



## **Big Data bases and applications**

### **D3.4 Planning for precision forestry by means of trafficability maps**

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## 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. trafficability), 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. Planning for precision forestry by means of trafficability maps

### Introduction

This report (D3.4) describes how planning for precision forestry may utilise trafficability maps. A previous report (D3.3) include the input data and methods to produce the trafficability maps.

### Background

New decision support systems are needed for precision planning of forest operations for enhancing the efficiency and environment friendliness in mechanized forest operations. For example, in Finland it is estimated that poor bearing capacity of the soil causes dozens of millions of euros loss annually in wood purchasing due to decreased machine utilization, sudden lay-downs and lowered machine productivity. Nearly 40 % of Finnish forest land is in areas, where are difficulties in trafficability at a certain time of the year.

The major challenge in mechanized harvesting is heavy seasonal variation in roundwood cuttings (Figure 1). Seasonal variation causes economical losses specially to forest machine entrepreneurs. The size of logging fleet has to be adjusted by maximum logging opportunities and industry requirements during best harvesting season, winter. Therefore, there are many machines idling during the low cutting seasons, especially during summer. Seasonal variation is caused mainly by the lack of suitable logging sites during summer, difficulties in trafficability of forest soil and gravel roads during thaw seasons and shorter and milder winters (Kärhä et al. 2017<sup>1</sup>). All these are weather dependent factors. One common target agreed by most of the practitioners in forest sector is to increase loggings during summer time. For allocating logging sites for summer, woody peatlands with good quality ditch network and spruce dominated thinnings have been the types of forest areas in special focus.

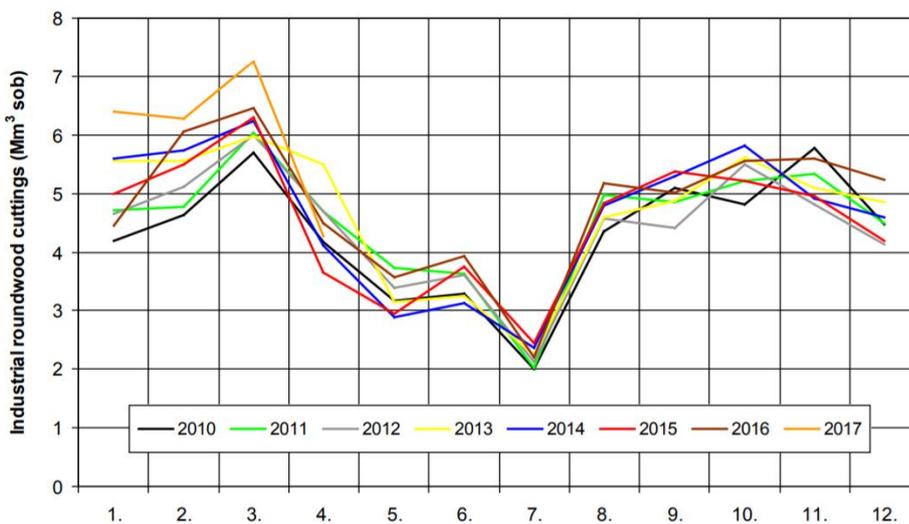


Figure 1. Industrial roundwood cuttings by month in 2010s in Finland.

<sup>1</sup> Kärhä, K., Tamminen, T., Leinonen, T. & Suvinen, A. 2017. Seasonal Variation of Production in Forest Industries and Wood Procurement in Finland. PPT-presentation in NOFOBE and NB-NORD Conference "Industrial Scale Bioeconomy and its Requirements" 14–16 June 2017, Lappeenranta, Finland. 47 slides

So far the decisions of classifying sites in terms of terrain trafficability, i.e. classifying sites for different seasons to be operable by forest machines, have been made subjectively. Terrain classification systems (e.g. Berg, 1982)<sup>2</sup> have been implemented and support for classifying the trafficability of the site has been made by collecting information from base maps and making visual detection while visiting the site. Sometimes forest planning practitioners have used field measurement tools such as steel rod sounding for receiving more information of the bearing capacity of soil, as example.

More precise forest big data in terms of measurement, estimation and positioning accuracy are currently available for decision support systems for planning and executing forest operations. By combining remote sensing data from forests and other available data from terrain the timing of forest operations, selection of machinery, bordering of site to be operated are becoming more precise. In EFFORTE-project, trafficability map methods have been further developed and tested.

