Big Data bases and applications

D3.6 Improved efficiency in precision soil preparation and other regeneration activities – system development and architecture

31 August 2017

Version	Date	Written by	Reviewed by	Approved by
1.0	31 August 2017	Erik Willén (Skogforsk), Jori Uusitalo (Luke), Timo Saksa (Luke), Harri Lindeman (Luke)	Tomas Nordfjell (SLU)	Jori Uusitalo (Luke)

Table of contents

1. EFFORTE project objectives

EFFORTE is a research and innovation project providing the European forestry sector with new knowledge and knowhow that will significantly improve the possibilities of forest enterprises to assemble and adopt novel technologies and procedures.

The project aims at enhancing the efficiency of silviculture and harvesting operations; increasing wood mobilization and annual forest growth; increasing forest operations' output while minimizing environmental impacts; and reducing fuel consumption in the forest harvesting process by at least 15%.

The project is based on three key elements of technology and knowhow:

1) Basic understanding of fundamentals of **soil mechanics and terrain trafficability** is a crucial starting point to avoid soil disturbances, accelerate machine mobility and assess persistence of soil compaction and rutting. The key findings and recommendations of trafficability related to EFFORTE can immediately be adapted in all European countries.

2) Due to decreasing Cost-competitiveness of manual work and maturity of technology it is now perfect time to realize the potential of **mechanization in silvicultural operations**. EFFORTE pursues for higher productivity and efficiency in silvicultural operations such as tree planting and young stand cleaning operations.

3) 'Big Data' (geospatial as well as data from forestry processes and common information e.g. weather data) provides a huge opportunity to increase the efficiency of forest operations. In addition it adds new possibilities to connect knowledge of basic conditions (e.g. trafficabillity), efficient silviculture and harvesting actions with demand and expectations from forest industries and the society. Accurate spatial information makes it possible for forestry to move from classic stand-wise management to precision forestry, i.e. micro stand level, grid cell level or tree-by-tree management. EFFORTE aims at achieving substantial influence to the **implementation and improved use of Big Data within Forestry** and through this increase Cost-efficiency and boost new business opportunities to small and medium size enterprises (SME) in the bioeconomy.

EFFORTE researchers will develop and pilot precision forestry applications that, according to the industrial project partners, show the greatest potential for getting implemented immediately after the project.

2. Improved efficiency in precision soil preparation and regeneration methods – system development and architecture

Sustainable forest management and planning is traditionally based on stand-level inventories and forest stands are delineated and formed either on operational or biological basis. Typically, the size of forest stand varies between 1 to 10 hectares. However, stands could comprise rather broad small-scale variation regarding tree species mix, soil properties, fertility, etc. The term **'Precision forestry'** is an emerging forest management concept based on observing, measuring and responding to the intrinsic variability within forest stands.

Based on modern techniques (e.g. airborne laser scanning) is it possible to produce trustworthy and in spatial scale precise predictions on site quality indices, diameter-height distributions and micro-topography for a given point, grid cell or on sub-stand level. Interlinking information of tree attributes and site index with topographical, cartographical and hydrological information provides a way forward to upgrade forestry efficiency. Further, increasing efficiency by 'precision forestry' does not interfere with environmental targets. On the contrary, precision forestry gives forest practitioners tools adjust to the unique features of the site by managing the forest more according to biological prerequisites, by adjust timing of forest operations and avoid forest traffic on sensitive spots.

Precision forestry philosophy – division of stand to smaller units and managing the stand at micro stand, grid cell or tree-by-tree level – provides a huge possibility to increase the forest growth. By adjusting species selection, young stand treatment procedures and thinnings according to precise information on soil properties (fertility, wetness, soil type) and micro-topography will inevitably lead to an increasing growth of a single tree. However, optimal solutions to execution have to be assessed via proper feasibility analyses including trustworthy information on growth and costs.

This report describes system development, data requirements and architecture of modern big data tools aimed at increasing forest growth and improving efficiency of soil preparation and regeneration methods. Broader and more detailed description of the most relevant data sources utilised in forestry applications is described in the EFFORTE report on *Mapping and SWOT analysis of existing and future big data sources (D3.1)*. The system requirements are described on a general level, not focusing only on IT-requirements, more on requirements based on input data, processing and further dissemination of results. The system architecture shows the preliminary system design, including the necessary building blocks to be further elaborated in later EFFORTE project deliverables on *Pilot software* as examples of processing tools. This report describes the situation in Sweden and Finland but most applications can with minor modifications be adopted in most European countries.

Data requirements

The data requirements section describes the proposed datasets to be included in the system.

Digital elevation models

Digital elevation models (DEM) are key requirements regarding precision soil preparation and other regeneration activities. The new DEM layers available both in Sweden and Finland are based on airborne laser scanning inventories and have a spatial resolution of 2 meter and may show important details for silviculture. For instance, in Figure 1 the road from right to left in the centre of the imageis easily detected. It ends close to the lake (blue colour in image). There are also some ditches with straight lines in the top centre part of the image. Apart from those artificial structures also elevation variability is clearly shown. All these features have a large potential to be used both in planning phase as well as in everyday operational use.

Figure 1. Detailed digital elevation model. © Lantmäteriet

Also, different datasets derived from the DEM may be of support for soil preparation and other regeneration activities. Slope may be calculated from the DEM and verges or other steep formations identified. Figure 2 illustrates a forest cutting (outlined in blue), a DEM and steep areas in reddish colours. These kinds of decision support are very useful when planning how to outline cutting area for harvesting to avoid terrain transportation in the steepest parts and cover efficiently the area in soil preparation.

