. The majority of the data collected by the Finnish Forest Centre is openly available in digital format under the act on the forest data system of the Finnish Forest Centre (66/2018). The database maintained by the Finnish Forest Centre contains information about, for example, the forest site types, growing stock, habitats of special importance and use of forests." (Metsäkeskus 2020)

3.1.2.1 A key service provided by the Finnish Forest Centre: Metsään.fi

A key role in Finland for various actors in the forest sector is taken by the Metsään.fi-services provided by the Finnish Forest Centre. It is the basis for several other, mainly privately operated, services that utilize information from this service. The service allows access to forest information and connects various stakeholders, such as forest owners and corporate actors, to each other (Figure 5).

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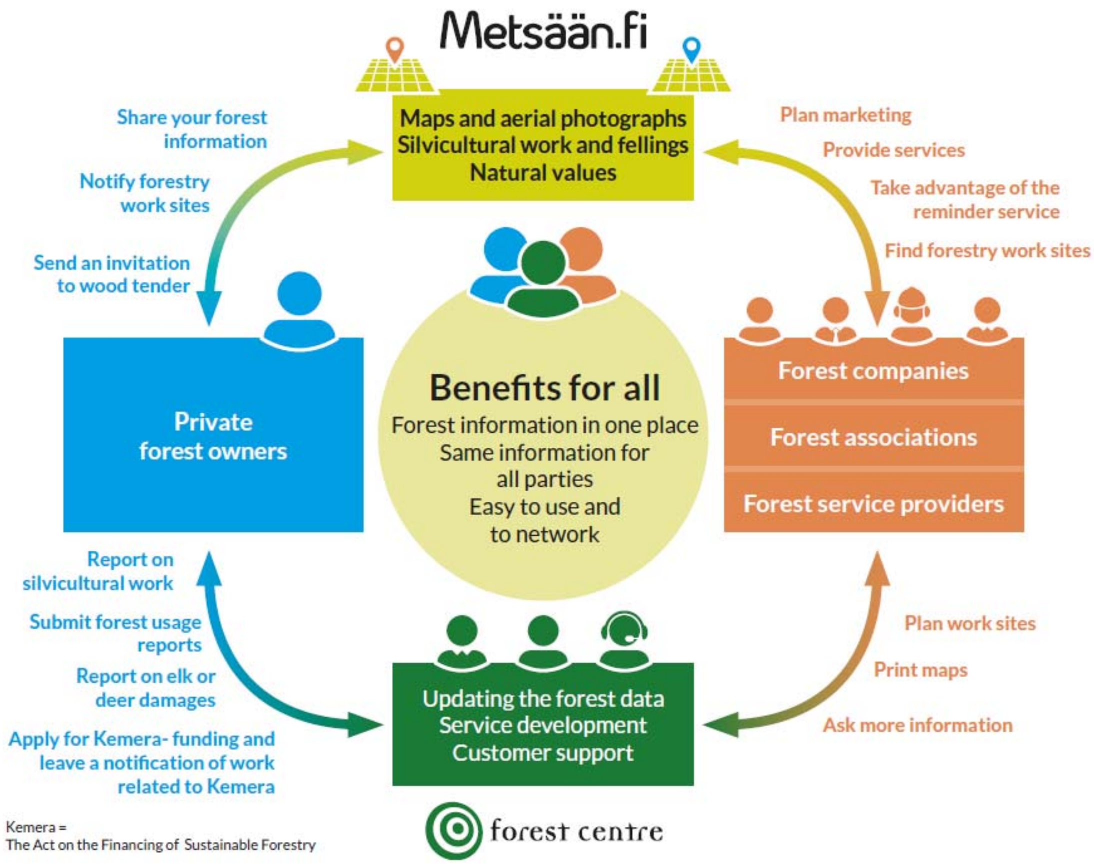

Figure 5. Metsään.fi-service provided by the Finish Forest Centre (Source: Metsäkeskus 2019a).

A detailed description of this free e-service can be found in the publication "Finland´s model in utilising forest data – Metsään.fi-website´s background, implementation and future prospects" by Valonen et al. (2019). Therefore, the functionality and other aspects covered by the mentioned report are not repeated within this document.

A description of the open forest data including the producer, description and data content, data collection method, data sources, updating frequency, reliability of the data, availability of data and conditions for use is available from the Finnish Forest Centre (Metsäkeskus 2019b).

3.1.2.2 Available other Finnish services:

Several other IT services are available in Finland, which are mainly owned and managed by companies, associations or joint efforts of various (mainly private) actors in the forest field. Most of these services are building on the available information and data, such as the forest inventory data, obtained from Metsään.fi-service. Selected examples of such Finnish services are listed below, each with a short description:

a) Kuutio®: www.kuutio.fi (Suomen Puukauppa Oy)

Kuutio® service is a fairly new, 2018 was the first complete year in operation, electronic marketplace for timber trade in Finland. Kuutio® was developed by Suomen Puukauppa Oy, a company founded

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by all the major actors in the forest sector. Kuutio® is a joint effort of the entire forest sector, designed together by both timber buyers and sellers. Over 90 per cent of Finnish timber purchasing volume was already part of the service. The aim of the e-service is to get the timber onto the market and attract the more passive forest owners, "Kuutio also improves competition in timber trade. The market mechanism will help to set the right price for the timber".

Kuutio® acquires the data directly from metsään.fi, within the service, the forest owner also receive an estimate of revenue from timber sales based on up-to-date statistics provided by the Natural Resources Institute Finland (Luke).

b) Wuudis: www.wuudis.com (Wuudis Solutions Oy)

Wuudis is an open electronic market place. Developed by Wuudis Solutions Oy, the IT solutions for forestry offered are electronic platform based services, currently divided into Wuudis Bioenergy and Wuudis Business.

c) Metsäselain: www.metsaselain.fi (Forest owner associations)

Metsäselain service is an application for members of a forest owner association that handles forest plan and information handling on a mobile device. The service is intended for forest owners and forestry experts.

d) Metsäverkko: www.metsaverkko.fi (Metsägroup)

Metsäverkko is a service offered by Metsä Group. It includes services for forest owners such as forest plan, maps, management of offers, ordering of services, timber sales and other related services.

e) eMetsä: www.storaensometsa.fi/palvelut/emetsa (Stora Enso)

eMetsä is a service offered by Stora Enso Metsä. It includes services for forest owners such as forest plan, maps, management of offers, ordering of services, timber sales, tax forms and other related services.

f) UPM Metsä: www.upmmetsani.fi (UPM)

UPM Metsä is a service offered by UPM Metsä. The service is an application that handles forest plan and information related to the forest owner's forest.

3.1.3 Norway

Several IT systems are available for users in the Norwegian forestry sector. They can be divided into IT systems for forest resources, governmental owned systems, private systems owned by forest organizations, forest prognoses & planning tools and systems for timber trading. These systems will be introduced in the following sub-chapters in more detail.

3.1.3.1 IT systems for Forest resources

This chapter describes the main IT system in Norwegian forestry and management in more detail.

3.1.3.2 Government owned systems

3.1.3.2.1 Kilden.nibio.no

"Kilden" (*the source*) is main map solution managed by the Norwegian Institute of Bioeconomy Research (NIBIO). Here, the entire department's data is gathered in one place together with a selection of other central, national data sets.

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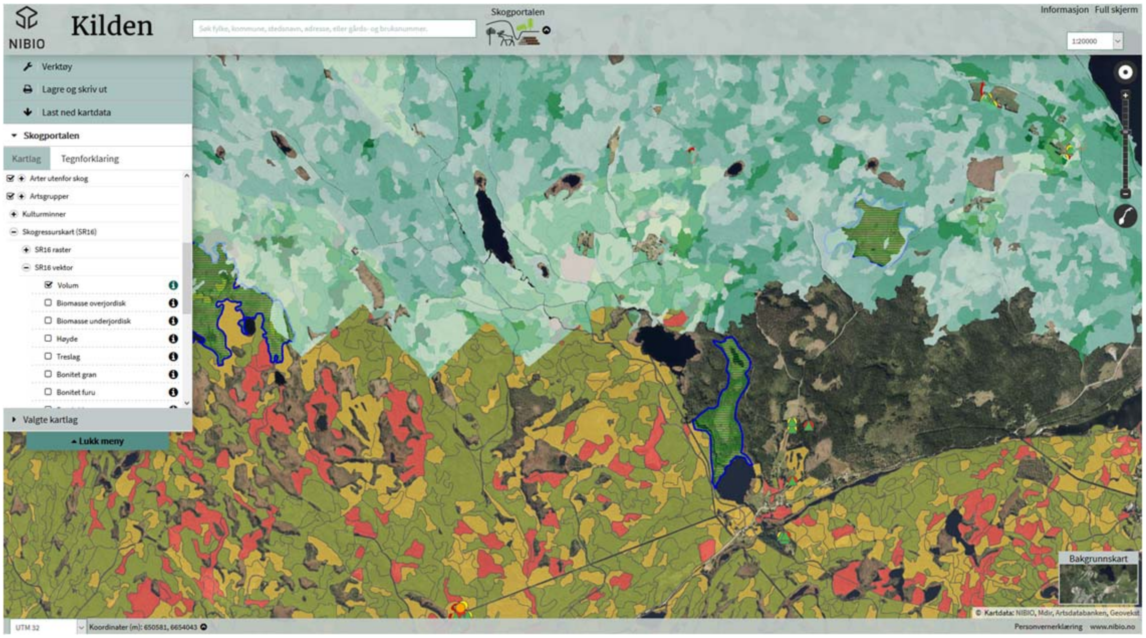

Figure 6. "Kilden" system shows age clAsses from forestry plans and SR16 (areas w/o forestry plans).