### 3. Utilization for enhanced precision planning

#### Depth to water (DTW) maps

The DTW model has been used as a map layer in forest operations in Sweden. First studies were performed in 2014. It was first used in trials to evaluate were damages to soil and water appeared in logging sites compared to the DTW model. The results<sup>3</sup> showed that more than 70 % of all serious damages (defined in the forestry act) and approximal 50 % of all soil and water damages appears within blue areas in the DTW model (Figure 2).

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<sup>2</sup> Berg, S. 1982. Terrängtypsschema för skogsarbete (in Swedish). Skogforsk

<sup>3</sup> Bergkvist, I., Friberg, G., Mohtashami, S., Sonesson, J. 2014. The STIG project 2010-2014. Report 818-2014. Skogforsk

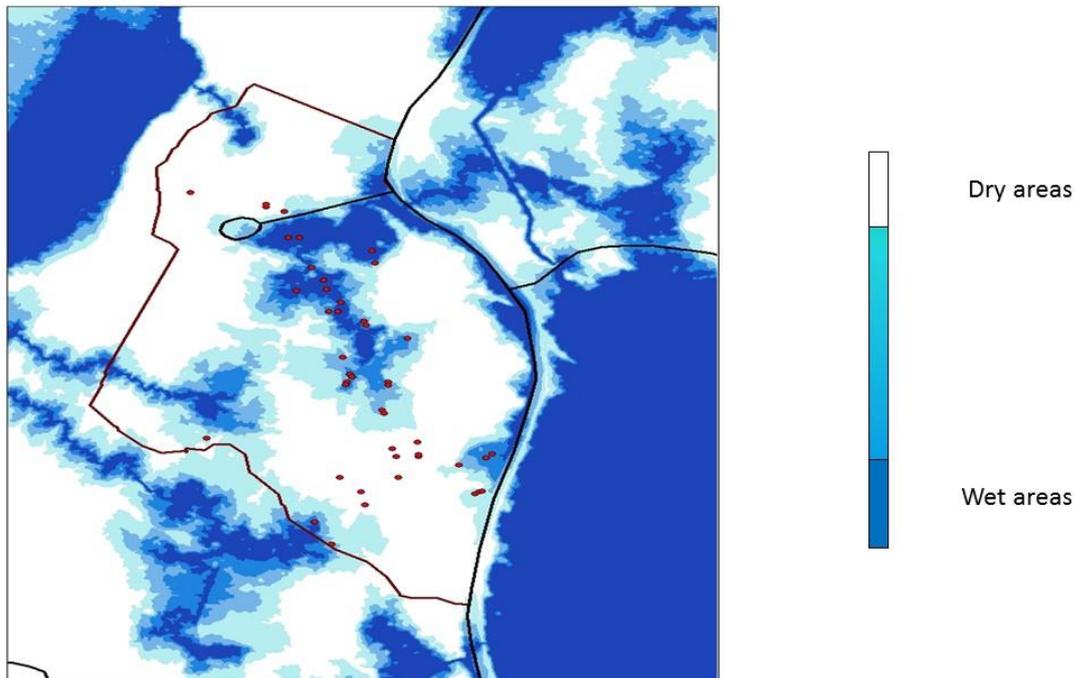
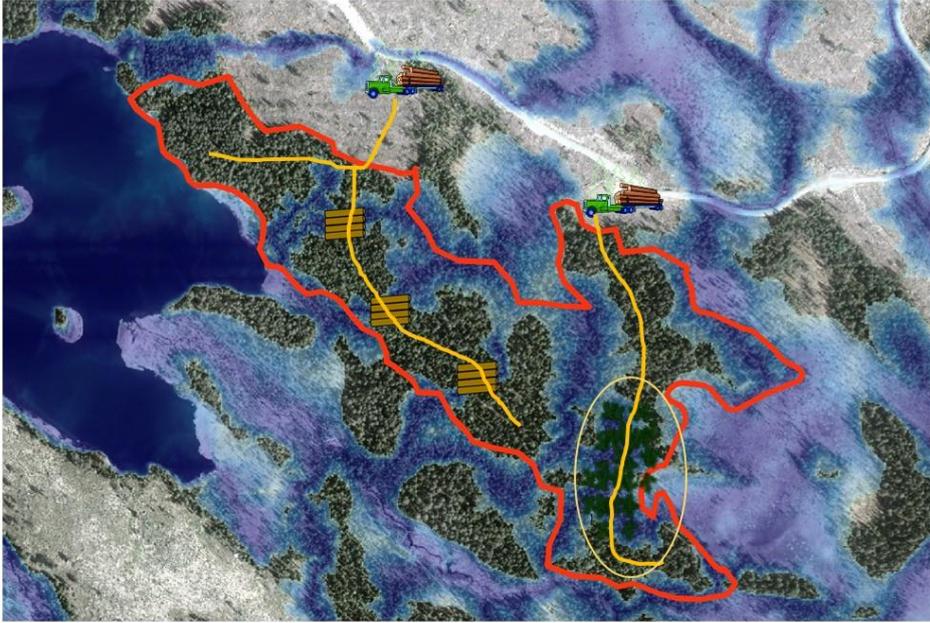