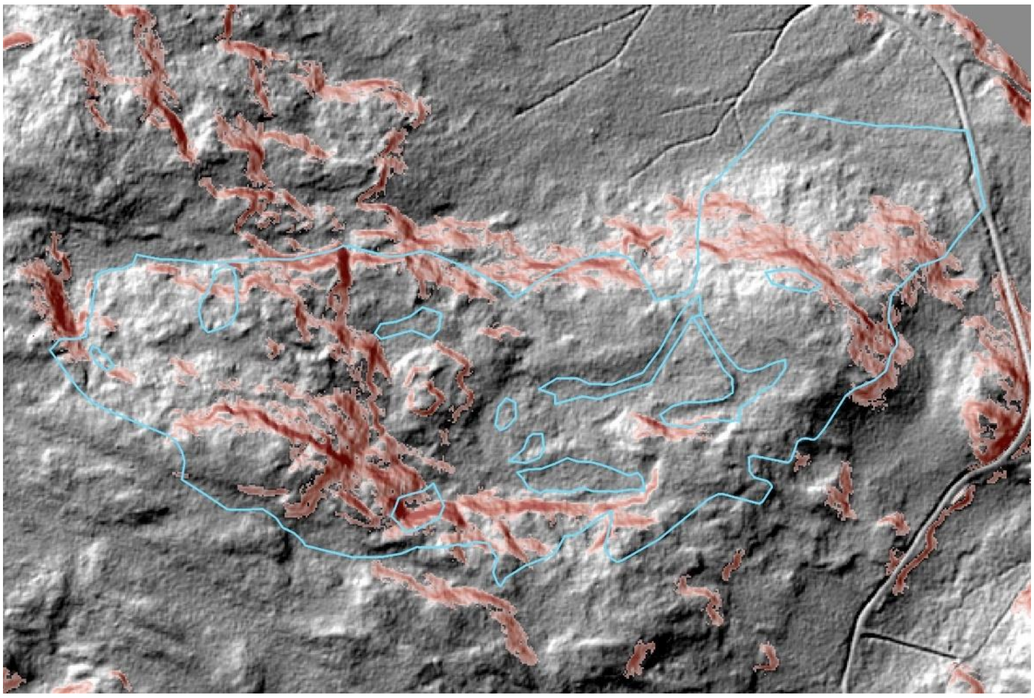

Figure 2. Slope derived from the DEM, steep areas in reddish colours. © Lantmäteriet

Figure 3 is a visualization from the same area as in Figure 2 but now tracks from the soil preparation are mapped and visualized. It shows how steep areas are avoided and soil preparation performed mostly in parallel to the steepest areas.

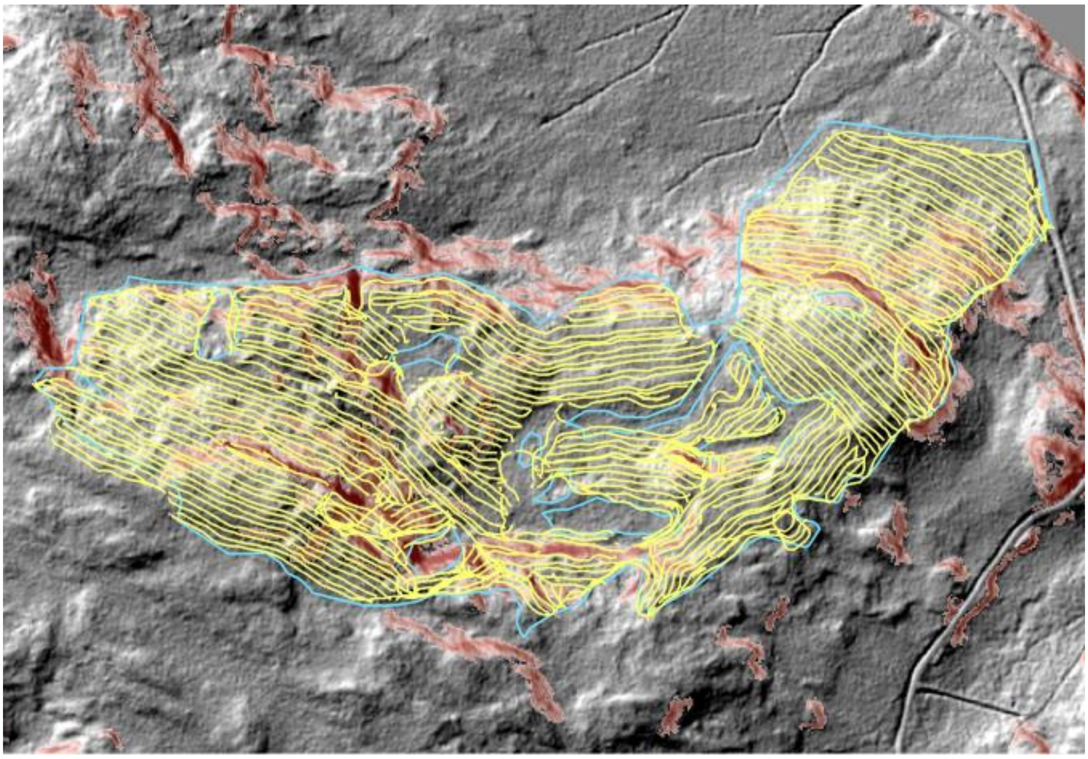

Figure 3. Tracks from soil preparation (yellow) on DEM with slopes indicated. © Lantmäteriet

The DEM may also be used to produce depth-to-water maps (DTW) with large potential both in soil preparations and other regeneration activities (Figure 4). DTW maps show where precipitation (water) is aggregated with finer soils compared to the surroundings. Finer soils are more sensitive to soil preparation and alternative methods or adjustment of soil preparation equipment should be considered. Also the finer soils should be taken in consideration when selecting tree species and the plant material. DTW maps can be also used to reject the wettest areas outside the soil preparation already in planning phase.