Forestry related map layers:

Age classes in forests show the average age of a stock registered by collecting data for forestry plans. The age classes are Harvest Mature Forest (Development Class 5), Older Forest (Development Class 4) and Younger Forest (Development Class 2 and 3). In addition to age classes in forests, you get up the quality, tree species, registration date and area.

SR16 - This data set is produced through automatic processing of existing map data, terrain models, 3D remote data (photogrammetry and laser) and data from NFI surfaces. The screen version of the map (SR16R) is made with 16 x 16 meter pixels. A vector map that generalizes the grid map to larger figures of relatively homogeneous forest is presented as an independent product with its own description (SR16V).

A key habitat is a delimited area that is particularly important for the conservation of biological diversity. According to the Norwegian PEFC forest standard, key habitat shall ensure habitats for species considered threatened on the Norwegian Red List.

Map layers for endangered species, protected areas, cultural monuments etc.

3.1.3.2.2 “Gårdskart”

”Gårsdskart” (*farm map*) is developed for displaying maps and area figures for agricultural properties.

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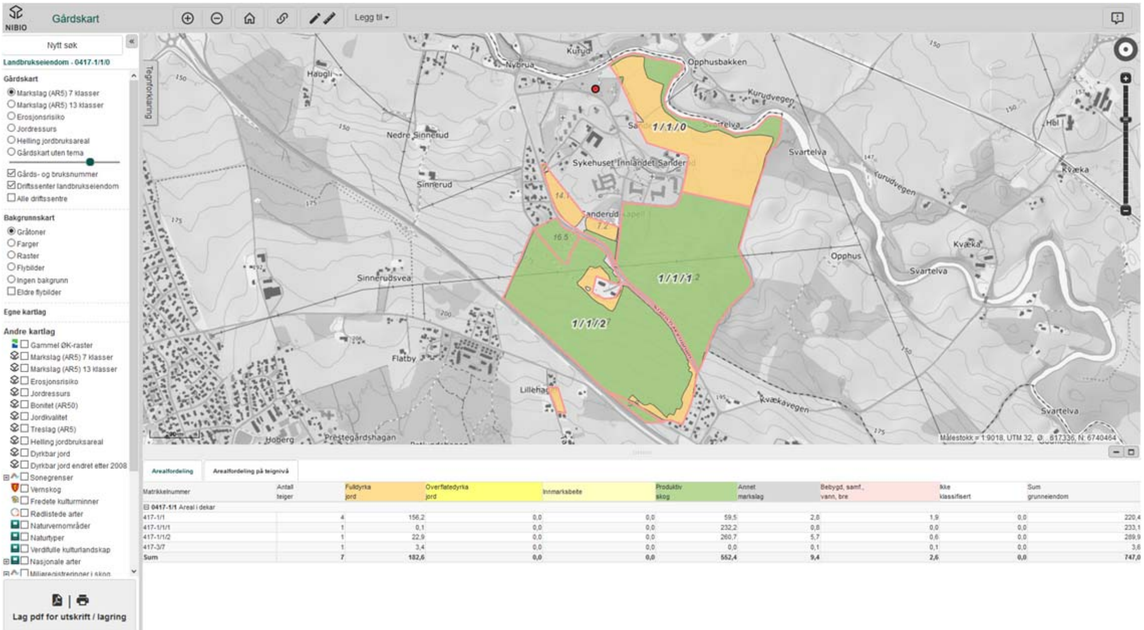

Figure 7. "Gårsdskart" (*farm map*) system for agricultural properties.

3.1.3.3 Private systems owned by forestry organizations

In Norway there are mainly 6-7 larger private forestry organizations that are jointly owned by the forest owners. Their main objective is to offer timber trade, harvesting services, and other forestry related services (silviculture) for their members. There are several forest information systems that have overlapping functionality.

3.1.3.3.1 System 1 – «DinSkog» owned by the organization Viken Skog

DinSkog ("Your Forest") gives you access to digital maps, file information, property information, environmental records and detailed background maps. You can print or store map sections for use in harvesters or other purposes such as silviculture planning or hunting. A central GiS warehouse in the Viken group provides the possibility to update the forestry plan after forestry activities by using a web page. The system is also accessible by an app. The system also collects harvesting data from the machines. A central GiS database that provides unique opportunities for synchronization between different users, so that both authorities and forest owners see the same information at the same time, including changes made.

DinSkog is also the GiS system for timber trade and other silviculture activities in the Viken system. Viken is the only forestry company in Norway that has developed a SAP business solution for their organization.

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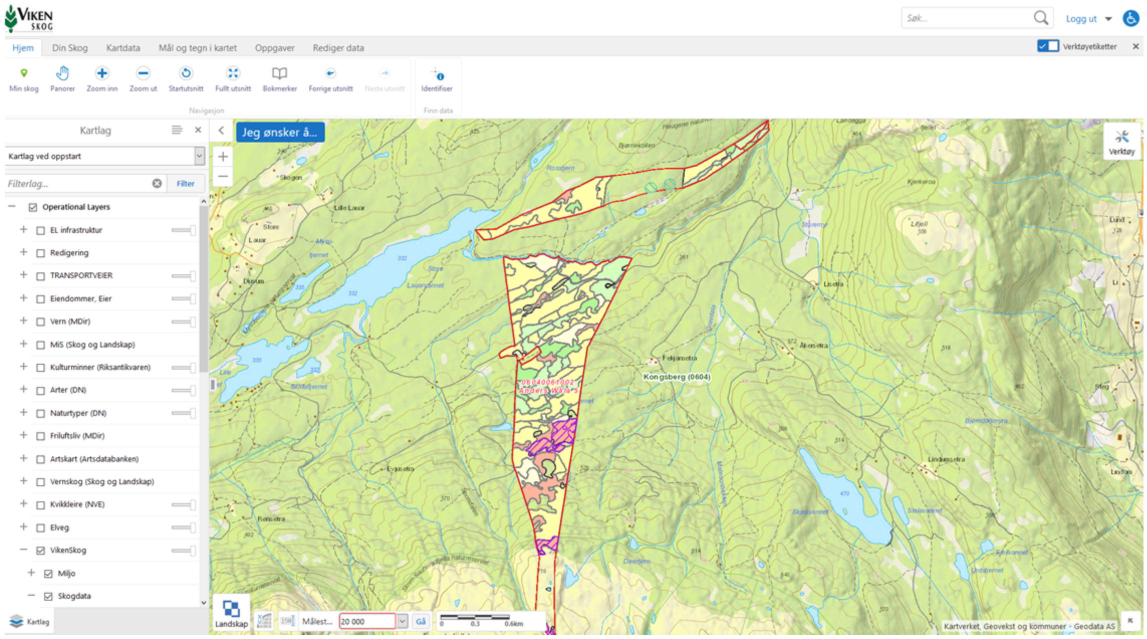

Figure 8. "DinSkog" system owned by the organization Viken Skog.

3.1.3.3.2 System 2 – ALLMA - owned by the organizations ALLSKOG, Mjøsen Skog and AT Skog

These three forest companies (Allskog, Mjøsen, ATSkog) are behind the development of ALLMA. The basic foundation of ALLMA is a modern database for the storage and production of forest management plans.