Figure 2. Soil damages compared to DTW model in one logging site in Uppland close to Uppsala in Sweden. Red dots = Soil damage.

In present Swedish forestry (2017) the DTW model or similar models (see below) is used in operational forestry in all the bigger forest companies and most of the smaller actors within the forestry. The models are integrated with other digital map layers in GIS-systems which is used in planning of forest management and as a map layer in forest machine computers. There are more and more different models and actors creating those kinds of GIS-layers and systems on the market but all models show water content in the soil, or distance from the ground surface to water.

In operational forestry the model is used for:

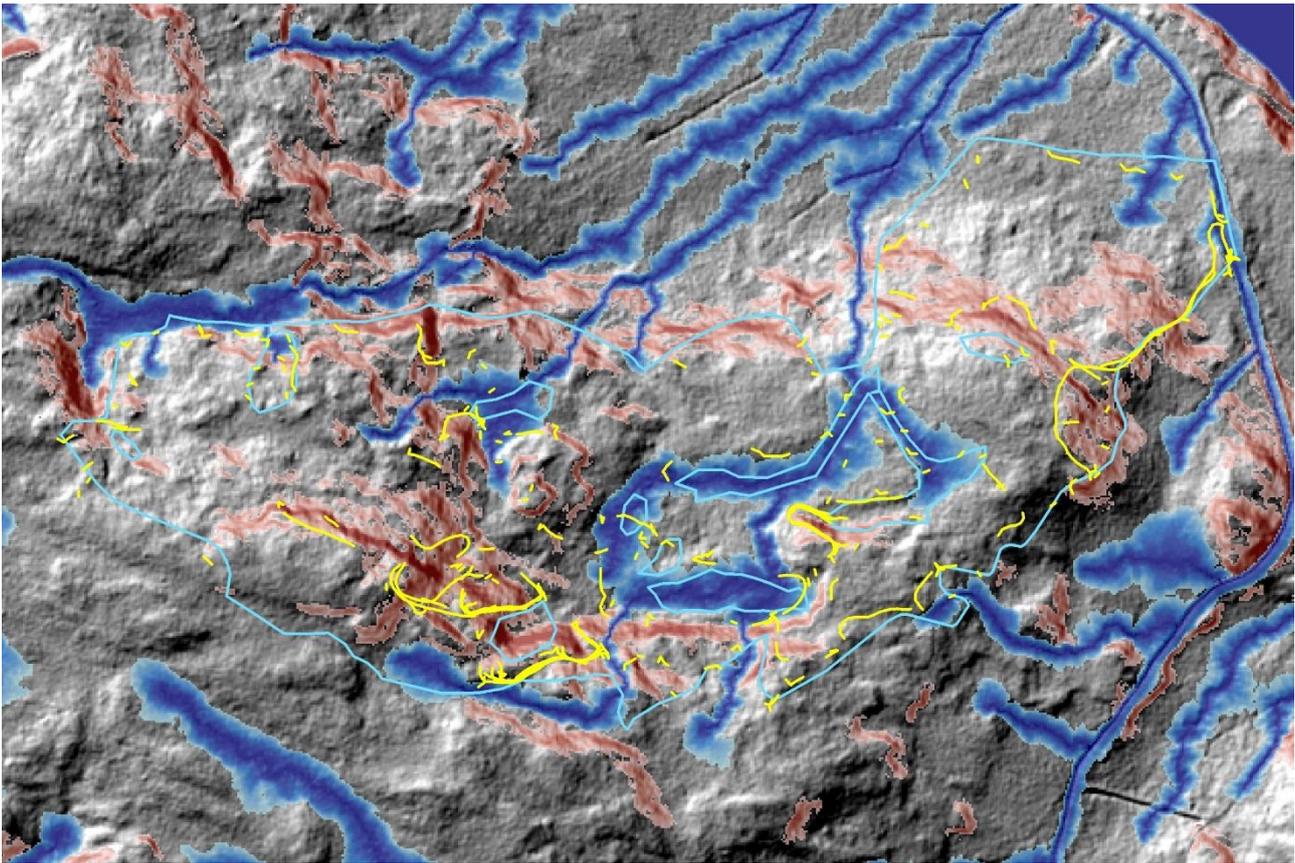
- Planning of forest management, such as site preparation and regeneration methods and planning of nature conservation
- Planning of forest operation, site preparation, thinning and final felling
- Planning of forest roads
- Detail planning of logging sites; where to place landings, main strip roads (where most of the logs are transported) and crossings over sensitive areas and water (Figure 3).