The DEM can also be used for analysing risks of erosion and nutrient run-off after different kind of soil preparation as well as adjusting water protection zones according local circumstances. DEM and different kind of wetness indexes could also be used for locating retention trees on places favourable for biodiversity and wood production.

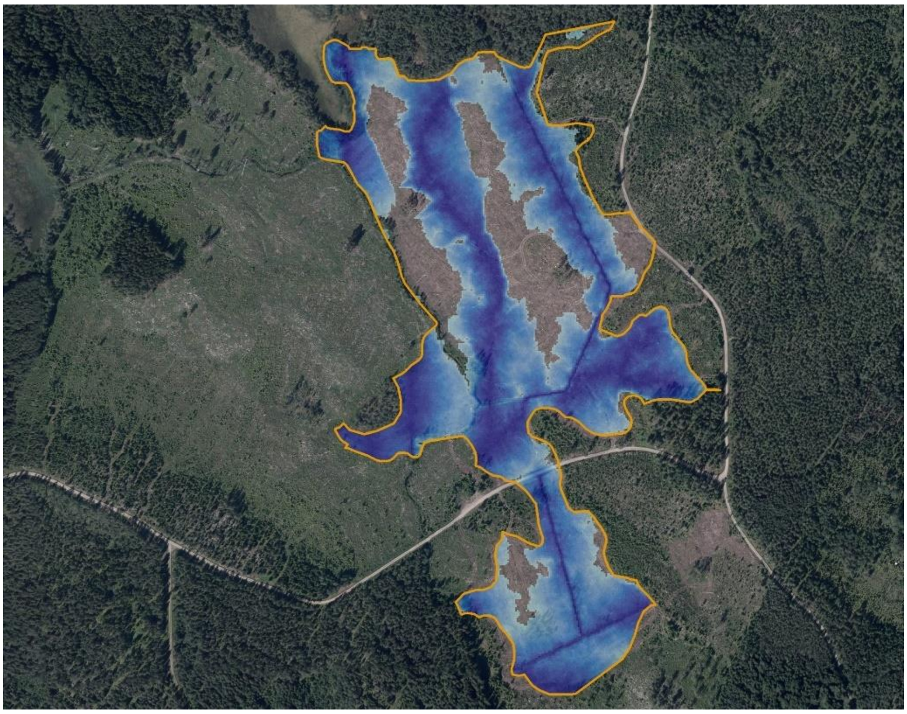

Figure 4. Depth to water map with a forest cutting (yellow outline) where blueish colours represent ground water within 1 meter depth. © Lantmäteriet

There are also additional information to derive from DEM of potential interest for precision soil preparation and other regeneration activities. One example may be the length from the nearest hill as dryer areas presumable are closer to the hill and this could have an impact on the selection of tree species, regeneration method and plant material, i.e. more often pine species are planted on dryer areas.

Another important ground condition for soil preparation is the soil roughness and this could be hard to get directly from the DEM. As most detailed DEMs are derived from Lidar data it might be possible to get the soil roughness from the Lidar point clouds. However, some studies indicate the need for more detailed point clouds than 0.5-1 hit/m^2 to get reliable measures of soil roughness. If such datasets are derived from denser point clouds it will be handled as a derivate from the DEM as e.g. slope.

Harvester data

The most detailed data from the forest are collected by the harvesters. Every stem is mapped in detail and with a de facto standard, StanForD 2010, used by all major forest machine manufactures. The position of each stem is today mostly defined as the position of the harvester while it is cutting the tree (i.e. no exact location of the harvester head). However it is likely that in the coming years exact location of the tree to be felled can be derived using information on crane and harvester head positions. Using only the harvester position you might gather information on stems harvested and visualize the stems within a harvested stand. Based on this information forest may be divided into sub-compartments according to tree or stand characteristics. Figure 5 visualizes a stand where the stand is divided into sub-compartments according to basal area. All stems are shown as yellow dots. Each sub-compartment is typically 0.5- 2 hectares and special tree or stand characteristics may be derived for each sub-compartment individually (Table 1).

Harvester data gives also possibility to describe variation in growth potential inside the cutting area. The size or growth rate dominant trees could be used as classification criteria for outlining sub-compartments and the selection of tree species could be based on the growth potential of each sub-compartment.