The forest management plan gives forest owners an overview of the property and gives a foundation for making good priorities. The forestry plan divides the forest into stands and recommends which measures should or must be carried out in the individual stock. Earlier, the forestry plans were only available on paper. With ALLMA, the forestry plan has become digital and always with you via iPhone and tablets. Technological developments have made the forestry plan even better and more useful than before.

ALLMA project the forest growth on stand level and adjust for silvicultural activities carried out, so that the forest information displayed is up to date.

ALLMA is also the GiS system for timber trade and other silviculture activities in the ALLMA group.

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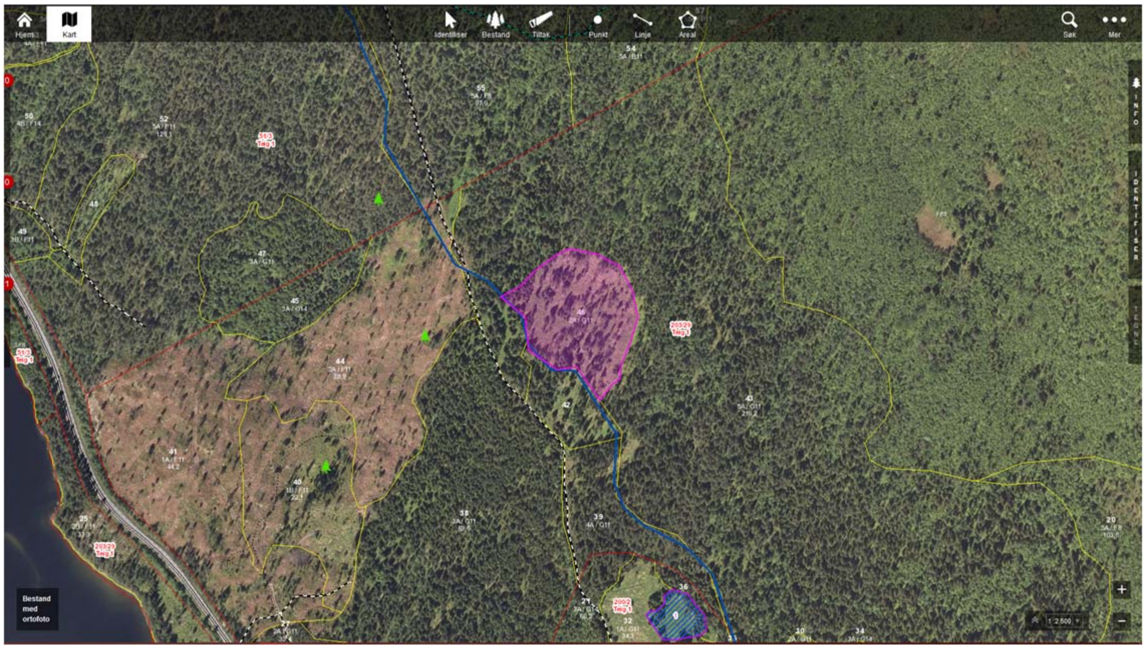

Figure 9. “ALLMA” system owned by the organizations ALLSKOG, Mjøsen Skog and AT Skog.

3.1.3.3.3 System 3 - Linnea - owned by the organization NORSKOG

LINNÉA is a PC based management system for operational forestry. The system is built around an advanced database with associated functions to manage a forest area by having one or more forestry plans operational on PC. All planned and carried out measures on the property, documentation of plant benefits, information in connection with environmental registrations, timber qualities, technical data etc. can be registered in the database

The file database can easily be connected to digital file maps and is ready for communication with the map systems ArcMap.

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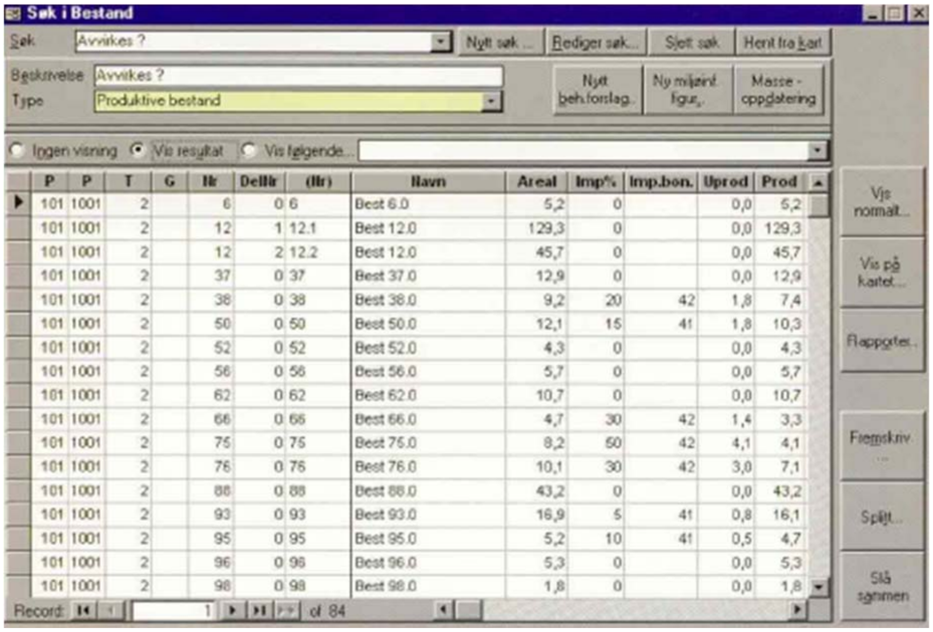

Figure 10. “Linnea” system owned by the organization NORSKOG.

3.1.3.3.4 System 4 – PAN (Agromatic AS).

PAN is a complete forestry plan program providing a basis for effective management of forest resources. PAN provides the possibility to edit maps and landing data, make annual projections of age and growth, add and modify treatment suggestions and environmental information, print maps and plan data to support more effective operational planning.

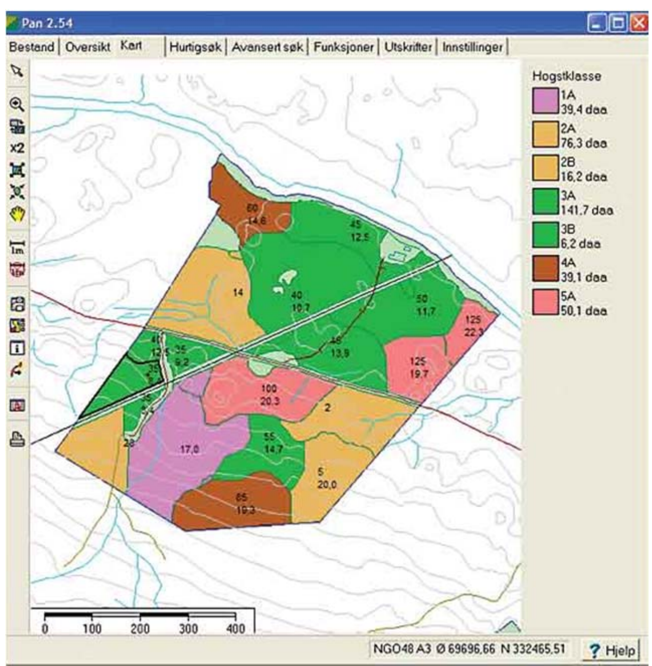

Figure 11. “PAN” is a complete forestry plan program (Agromatic AS).

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3.1.3.4 Forest prognoses /planning tools

3.1.3.4.1 System 5 – GEOSKOG – owned by Statskog SF (government), Foran AS, Jordskifteretten (THE LAND CONSOLIDATION COURT OF NORWAY), Viken Skog SA and SB-Skog

GEOSKOG is developed by Statskog and Geodata. The system projects the forest growth over a time horizon of 100 years, with 3D visualization of the terrain. The system also calculates and priorities when different silvicultural activities should be conducted and has also the ability to suggest the optimal forwarding routes in the terrain.