*Figure 3. Example how different digital layers and the wetness models are used for detailed planning in operational forestry. The map shows landings, main strip roads, crossings and sensitive areas where extra careful methods are to be used.*

Another example is that the DTW maps are included in most cutting directives and also in the harvester GIS for operational use.

Further efforts in the EFFORTE project include how to use the DTW maps with other data to produce even more precise decision support tools. Figure 3 illustrates a map layer that combines DTW with aerial photographs, landings and suggested locations of main strip roads. Figure 4 shows an area where soil preparation was conducted. Yellow lines indicate non-productive soil preparation. The machine making soil preparation has tracked the points where the soil preparation aggregate has not touched the ground. The DTW map is put on the Digital Terrain Model (DTM) and steep areas in reddish colours. It seems that non-productive soil preparation occurs both along steep areas and wet areas according to the DTW maps. Further studies are needed to explain in more details, but some variation may be explained by DTM and DTW maps.



*Figure 4. DTW maps for soil preparation planning.*

The DTW model and similar are examples on successful implementation of new techniques and methods that has been quickly adapted and integrated in the operational forestry. The development and application has been proceeded closely with the forestry, foresters and machine operators which has been a natural and necessary way to success (Figure 5). This process evolves over time when operational experiences provide feedback and refinement are tested and implemented in updated trafficability maps.