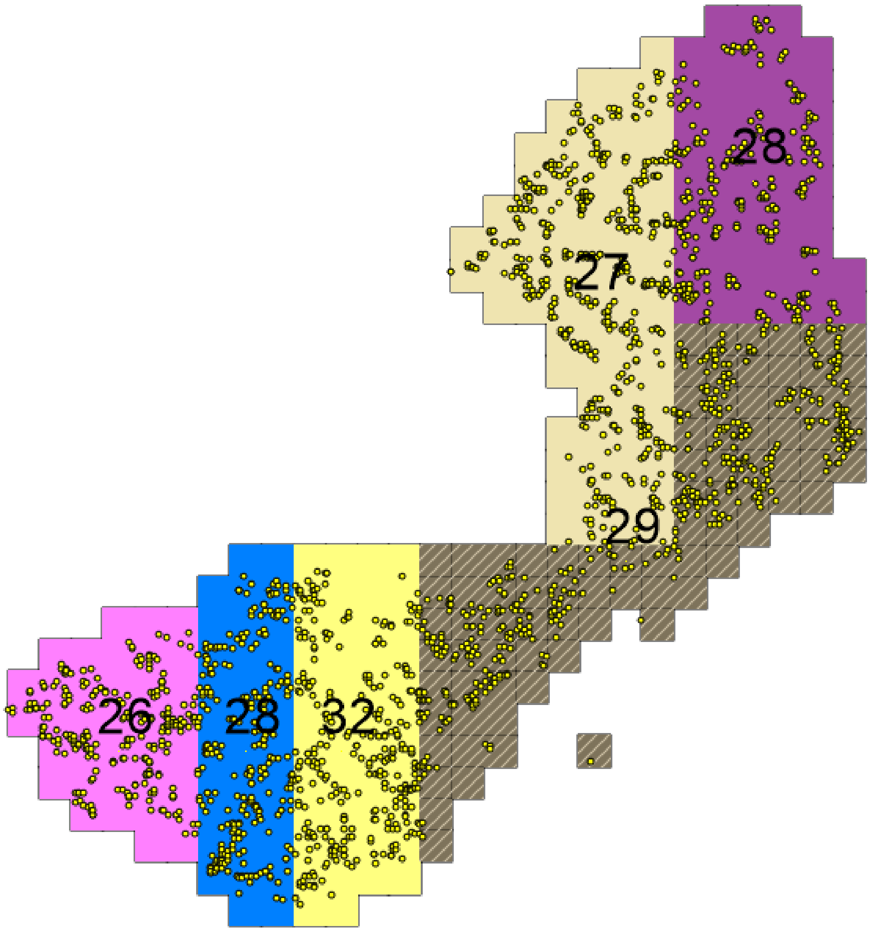

Figure 5. Sub-compartments from harvester data based on basal area

Table1. Statistics from one of the sub-compartment.

Id	Tree species	Volub	Volsk	Basal area	Mean height	Mean diamater	Stem average size	Number of stems
22824	Totalt	257,3	297,0	29,2	23,9	32,3	0,50	514
22824	Pine	63,8	73,9	7,1	23,7	33,5	0,67	96
22824	Spruce	185,8	214,2	21,1	24,0	32,0	0,47	398
22824	Deciduous	7,6	8,9	1,0	24,1	29,2	0,38	20

New forest machines that employ the StandForD2010 standard compile harvester data into the HPR-file. The file can be interpreted with a software, Hpr-analys, developed by Skogforsk. The software comprises nice tools to classify and visualize tree characteristic of the felled trees within the stand. The software also encompasses a feature that allows data conversion to ARCGIS-formats. This feature gives us the possibility to link harvester data to numerous data sources that may be beneficial in decision-making. Although the Hpr-analys-software has been developed in Sweden, within EFFORTE project, have successfully been able to utilise the tool in Finland, and link harvester data to various additional data sources (Figure 6). In EFFORTE we will diligently explore together with our industrial partners various exciting alternatives to find the most appropriate ways to benefit this technology.

