EFFORTE –
'Efficient forestry by precision planning and management for sustainable environment and cost-competitive bio-based industry'

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 720712
Project duration: 1.9.2016–30.8.2019.
Coordinator: Natural Resources Institute Finland (Luke).

Deliverable D4.6 Validation of cost-efficient and productive silviculture		
Work Package 4 – Validation and analyses of expected impacts		
Task 4.6 Validation of cost-efficient and productive silviculture		
Due date	30.06.2019	
Author(s), organisation(s)	Isabelle Berqkvist, Timo Saksa, Jori Uusitalo	
Date of publication	30.06.2019	
Dissemination level		
PU	Public	X
PP	Restricted to other program participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	
Nature of the Deliverable		
R	Report	R
P	Prototype	
D	Demonstrator	
O	Other	

Validation of cost-efficient and productive silviculture

June 30, 2019

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. Introduction

This document compiles together novel methods and tools developed and/or tested within the Efforte project that are aimed at improving efficiency of silvicultural operations and accelerating forest growth. For each tool, the report provides a short description and the status of the application at the end of the project. Moreover, each application is graded for technical readiness, fit for purpose, complexity, burden for maintenance and validity of the predictions. The grading has been executed by following the grading rules given at table 1. The IPR issues have also been described. The technical readiness is graded by the Technical Readiness grading system by the Horizon 2020 (figure 1).

Table 1. Grading rules used in the tool validations.

Technical readiness	
+++	The system has been proofed to work in practice and provides logical results
++	Most important parts of the system has been shown to work
+	The concept/idea has been shown to work
Fit for purpose	
+++	The system fits well for the purpose and gives useful decision support to improve operations
++	The system fits reasonably for the purpose and eases operations at some extent
+	The system fits poorly for the purpose
Complexity	
- - -	The system is very complex and requires links to numerous data sources
- -	The system has some features of complexity
-	The system is rather simple
Maintenance	
- - -	The system is laborious/maintenance costs are rather high
- -	The system needs updating frequently and causes some maintenance costs
-	No significant maintenance costs exists
Validity of the predictions	
+++	The system produces trustworthy predictions all year around
++	The system produces non biased predictions but the there exists plenty of variation
+	The system shows tendency/classification but no accurate numbers

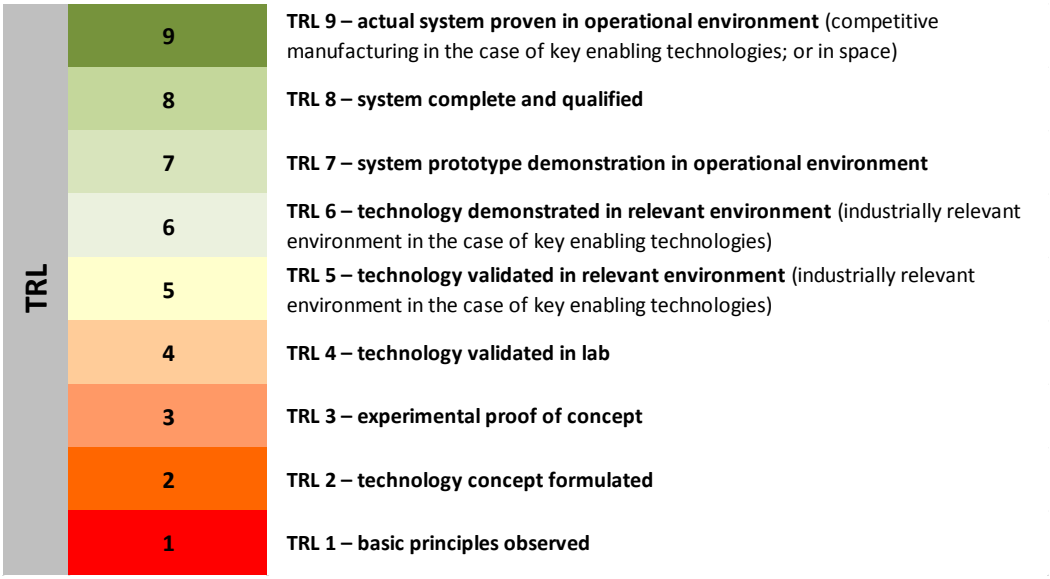

Figure 1. Definitions for the technology readiness levels (TRL 1-9) according to the Horizon 2020 – Work Programme 2014-2015.