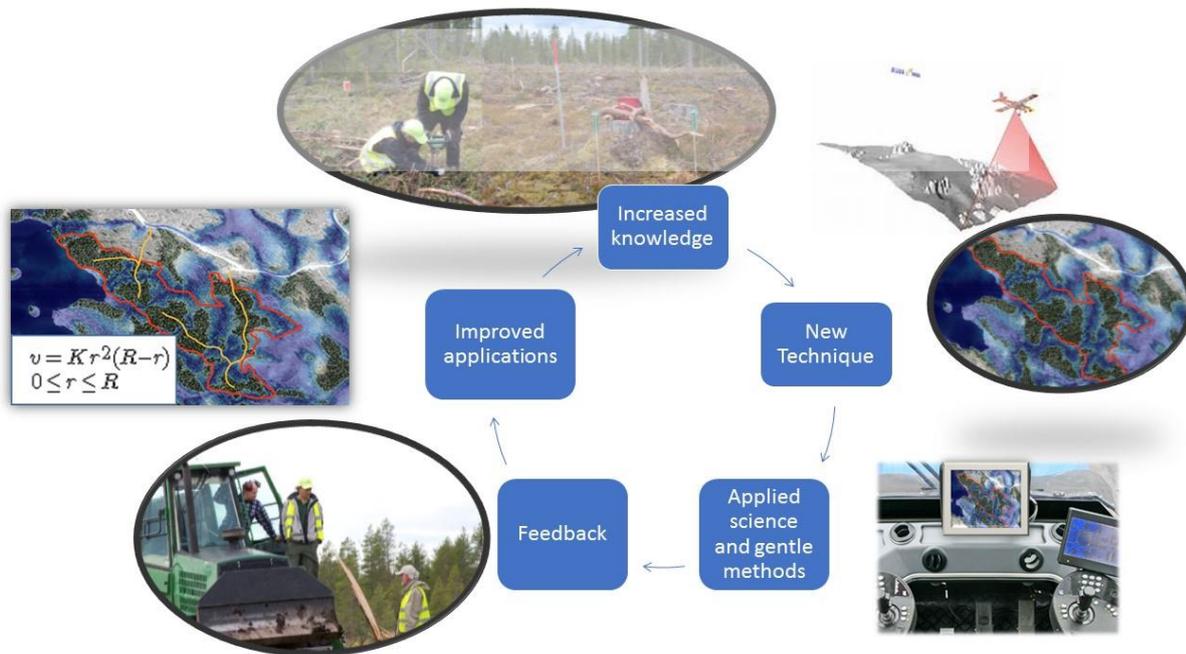


Figure 5. Example how to work successful with applied research and development.

### Static trafficability map method

The static trafficability map method produces five-class trafficability classification to forest land for every 16x16m pixel size. The static forest trafficability map is a classification of every map pixel to class describing the season when the harvesting operations may take place without causing significant damages to soil using standard logging machinery (harvester, forwarder).

Determining the season when to harvest the site has been used a long time in wood procurement in Finland. Earlier has been used three-class classification with, 1. Operations possible in any season, 2. Operation possible in summer and 3. Operations possible only during winter (frost time or time of thick layer of snow). Determination has been subjective and decision of the class has been usually done by a person responsible of buying the wood and visiting at the site. The accuracy of subjective-based classification has been somewhat poor. In addition, usually sites with some challenges in trafficability are preferred to define for lower bearing class (i.e. more sensitive site than it is) by minimizing the risk of having problems during operations if higher bearing class would have been selected.

In the new static trafficability map method user can have more supportive information of the forest site for decision making how to classify it to certain season and condition. Moreover, trafficability map presents trafficability class in each pixel, thus allowing the reformation of the site to the feasible size and form. This can be done even before the deal of timber trade with the forest owner. One target for this has been to enlarge the cutting sites. Currently, there are too much small cutting sites with increased expenses of fixed costs of harvesting per cut timber volume and decreased percentages of machine utilization for forest machines, which are impacting negatively on economy.

Another important feature in the product is that site planner can observe bigger forest areas and detect better sensitive places within the area. Map presentation illustrates with different colour variation the

trafficability changes in the area. This procedure offers information to make decisions whether to separate part of the area to different cutting seasons or keep it as one cutting object. Moreover, method pinpoints sensitive locations inside harvesting site, which should be considered while planning the operations at the site. Does it require a special machinery for soft soils, special attention during harvesting or should some small areas be untouched during operations at the site? With this method, it is easier to take these questions into consideration. Trafficability map could therefore be useful also for harvester and forwarder operators.

Even though dynamic component does not exist in static trafficability map, it can be assumed that understanding the connection of weather changes and map presentation of trafficability, the scheduling of sites to cutting order would improve along with increased experience. In each harvesting season, strong weather changes can have distinct change in trafficability at the site. With the use of static trafficability map, it has to be experienced, how certain weather change will effect on trafficability in each site and in each static trafficability class.

In Figure 6 trafficability classification has been conducted to the forest area, which includes mineral soil and peatland forests. New trafficability map method divides, as example, peatland forest to three different classes, either operable during dry or normal summer or operable only during frost of thick layer of snow (=winter). Almost the similar division of classes has been made for mineral soils added with thaw season. According to map illustration, some peatland areas could be determined to be cut during dry or even normal summer season, thus decreasing seasonal variation of cuttings.