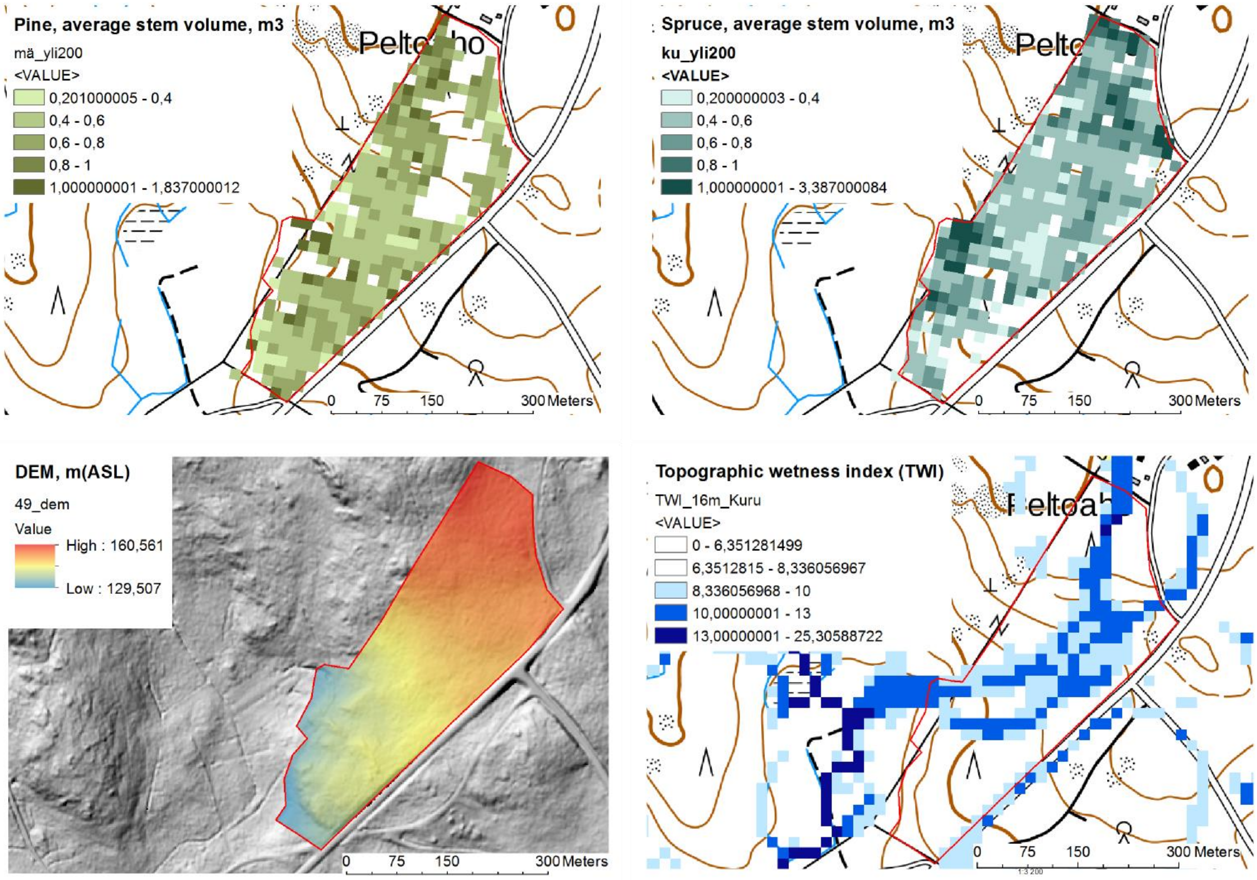

Figure 6. Information on exact location on trees may be linked with other data sources, such as DEM, TWI, etc. Data acquired from a logging site from Middle Finland. Data source and base map: National Land Survey of Finland

It is also possible to record additional information about the growing stock during harvest. Information about rot distribution within the stand may be used to plan tree species composition in the regeneration, see example below, or taking other measures for a successful forest establishment (Figure 7). Considerations taken may also be recorded, e.g. snags or stumps to protect cultural heritage. All recorded considerations may be used in coming silviculture operations to ensure the protection of the considerations.

Figure7. Example of spruce rot distribution – 32% of stems affected. © Lantmäteriet

Cutting directive

Cutting directives are produced by forestry planners or timber byers in advance to forest operations. The forest to be cut are inspected in field and normally all necessary planning is performed during that one visit. The directive normally consists of documents and maps. It includes ground conditions, a description of the forest to be cut, instructions to cutting teams (e.g. landing sites, where to put the cabin), considerations, forwarder distance and yield estimates (Figures 8 and 9).

In addition, information about soil preparation and other regeneration activities is collected. Recommendation for soil preparation method, regeneration method and main tree species to be cultivated are planned. These may be updated if additional information is collected by the harvester teams.

Traktbeskrivning

Traktdel	Areal	SIND	Ålder	GYL	Åtgärd	Grot	Certifiering	UR	TGL	Fröträd/Skärm	Uttag m3fub/ha	Uttag m3fub	Medelst am	Medelväg
66G7H9707	1,2	T22	86	221	SH		FSC PEFC	1,2	730		141	171	0,28	890
66G7H8708	4,1	G27	86	222	SH	4,1	FSC PEFC	4,1	370		304	1257	0,58	160
66G7H9607	28,2	T25	86	222	SH	28,2	FSC PEFC	28,2	730		250	7068	0,47	720
Total	33,6					32,3		33,5				8495	0,48	641

Anteckningar: 66G7H9707 : Ingen grotning.

66G7H8708 : Behövs fler naturvärdesträd kan grupp placeras i nord, nordvästra kanten.
En zon om ca 5 m närmast diket underröjs ej om det inte gynnar det lilla löv och hassel som finns.

66G7H9607 : Bestånd med varierad bonitet, en del inslag av häll. Ge akt på översilningar/fuktigare stråk som

Figure 8. Illustration of cutting directive document -description of forest to cut with notes about considerations.

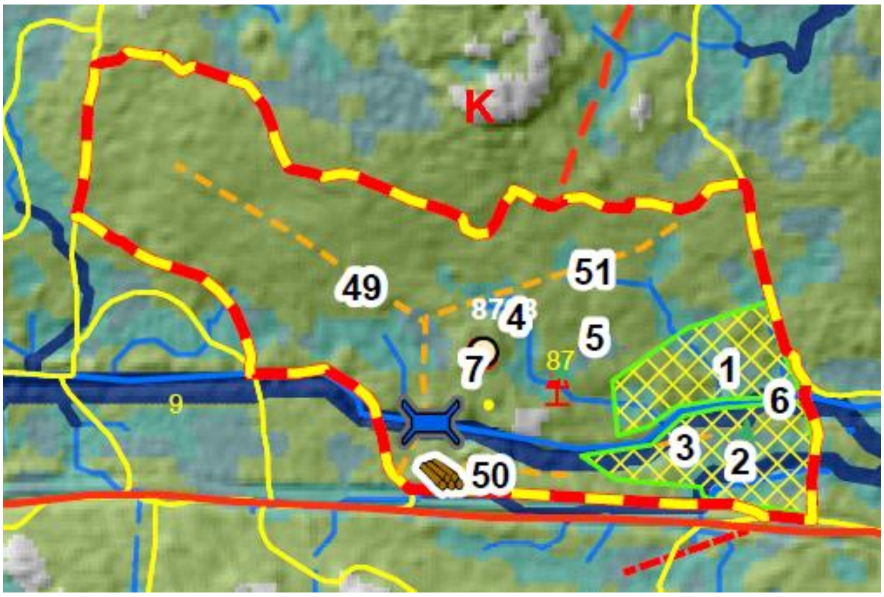

Figure 9. Cutting directive map with number as references to the document (Figure 8) for further descriptions.