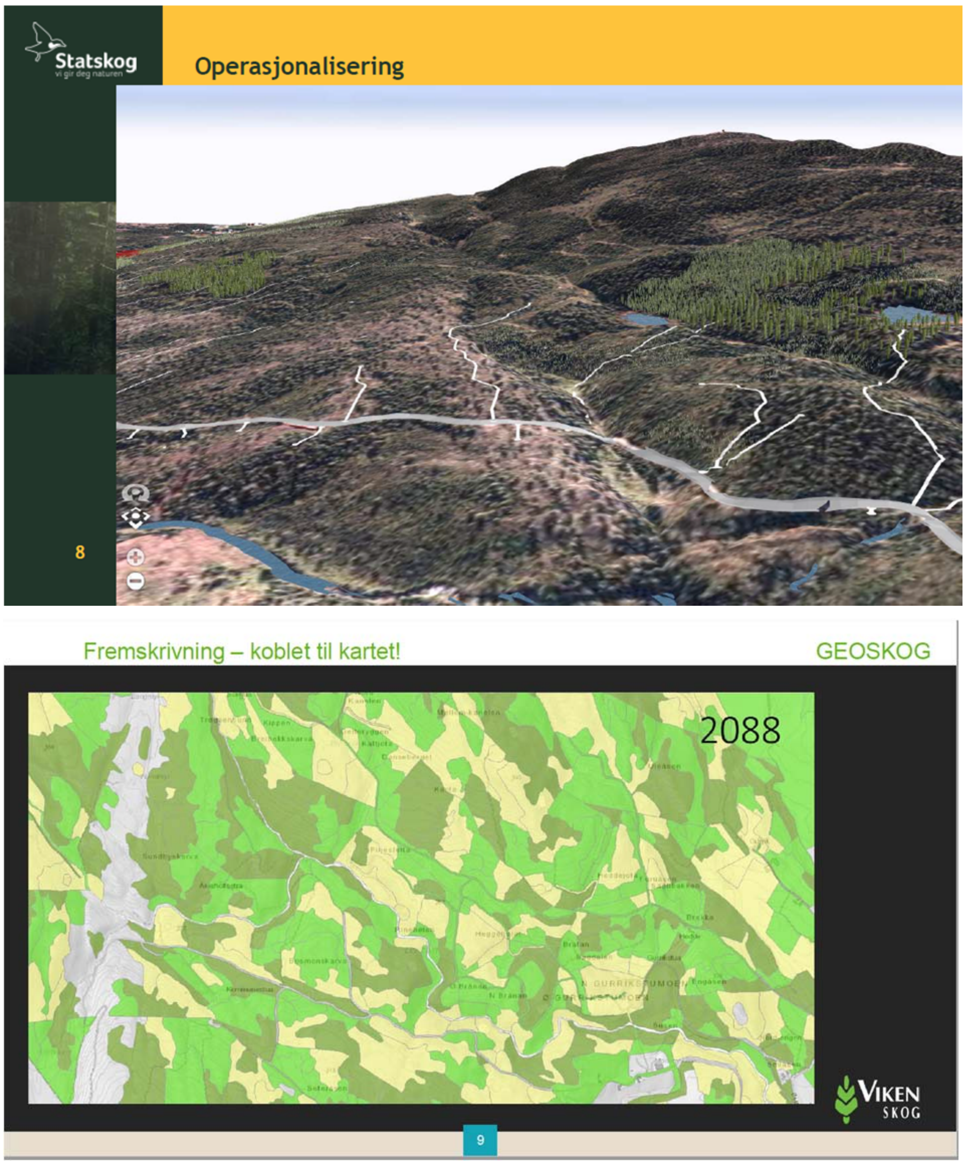

Figure 12. "GEOSKOG" owned by Statskog SF (government), Foran AS, Jordskifteretten (THE LAND CONSOLIDATION COURT OF NORWAY), Viken Skog SA and SB-Skog.

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3.1.3.4.2 System 6 - SGiS – developed at the Norwegian University of Life Sciences (NMBU)

A system developed to simulate stand development and optimization of forest management in a GIS interface. Based on the system GAYA, developed at The Swedish University of Agricultural Sciences (SLU) that simulated the stand development with different silviculture activities. The system optimises the silviculture based on the system "J", developed by METLA in Finland.

The system is used to analyse stand development with different silviculture alternatives and/or environmental restrictions.

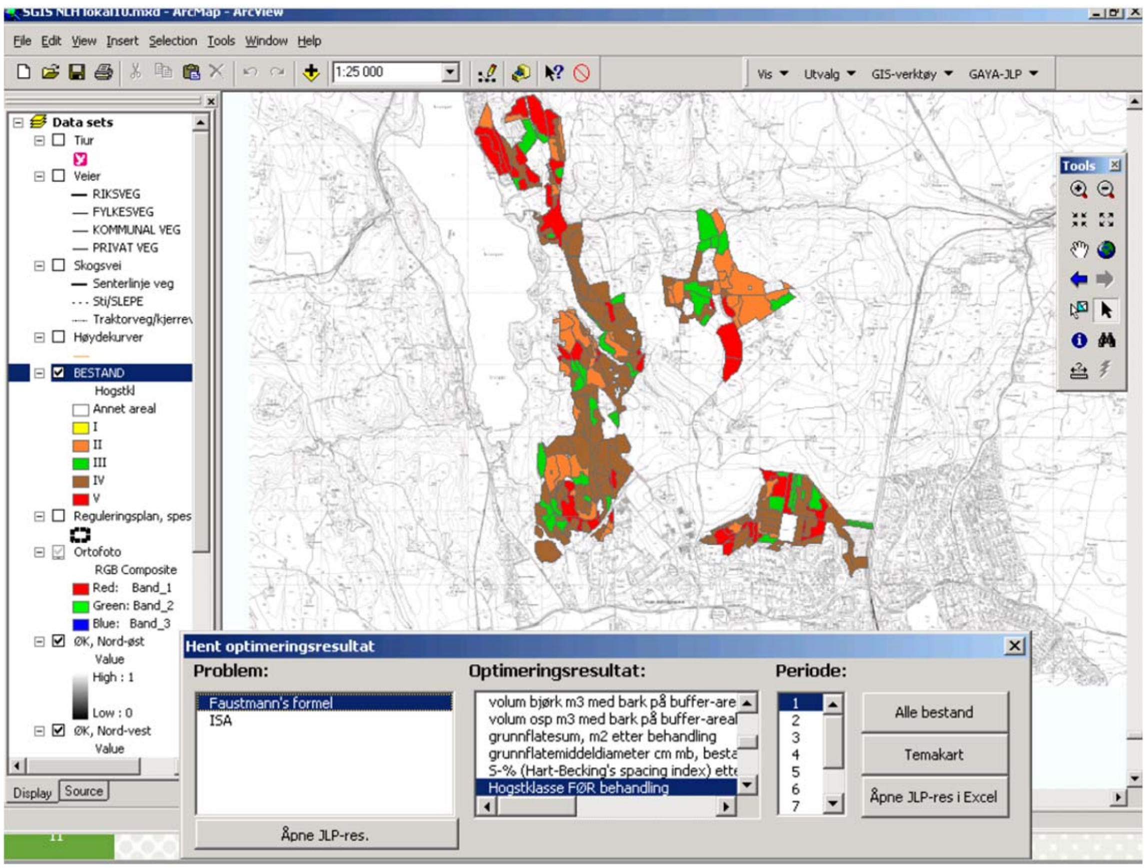

Figure 13. "SGiS" developed at the Norwegian University of Life Sciences (NMBU).

3.1.3.4.3 System 7 - The Heureka system

A series of software developed at The Swedish University of Agricultural Sciences - SLU that allows the user to perform a larger amount of different analysis and management plans for forestry. The system can perform short- and long-term projections of timber, economy, environmental conservation, recreation and carbon sequestration.

Heureka is a powerful planning and analysis system with multiple functions. Using the system requires a certain minimum competence level with IT-systems and forest planning.

The system has been adopted for Norwegian forest with Norwegian growth, volume and harvesting models.

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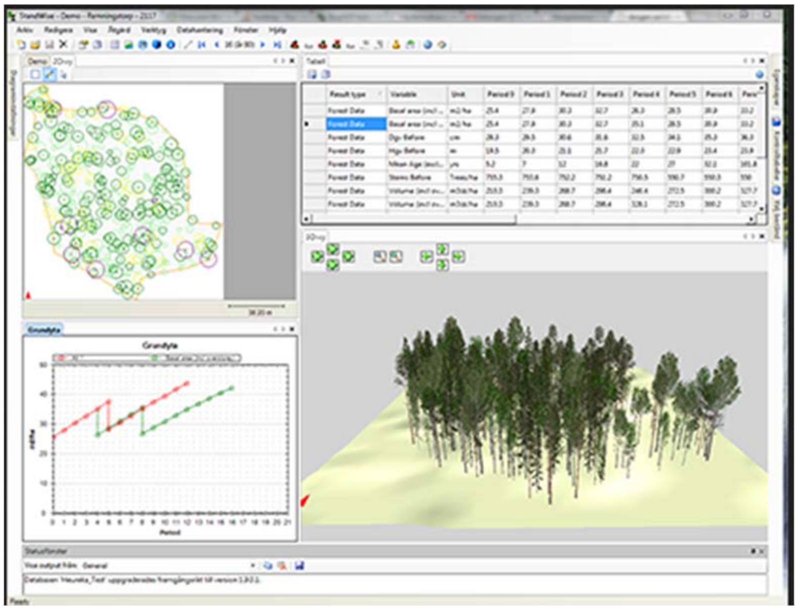

Figure 14. The "Heureka" system is a powerful planning and analysis system with multiple functions.