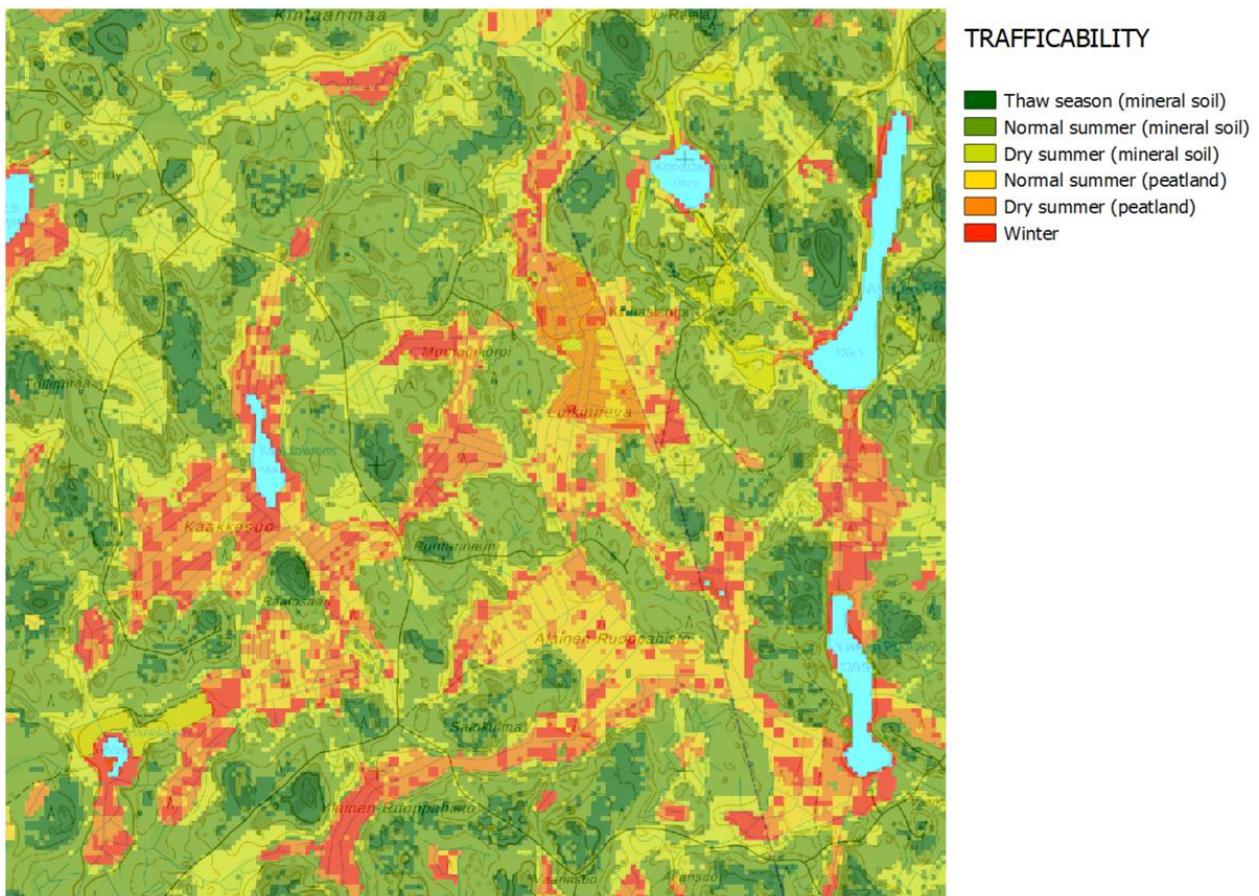


Figure 6. Map illustration from forest area in Finland by static trafficability map method by Arbonaut Ltd.

Moreover, map illustration expresses difficult areas at the site in terms of terrain trafficability. These findings from the map can be taken into account into planning of cutting and forwarding the timber; how to plan the main tracks and how to manage or even avoid weakest points. However, the accuracy in pixel level varies, and therefore, precise planning of harvesting at the site should not be done only by the information of static trafficability map.

### Dynamic trafficability maps

While the static trafficability maps are chiefly aimed at classifying and defining the season when harvesting within that forest stand is possible, dynamic trafficability maps may in the future provide more accurate information in defining exact timing for operation or in finding the most appropriate routes for logging trails.

The SpatHy model that is under the development process in Luke is a hydrologic and ground water model that combines topography with information on trees, soil data and weather data. It can be used in making predictions on soil moisture content at certain point and certain moment provided weather data is available (Figure 7). It can also be linked with weather forecast giving a possibility to predict soil moisture content of soil with various probabilities of weather forecasts. Provided spatial hydrology models can give accurate moisture content estimations, forest operations in the future may be mastered with modular moisture content – Penetration resistance – rutting model structures.