Soil maps

Selection of regeneration method as well as selection of soil preparation method depends on soil characteristics. Fine textured soils are not suitable for direct seeding because of risk of frost heaving and soil preparation method (like mounding) should adjusted according to soil particle size. Large areas of peat layered soils also need special attention in terms of soil preparation and replanting (technique and plant material).

Most soil maps are however quite general and not detailed enough for operational planning, but as the details vary along the country it might be useful at least in some areas. There are also initiatives to try to map certain soil conditions with a high degree of detail. In Figure 10 the clay content are mapped with a 50-meter spatial resolution. Such detailed information may be highly useful for silviculture operations.

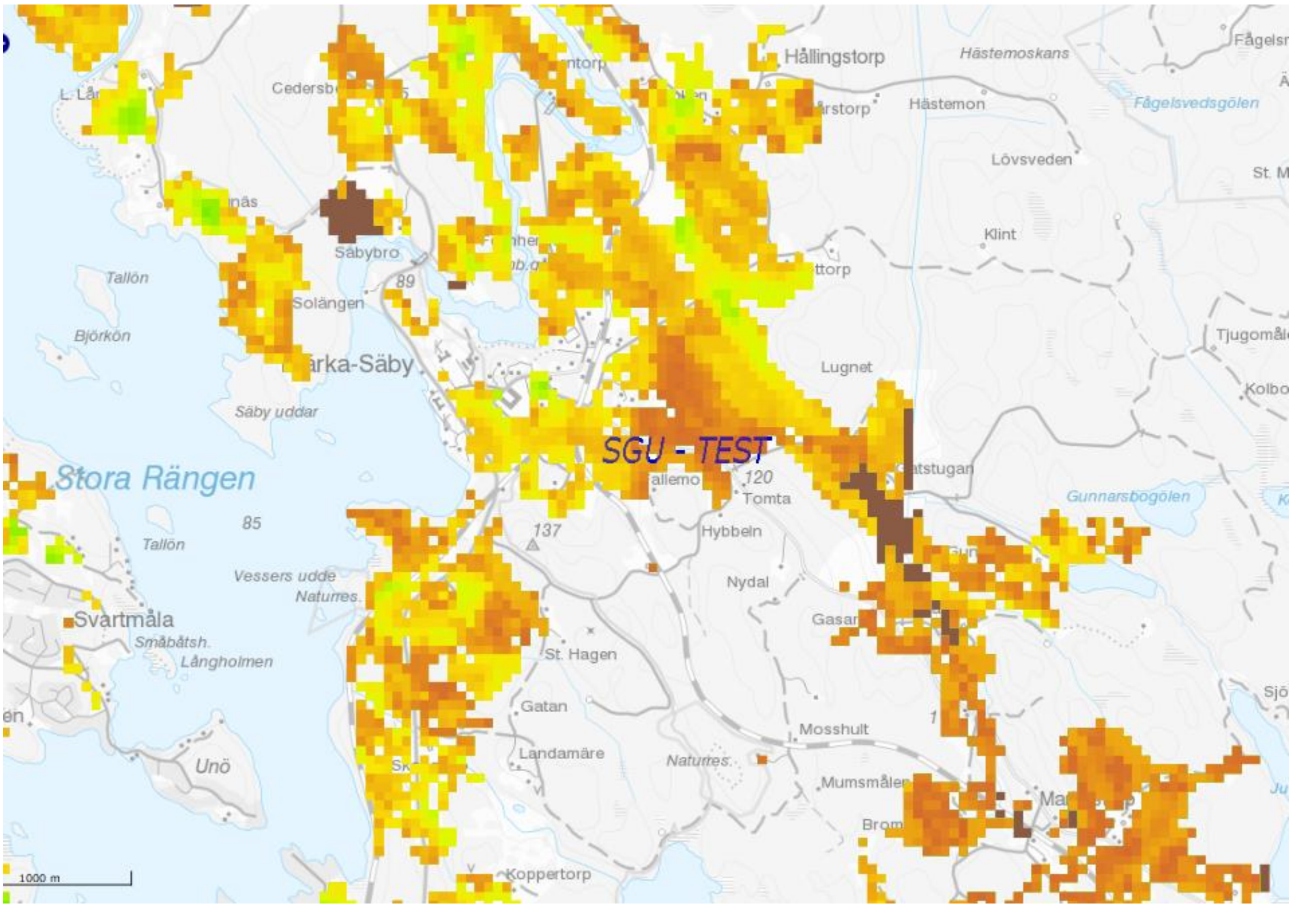

Figure 10. Detailed map on clay content. © SGU, Lantmäteriet

Environmental and cultural heritage considerations

National databases on environmental and cultural and environmental considerations are important to include in a system for improved efficiency in precision soil preparation and other regeneration activities. Some of those considerations may accept soil preparation and other regeneration activities, but with special concern. For instance, protection zones around lakes and rivers could be planned more precisely with Big data than before. Such concern must be known and considered in silviculture operations. In most environmental or cultural heritage considerations soil preparation or regeneration is prohibited. The inclusion of environmental considerations and cultural heritage should be included in the proposed system.

Weather data

Data on weather conditions may be used in different applications for soil preparation or regeneration. Together with soil or DTW maps weather data may predict trafficability and preferred methods for soil preparation. It may also be used for regeneration planning, e.g. plant distribution and handling. Weather data are often used in hydrological models possible to integrate in system oriented approach together with other data specified in this report (Figure 11). Climate data may be very useful in selecting plant material for the forest to be established and grow in a changing climate, but this is not included in the current system requirements as it focuses on precision soil preparation and regeneration methods in shorter terms.