3.1.3.5 Systems for timber trading.

There are several systems for timber trade in Norway and this list describes a selection of the systems that are specially made for forestry.

3.1.3.5.1 System 8 – Sector-wide solutions operated by Skog-Data AS

Virtually all systems used in the timber trade are developed by the forestry sector jointly through the company Skog-Data AS, which also operates the solutions. The sector-wide IT-solution (Skog-Data) provides a common digital beam connecting the supply chain partners from forest to industry. The solution supports planning, follow-up and payment for forest owners, harvesting and transport contractors, supply organizations and mill customers. Modules are available for each business link, with corresponding web-applications, and report generation routines.

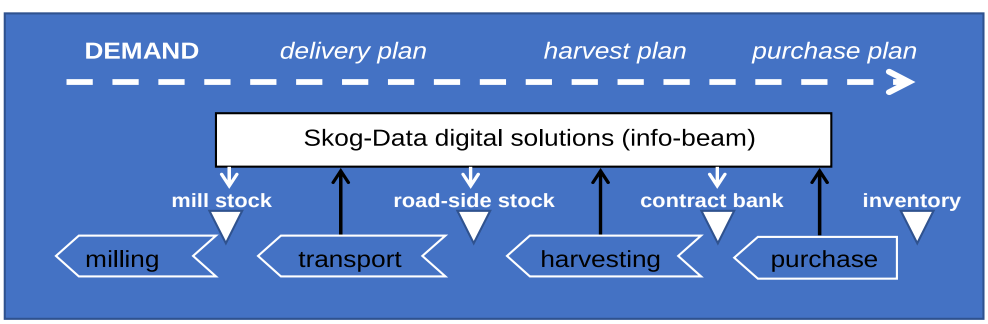

Figure 15. Sector-wide solutions operated by Skog-Data AS.

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The main systems for timber trade include:

- «Virkeshandel» (*wood trade*) - Timber trade from forest owner, through forest owner organization to the industry.
- «TR-Prod» (*production and transport*) - The system for controlling and running the transportation of timber from the forest to the industry.
- «Innmåling» (*scaling*)- forest timber which is harvested for processing, hall or export is measured by Norsk Virkesmåling who is a measurement association owned by both sellers and buyers of timber, and the system for managing the measurement is called "Innmåling".
- «Pris/avregning» (*pricing/payment*) – calculation of the volume from the "Innmåling" when combined with the price given by the system "virkeshandel" initiates invoicing.

3.1.3.5.1.1 System 9 – FeltApp, by the company "Per & Per"

The system handles over 20 million cubic meters in Scandinavia. Offers functions for, among other things, contracting and planning measures such as thinning, planting or soil preparation. Current information such as environmental considerations, ancient monuments, property borders, forestry plans are easily accessible. Drone support is available as an option, for a more efficient work.

Used as a base system for the timber trade for the following companies in Norway: NORTØMMER AS, Viken Skog, Glommen Skog.

3.1.3.5.2 System 10 – Different custom-made company-specific systems.

SB Log – A system used by SB- Skog for handling all the forestry related activities in a GiS based system.

«SBL app» is the system that Mjøsen Skog uses for all their activities to connect their CRM system with ALLMA and Skog-Data system.

Different custom-made user interface towards the companies CRM systems.

FeltGiS - makes data collection from harvesters and forwarders easily and automatic using cloud services, with or without mobile cover.

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3.2 Business process mapping (BPM) of selected cases

The main focus of this chapter is the description of results of the BPM of selected cases in Finland and Norway. Mapping the business processes required in procuring services or forest based products enabled them to be systematically analysed - within their respective operation environment described in more detail below.

3.2.1 Case Finland

In Finnish conditions, the selected focus is on selected tools/ general level covering the principle of tools (e.g. IT markets) and a comparison between “Online IT platform” vs. “traditional offer inquiry”.

The assessment focused thereby on the match making between the forest owner and the need for a forest service with a service provider. The produced simplified process maps give an indication of the steps from a forest owner perspective when using an online IT platform. The process maps show the beginning of the activity when joining starting with the registration at the IT service until the a service announcement has been sent to a service provider (Figure 16) and from the beginning of the match making with the sending of the service announcement until then end of the activity through the financial accounting or payment of the utilized service (Figure 17).

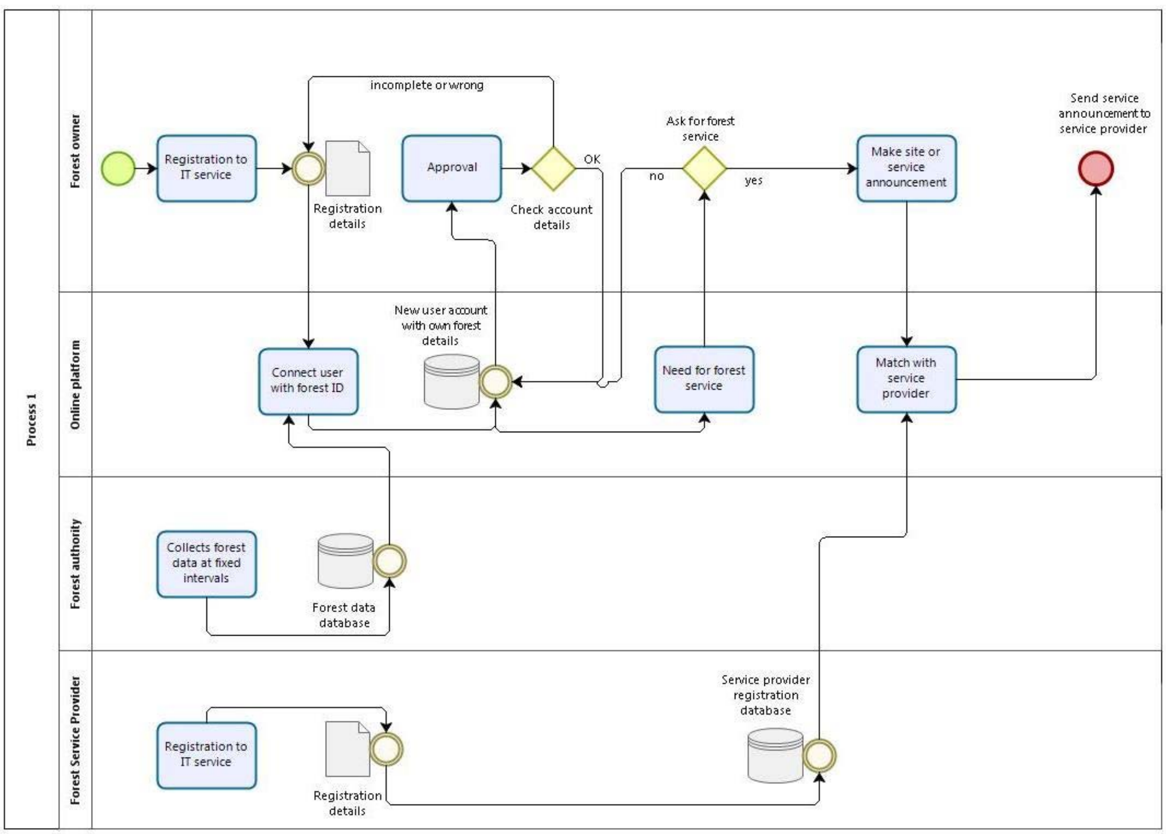

Figure 16. Example process map with simplified steps for a forest owner from the registration to the IT service until a service announcement.