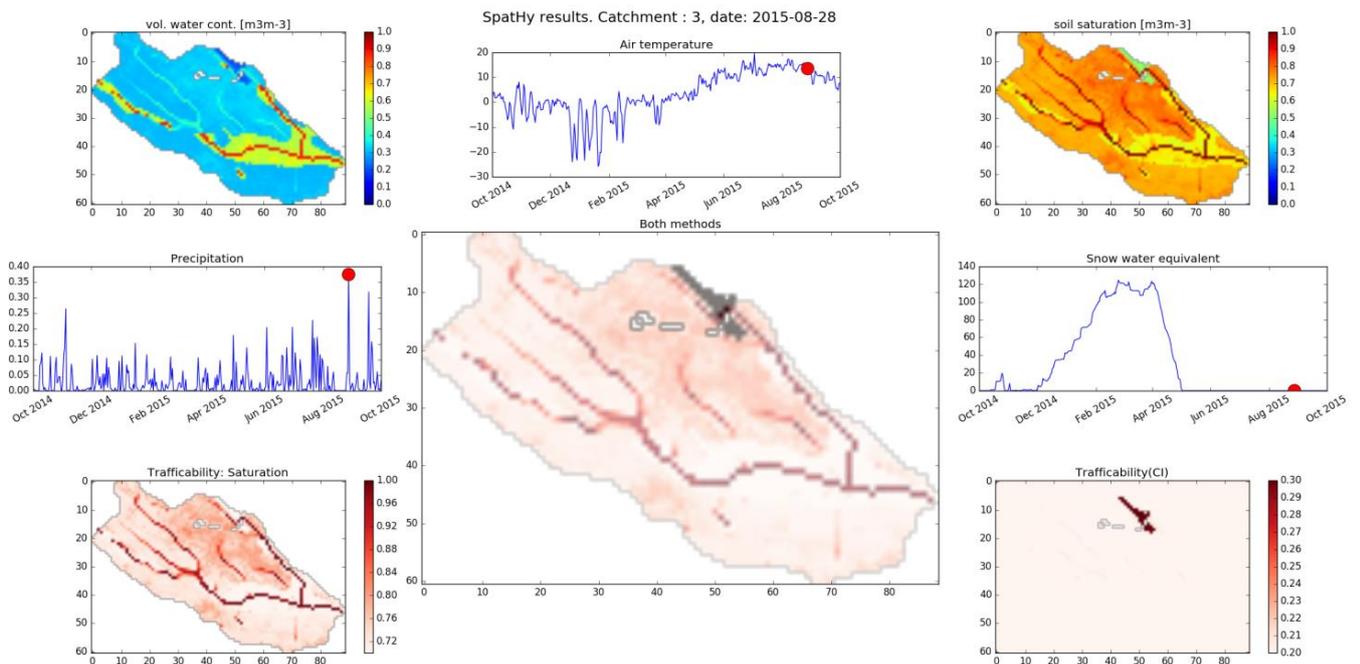


Figure 7. A map of soil water content, saturation and trafficability computed using SpatHy-model.

## 4. Conclusions

Trafficability maps are very useful in precision forestry planning although the level of maturity varies a bit along the alternatives. However, they are all operational, or close to, and demonstrations show many applications where they are or will become useful. Currently, the main importance is to use them, gather experiences and develop them further. The approach in Figure 5 is ongoing in the EFFORTE project and more results to be reported in WP 4.

The DTW map is more of a general nature and provides decision support for the forest planner or operator to be further analysed (often via visual interpretation). This is well suited for many applications and as the map is intuitive it is easy to explain how it is produced. It is also possible to understand when the map provides non accurate estimations.

The static trafficability maps are easy to understand and all forest areas may be mapped with a thematic class, as in figure 6. The use of several input datasets makes it more sophisticated and detailed. The map provides good decision support on at what time of the year the site should be operated. However, exact placement of logging trails or spatial variation of trafficability within the stand at certain moment requires more sophisticated tools.

The dynamic trafficability maps holds the same resolution (16 x 16) as the static map but include a feature to make estimations on soil moisture content according to actual weather conditions. While there are open access to weather data in most European countries, it is at least theoretically possible to exploit this kind of tools in forest operations more broadly. The models are however rather specific and may require country specific modifications. Challenges in spreading and updating these kind of huge data sets continuously may also prevent large scale.