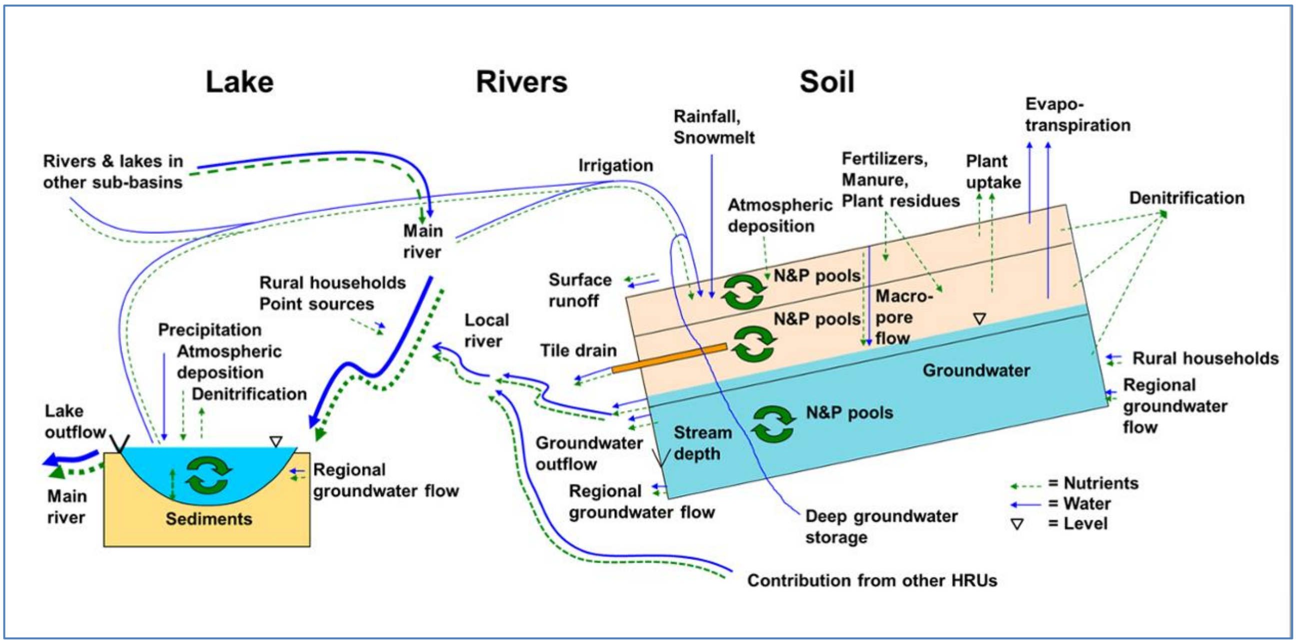

Figure 11. The HYPE hydrological model. © SMHI

3. System requirements

System requirements include the preliminary requirements for hardware, software and other requirements. Other requirements also include data formats and standards.

Recommended hardware requirements

The system should be able to run on ordinary office PCs with specifications as specified in the table 2.

Table 2. Recommended hardware requirements

	Requirement
Operating system	Windows 10, 64-bit operating system
CPU	2.40 GHz
Memory	8.00 GB
Hard Drive	100 GB of free space

Recommended software requirements

To run and use the results from the system the recommended software requirements are listed in the table 3 and recommended data formats in table 4.

Table 3. Recommended software requirements

Application	Software
Internet Browser	Internet Explorer 11, MS Edge
GIS and Image processing	ESRI ArcMap 10 or Pro, including spatial analyst
Statistics	MS Excel
Harvester data processing	Hpr-yield, hpr-CM, Forest prognosis (Skogforsk in-house sw[1])
Database	MS SQL-server, PostgreSQL + PostGIS

Other requirements

Table 4. Recommended data formats

Data type	Format
DEM, DTW, Slope	Geotiff
Harvester data	StanForD 2010 (*.hpr), Forestand, ESRI *.shp
Cutting directive	XML, Forestand
Soil maps	Geotiff
Environmental and cultural heritage considerations	ESRI *.shp
Weather data	Geotiff, ESRI *.shp
Decision support	XML, Forestand, geotiff, ESRI *.shp

4. Proposed system architecture

The proposed system architecture shows the preliminary system design in terms of data flowchart, databases, processing steps and distribution to operational users.

Figure 12 present the overall system architecture with four major corner stone's further described in the figure 13. The distribution of decision support to forest machines, tablets or other mobile devices are not described in detail as different users, forest companies and entrepreneurs use different devices. Distribution using any kind of cloud service is preferred to enable easy access for any approved user.