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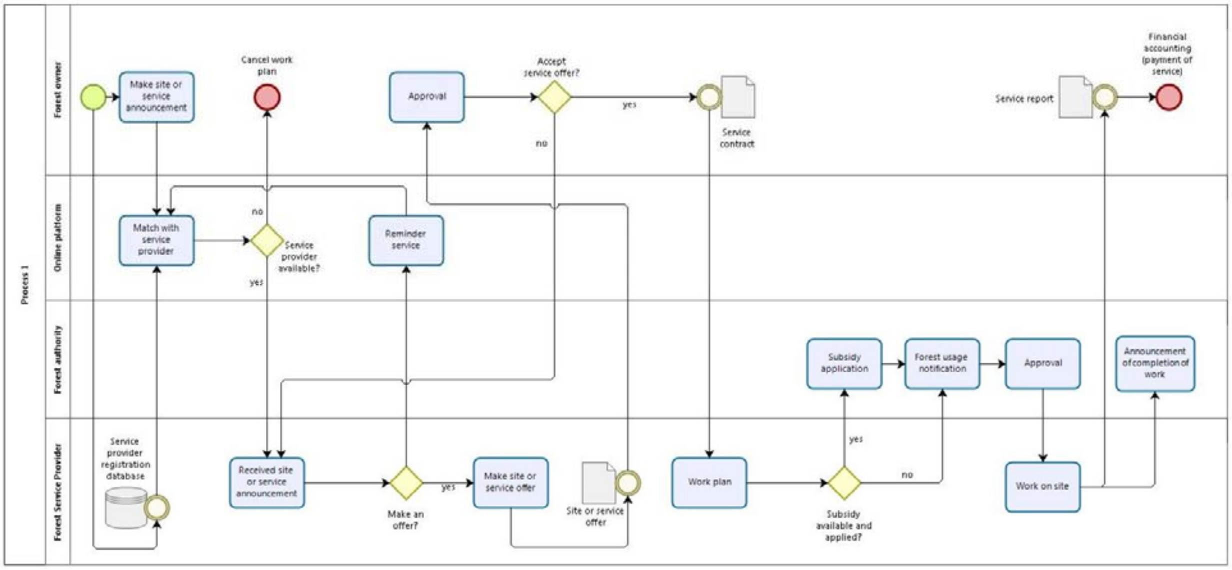

Figure 17. Example process map with simplified steps for a forest owner example with focus on match-making from the beginning of the match making with the sending of the service announcement until then end of the activity through the financial accounting.

The utilization of available online market places by forest owners builds on publically available services including their (open source) data and information, therefore their principle functioning is slightly different (Figure 18).

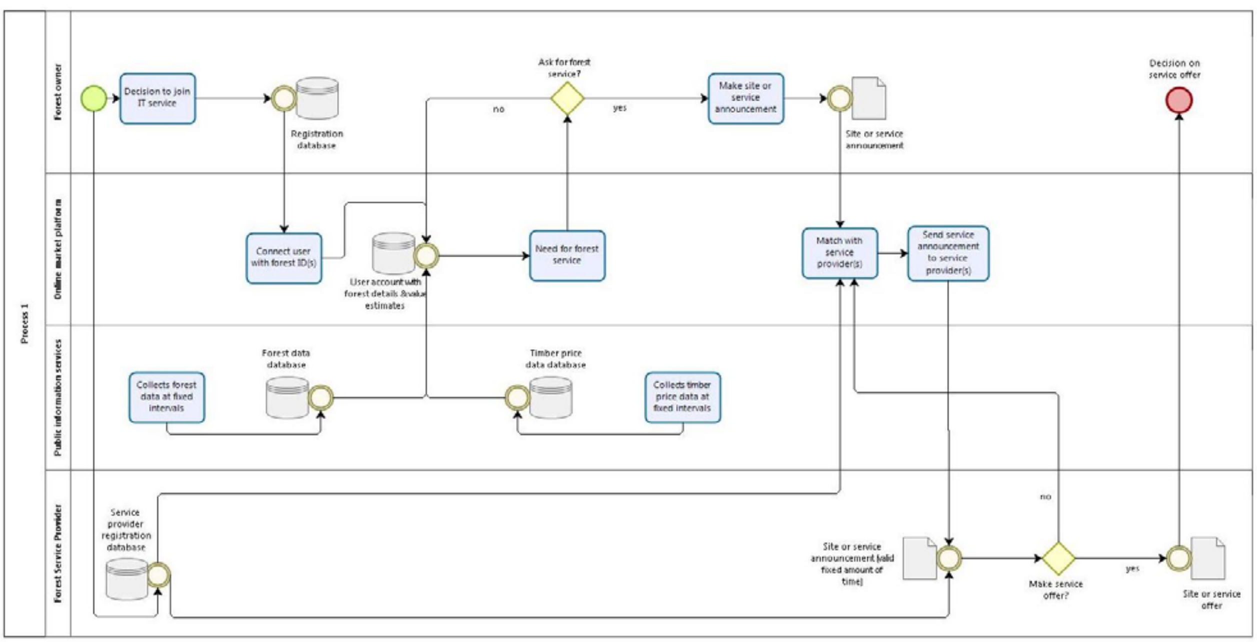

Figure 18. Example process map of simplified steps and principles when using available online market places.

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The traditional direct offer inquiry assumed a direct contact between the forest owner and a service provider without intermediate actors (Figure 19).

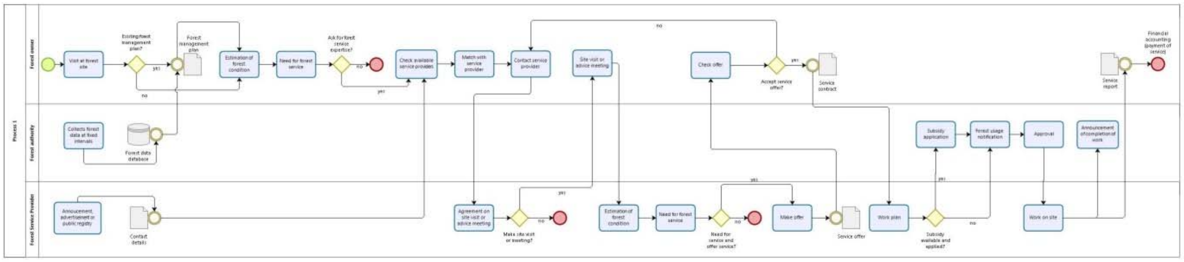

Figure 19. Simplified example process map showing the entire chain of a traditional service purchasing process from a forest owner perspective using traditional direct contact to a forest service provider.

Using the number of interactions as an indicator of process efficiency of the alternative business models, the simplified process of the "traditional direct offer inquiry" showed three main actors and numerous data exchange processes between the actors, depending on the availability of subsidies and assuming the contact to one main service provider (Figure 20).

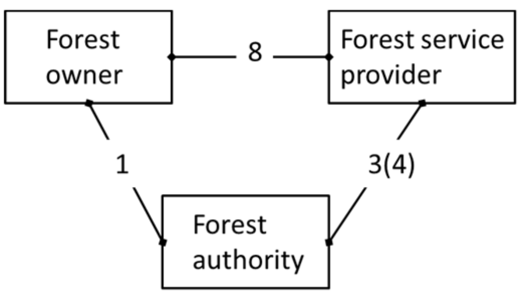

Figure 20. Example of process map for a traditional service purchasing process from a forest owner perspective using traditional direct contact to a forest service provider with 3 main actors and numerous data exchange processes. The number of data exchange processes between the forest service provider and the forest authority depends on the availability of subsidies assuming that the service provider takes care of the announcement.

The case "Online IT platform" focused on a simplified general level covering the principle of tool "Online IT platform" based on the available service Metsään.fi from a forest owner´s perspective (Figure 21).

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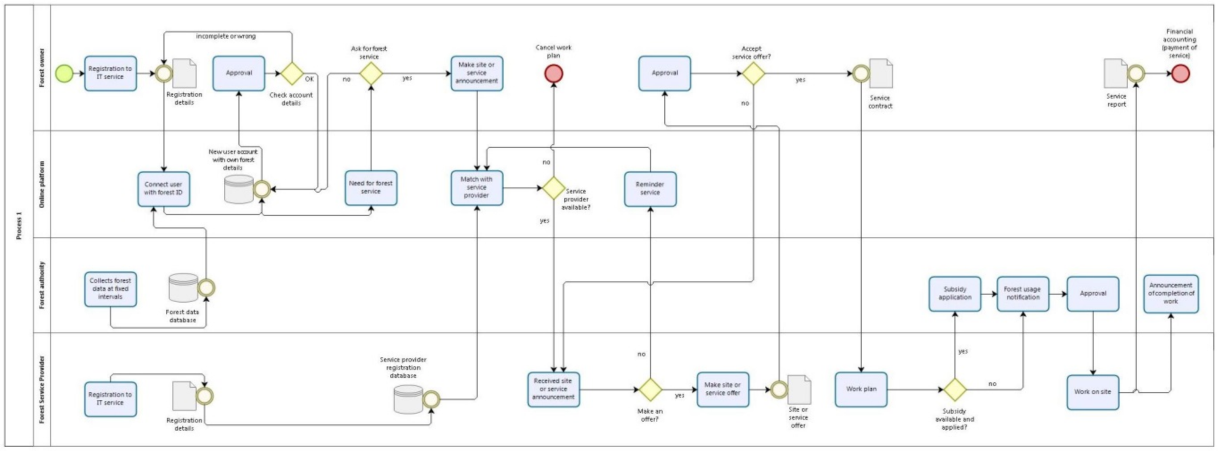

Figure 21. Simplified example process map showing the entire chain of a service purchasing process from a forest owner perspective using online IT platform.