[1] Freely available for Skogforsk partners (stakeholders)

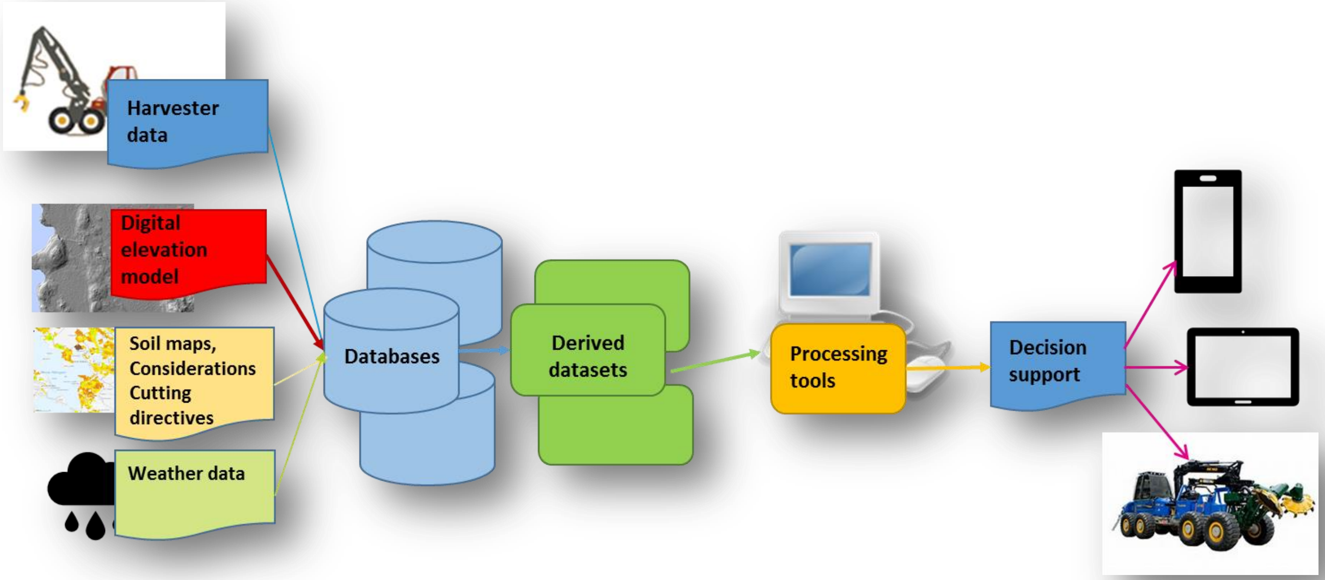

Figure 12. Overall system architecture of utilising big data in soil preparation and other regeneration activities.

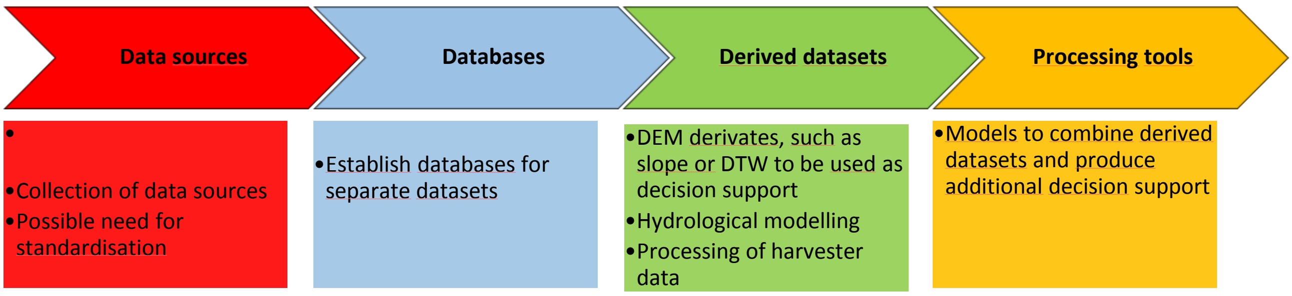

Figure 13. Four corner stones of utilising big data in soil preparation and other regeneration activities.

The data sources have different owners where harvester data and cutting directives are owned by the forest companies while the other datasets are from the Land Survey, Met office and Geological Survey. Public datasets may soon be structured in databases accessible through webservices and not necessarily at the user's premises. Currently every user needs to establish their own database of all datasets.

The production of derived datasets is based on different methods and to be performed by users themselves or, in some cases service providers. Some of the derived datasets are based on expert tools and knowledge, e.g. hydrological modelling often performed by the Met office. The processing of data owned by the forest companies should be processed by themselves or approved service providers. Note that some of the derived datasets will be used as decision support without further processing.

The processing tools will combine derived datasets and produce several decision support tools for different applications and users. Some of them will be used in planning and other in operational forest activities., Both in planning and in regeneration activities different devices will be needed in decision making , such as mobile devices, tablets, etc. and they will be integrated in forest machine data systems.

5. Conclusions

The proposed system architecture is based on state-of-the-art databases such as a detailed digital elevation model, harvester data, soil maps and weather data. They are available in many European countries and therefore a clear potential to be utilised even more in soil preparation and other regeneration activities. Even with rather basic processing those datasets may be of significant support. It also implies the potential to introduce some decision support to be followed by more advanced methods.

Harvester data are never freely available and it is important for forest companies to secure access to the data. For operational use, separate harvester databases should be set up where it may be possible to extract data for combinations with other datasets to produce detailed decision support. The setup of the harvester database requires special attention as it soon evolves to substantial databases and may be used for several applications also apart from soil preparation and silviculture. For research organisations, it is crucial to secure access to harvester data, preferably in co-operation with a forest company to implement the results.

More advanced models including soil maps and weather data may also be utilised to produce decision support. It is likely that it will add significant improvements, but during the EFFORTE project this is further studied. They may vary in different countries why these kinds of models likely need national or even regional testing and refinement.

The importance of standards cannot be underestimated. When large databases will be established a smooth data exchange is a prerequisite and some extra effort put in this domain ahead of implementation is necessary. This is of special interest for those datasets where limited standardisation efforts have taken place.

The proposed architecture should be able to run on ordinary office PCs, however there might be other requirements in the modelling to produce certain input data, e.g. hydrological models.