The number of interactions (as an indicator of process efficiency) in the simplified process of the "online IT platform" showed four main actors and numerous data exchange processes between the actors, depending on the availability of subsidies and registration situation of actors and without a reminder function (Figure 22).

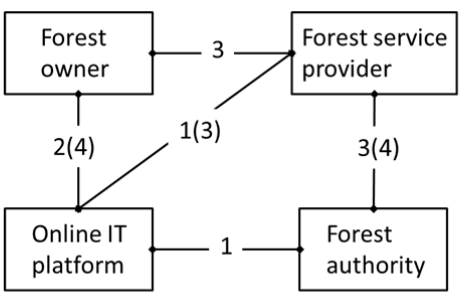

Figure 22. Example of process map for a service purchasing process from a forest owner perspective using an IT service platform with 4 main actors and numerous data exchange processes. The number of data exchange processes between the forest service provider and the forest authority depends on the availability of subsidies assuming that the service provider takes care of the announcement, the number of data exchange processes between the forest service provider and the Online IT platform depends if the service provider is already registered to the platform, the number of data exchange processes between the forest owner and the Online IT platform depends if the forest owner is already registered to the platform.

In addition to the reduced amount of data exchange processes for the forest owner, the processing time of data exchanges is being reduced. This is the case as the online IT platform performs its process basically almost instantly and without major delay. Nevertheless, the entire reaction and handling time in both cases still depends on individual persons involved.

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3.2.2 Case Norway

For all 27 simulations, the distributions of monthly KPIs are shown below in figure 23. The distributions can be compared between panels from the smallest contract bank (1 quarter) to the largest (3 quarters). In this case the cover time is expressed as the number of quarters of production time which the contract bank corresponds to. For each KPI (deviation from production goals, machine hours, distance between sites) the distribution narrows as the contract bank cover time increases.

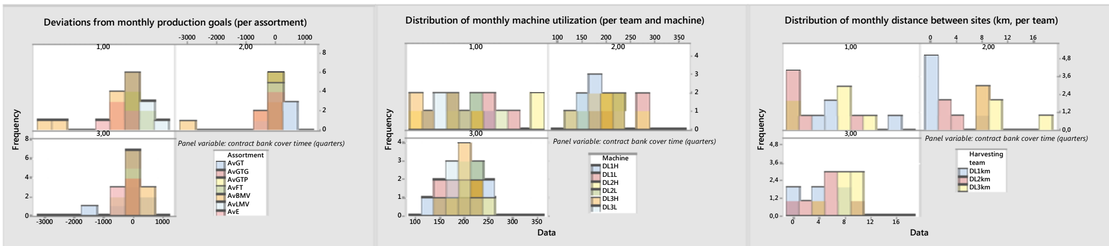

Figure 23. Distribution of monthly production KPIs for three sizes of contract bank (panel variable: 1-3 quarters). Deviations from monthly production goals (left), machine utilization (middle), and distance between harvesting sites (right).

Between the 27 simulations, there exists considerable variation in the solutions as a result of the varying levels of production bonus (1, 5, 10 NOK/m^3). Figure 24 shows the combinations (trade-off) of relative deviations in monthly production (from defined goals) and machine utilization (from defined hours). An insignificant bonus (1 NOK/m^3) maintained small deviations in machine utilization (< 10 % on the x-axis), but allowed extreme variations in production (up to 70 % on the y-axis). A significant bonus (10 NOK/m3) maintained minor deviations in production (< 25 % on the y-axis) while allowing greater deviations in machine utilization (up to 20 % on the x-axis).

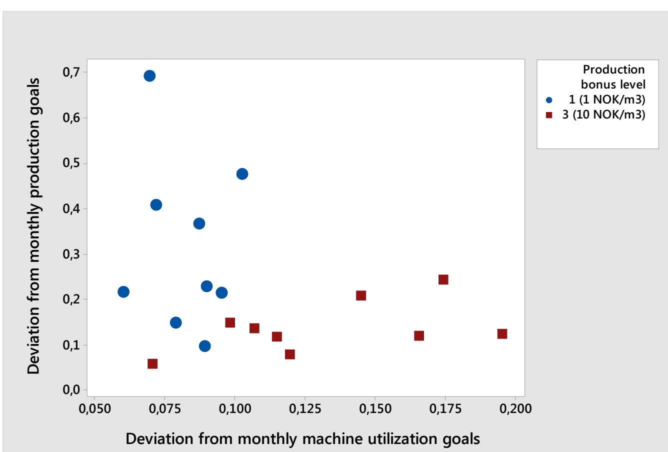

Figure 24. The relationship between monthly deviations from goals for production (y-axis) and machine utilization (x-axis) with two different levels of production bonus (1 and 10 NOK/m^3).

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Given the original 3 levels of contract bank cover times (3, 6, 9 months) it is also possible to track how the KPIs vary in relation to the remaining cover time as the simulation passed from March (winter) to April (spring thaw) and May (early summer).

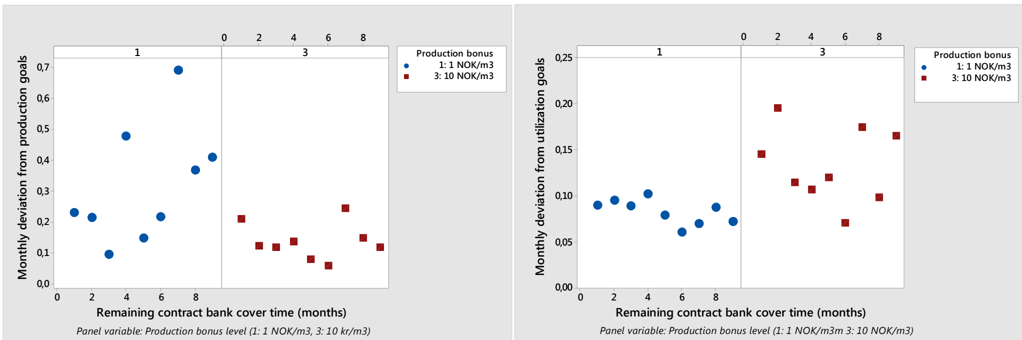

Figure 25. Deviations from production (left y-axis) and machine utilization (right y-axis) goals with increasing contract bank cover time (months on both x-axis) with two different levels of production bonus (blue: 1 and red: 10 NOK/m^3).

With an insignificant bonus for meeting production goals (1: 1 NOK/m^3) production deviations increased steeply with the increased cover time (Figure 25, left) while utilization deviations decreased slightly from an already low levels of approx. 10 % (Figure 25, right). With a high production bonus (3: 10 NOK/m^3) production deviations maintained low levels (10-20 %), while utilization deviations started high (15-20 %), decreasing with increasing cover times.

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4 Discussion & recommendations

Open forest data is the foundation for all forest operations. It contains valuable information on stands that helps us to understand our forest reserves better. Digitalization helps also to tackle the problem, that many forest owners lack the practical knowledge and know-how of managing forests and timing the operations accurately, because the owners are often far away from their stands. Thanks to open digital forest data, a forest owner who lives elsewhere can use the online service to access high-quality information to help in decision-making, irrespective of where they are. Open forest data helps forest owners to understand their forest: what kinds of trees, habitat and nature value there are, and how the forest can be used – or left unused – either economically or recreationally. In addition, it is possible to give others permission to utilise the information. This way, a forest industry operator could approach a forest owner for example with a seedling stand management offer.

The presented Finnish case study compared between the case "Online IT platform" and the case "traditional direct offer inquiry". The traditional direct offer inquiry thereby assumed a direct contact between the forest owner and a service provider without intermediate actors, while in practice intermediate actors such as FOC´s are regularly involved. Nevertheless, it is assumed that the involvement of additional intermediate actors will lead to an increased the number of actors and total number of processes therefore further increasing the already shown efficiency gap between the two main scenarios. The processes have been mapped from a forest owner perspective when matching the service need with a service provider offering such a service. This was done in a comparable, nevertheless simplified way leaving a certain degree of uncertainty and limitations.

The recommendations are based on the performed "As-Is" process mapping and identified general possible improvements when utilizing "Online IT platform" compared to the "traditional direct offer inquiry" mainly through visual observation. This study showed that the presented model applying an online IT platform required less process interactions than the traditional direct inquiry alternative. With the presented results of the "Online IT platform" being more efficient, the current design of the Finnish tool can be considered an optimal design of a service tool when compared to a common traditional offer inquiry. This is particular the case for the study performed in the compared and selected countries, although this is also valid for most other European countries as far as known. Thus, the presented Finnish case can be considered as an optimal design of a wood mobilization tool, especially when implemented at other regional levels compared to the state-of-the-art situation in other regions that were part of this task of mapping the existing IT services. Through the transfer of the presented design and best-practices, other regions could equally benefit from the efficiency improvement potential offered through the adaptation of such technology and service.

Although the benefits of the online platforms are apparent, discussions within the consortium raised further questions on the issues of privacy, data protection and competition between traditional actors in the field. This issue was a concern particular regarding the currently strong role of FOC´s on the markets. Thus, the further development towards efficient business tools and services for stand treatment and wood mobilization requires the involvement of various actors and stakeholders in the field, especially in countries or regions without such existing online IT platforms. Nevertheless, as shown through the Finnish case, other key actors in the field, including FOC´s and partly also in a joint effort, are utilizing the benefits and have created their own IT solutions, online market places and IT services building on the openly offered services and information. The aim of such e-services is also to being able to mobilize timber onto the market and attract the more passive forest owners. Nevertheless, the customer relations, e.g. through cooperative structures or the membership in associations, might influence how IT tools are working; how a customer is connected to the service company, for example, might effect on the tools (fee, trust, history, cooperative membership etc.).

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Recommendations for the further development of services and platforms could include the following aspects: emerging the Finnish case study on an "online IT platform" could include further analytical steps such as quantitative analyses and reengineering of business processes based on actual data on time spent by process owners on the different involved processes, such as the organisational and managerial work load (OMWL). Based on such analyses and a quantification of the OMWL, their respective costs could be calculated for example in form of the opportunity costs for further comparisons.

In the Finnish case, the task concentration was on an increased mobilization of raw material as well as an improvement of the efficiency of the processes from a forest owner perspective in addition to make whole the process as easy and convenient to forest owners as possible. A two-way exchange of key performance indicators, e.g. from benchmarking activities or from the TECH4EFFECT efficiency portal, with the presented system is currently still limited given the focus on the matching with a service provider performing the actual forest operation service. However, indirectly through the given service offer and competition between service providers a benchmarking may impact the overall efficiency of the service. In return, the history of a stand treatment, for example whether a pre-commercial thinning has been made or not, is important information for the service providers and might have an effect on the operations itself and their profitability. Also quality of work plays an important role, the importance of a quality control and factors to be taken into account in planning, controlling and improving the quality of forest regeneration activities has been studied in Finland on forest regeneration services by Kankaanhuhta (2014). A quality control loop after the conducted work through the service providers, e.g. using mobile applications, could contribute to the high quality outcome of a forest service system.

In the Norwegian case, the task concentration was on the potential for a more effective wood supply process for the FOA. The study provided generalized business process maps for purchase and production planning in a Norwegian farm forestry context (Figures 2 and 3), as well as how long-term forest management agreements may change the processes. For an FOA, such agreements ultimately provide the potential to stabilize wood purchase in a hot domestic market, as well as increase planning horizons in terms of the production cover time of the FOA contract bank. The innovation also offers the potential to reduce purchase lead times for initial contact with the forest owner (Figure 4). This can be particularly useful when periodic deviations in demand, production or operating conditions require rapid re-balancing of the contract bank.

A small simulation test was performed to test the effect of an increased contract bank (from 3 to 9 months) on production KPIs. Overall, the increased cover time reduced variation in monthly production and machine utilization per harvesting team (Figure 23). While an increased contract bank resulted in reduced monthly deviations in machine utilization for all scenarios, the monthly deviations from production depended on the use of an incentive (bonus) to meet monthly production goals (Figure 24). Most of the observed trends were logical, given the increased degree of freedom for selection of harvesting contracts enabled by the enlarged contract bank. There are a number of limitations to the general value of the results. First, the study was limited to 3 harvesting teams, which is a rather small organizational unit when attempting to deliver precise production volumes per assortment. Second, the contract cover times span from 3 to 9 months, which are rather long for Norwegian farm forestry. During its inception, only a small portion of the contracts in the contract bank could be expected to originate from such service agreements. The trends shown here were based on comparing KPIs between monthly optimization solutions. The solutions reflect the bonuses and costs included in the goal function employed. In the absence of a significant incentive for meeting production goals (prerequisite for meeting subsequent mill delivery plans), contract selection for the coming month was driven primarily by contractor needs for even capacity utilization and short relocation distances. With the addition of a significant production incentive, contract selection was driven by a balance between mill customer service levels and contractor goals.

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5 Literature

At Skog (2019). Retrieved from: https://www.atskog.no/bedreskog/

Haapaniemi M., Olsson D., Fjeld D. (2011). A generic process model for delivery scheduling of biofuels in Sweden. 34th Council on Forest Engineering, June 12-15, 2011, Quebec City (Quebec). 10 pp.

Kankaanhuhta V. (2014). Quality management of forest regeneration activities. Dissertationes Forestales 174. 93p. https://doi.org/10.14214/df.174

Metsä Group (2019a). Virtual forests are coming: Forest management takes a leap into the digital age. Web article. Retrieved from: https://www.metsagroup.com/en/Campaigns/IntelligentMetsa/intelligentforest/Virtual-forests-are-coming/Pages/default.aspx

Metsä Group (2019b). Wood supply goes digital. Web article. Retrieved from: https://www.metsagroup.com/en/Campaigns/IntelligentMetsa/intelligentforest/Wood-supply-goes-digital/Pages/default.aspx

Metsä Group (2019c). Modern data saves environment. Web article. Retrieved from: https://www.metsagroup.com/en/Campaigns/IntelligentMetsa/intelligentforest/Modern-data-saves-environment/Pages/default.aspx

Metsäkeskus (2019a). Metsään.fi. – Plan, manage online, find resources, provide services. Metsäkeskus. Leaflet 1/2019. Retrieved from: https://www.metsakeskus.fi/sites/default/files/metsaanfi-eservices-for-forest-owners-broschyr.pdf

Metsäkeskus (2019b). Open forest data. Product description. May 2019. Retrieved from: https://www.metsaan.fi/sites/default/files/avoin-metsatieto-tuotekuvaus-english.pdf

Metsäkeskus (2020). General information about open forest data. Web article. Retrieved from: https://www.metsaan.fi/en/general-information-about-open-forest-data

Ministry of Agriculture and Forestry (2020). Forest inventories. Web article. Retrieved from: https://mmm.fi/en/forests/forestry/forest-inventories

Müller F., Jaeger D., Hanewinkel M. (2019). Digitalization in wood supply – A review on how Industry 4.0 will change the forest value chain. Computers and Electronics in Agriculture 162: 206-218.

Rauch P., Borz S.A. (2019). Reengineering the Romanian Timber Supply Chain from a Process Management Perspective. Croatian Journal of Forest Engineering. 10 pp.

Rauch P., Gronalt M. (2005). Evaluating Organisational Designs in the Forestry Wood Supply Chain to Support Forest Owners´ Cooperations. Small-scale Forest Economics, Management and Policy, 4(1): 53-68.

Valonen M., Haltia E., Horne P., Maidell M., Pynnönen S., Sajeva M., Stenman V., Raivio K., Iittainen V., Greis K., Laitinen K. (2019). Finland´s model in utilising forest data - Metsään.fi-website´s background, implementation and future prospects. PTT reports 261. Helsinki 2019. 90pp.

Viken Skog (2019). Retrieved from: https://www.viken.skog.no/tjenester/skogpakker/

Windisch J., Röser D., Mola-Yudego B., Sikanen L., Asikainen A. (2013a). Business process mapping and discrete-event simulation of two forest biomass supply chains. Biomass & Bioenergy 56: 370-381. https://doi.org/10.1016/j.biombioe.2013.05.022

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 720757.

Windisch J., Röser D., Sikanen L., Routa J. (2013b). Reengineering business processes to improve an integrated roundwood and energywood procurement chain. International Journal of Forest Engineering 24(3): 233-248. https://doi.org/10.1080/14942119.2013.857833

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 720757.