3. Developed tools

3.1 Simulation and system analysis tool for selecting regeneration method

Summary

Reforestation of a clear cut site is mainly performed with continuously moving soil preparation methods (e.g. scarification or mounding) and manual planting of seedlings in Sweden. There are alternatives, for example Bracke p11 and M-planter both equipped with a boom-tip mounted planting device that are currently the only fully mechanized systems available commercially. During the years there have also been trials with continuously moving mechanized planting devices, for example the Silva Nova. The Kovesen- concept tested within EFFORTE was built on the same idea as the Silva Nova (but did not include the planting device, see deliverable 2.2). Development towards more mechanized methods and probably also automatized methods is needed concerning future risk of shortage of labour in the forestry, necessity of increased quality and precision as well as wish for higher efficiency. A simulation and system analysis tool by using the Extent Sim software was developed to provide more knowledge and understanding about potential of different planting methods (manual planting with disc-trenching compared to various mechanized planting concepts).

Status of the application at the end of the project

The simulation and system analysis tool was tested comparing todays manual planting systems with possible future mechanized planting systems (Silva Nova and a theoretical fully automatized system) with logical results.

Technical readiness (TRL 3) (+++)

This is a tool that can be used today but it is of course possible to develop it further.

Fit for purpose (+++)

This kind of studies are very valuable since they give a good idea of the possibility to develop a competitive system out of different concepts.

Complexity (-)

The tool is not very complex since it is built on existing software.

Maintenance (-)

No maintenance needed, but the tool can be improved.

Validity of the predictions (+)

As always it depends on in-data.

IPR

The Extent Sim is a commercial product. Skogforsk owns the rights for the simulation algorithms developed.

3.2 Identifying nature conservation areas

Summary

In the EFFORTE project we have developed a methodology to utilise remote sensing and geographical data to map low productive wetlands and their adjacent wet forests that should be retained because of their high conservation values according to the environmental goals set up by the forest sector and the Forest Agency.

We surveyed 19 wetlands in the field in order to digitally mark the area that should be retained in a hypothetical final felling if the goals for good environmental consideration are to be achieved. The wetlands included low productive wetlands and their adjacent wet forest with high conservation values. Remote sensing models were made retrospectively in ArcMap to find what geodata and geographical tools that could be used to find this target retention area. The project showed that there is great potential to map open wetlands and surrounding wet forests with high conservation values by means of remote sensing. Such mapping can help with logging planning to leave appropriate retention areas and avoid driving damages on soil and water. The remote sensing models combined different types of geodata to achieve this specific mapping and had much higher accuracy than other existing geodata mapping wetlands and wet forests.

Status of the application at the end of the project

This tool has only been tested in a study.

Technical readiness (TRL 3) (++)

Since terrain and water models from LIDAR is widely used within the forestry, this tool could be used in a simplified mood today. More precision and accuracy is requested thus and it is important to take the next step in the development in cooperation with the forestry and the end users.

Fit for purpose (++)

Improved decision tools for silviculture and nature conservation is needed in the forestry.

Complexity (-)

The tool is built on terrain and water models from LIDAR (widely used within operational forestry) and hence not very complex. Difference and variation in the landscape and terrain conditions implies adaptation of the model in different areas.

Maintenance (-)

The tool is built on terrain and water models from LIDAR which is rather static. The scanning will be repeated thus concerning tree canopy layer and resolution.

Validity of the predictions (+)

The first tests have showed quite valid predictions, but we will continue with further tests

IPR

The methodology is developed by Skogforsk that owns rights for the system.

3.3 Tree species selection tool

Summary

Within EFFORTE a method for tree species selection for next tree generation was developed and tested in co-operation with MetsäGroup company. Tree species selection method was based on localized harvester data (HPR-data) and available forest data. Site index was calculated based on the height of dominant trees and stand age to each 16x16 metres pixel. Then site index was converted to local growth potential (mean annual increment, m3/ha/year) for each cell as an average of 9 neighbouring pixels. After that, micro stands for different tree species were delineated merging pixels based on local growth potential with different threshold values. These threshold values were chosen so that they corresponded to the possible points of changing tree species to grow. More detailed description of this method can be found in Deliverable 2.6 Economical unit size in precision forestry.

Status of the application at the end of the project

Tree species selection method has been tested during EFFORTE-project. The procedure of determining local growth potential has been documented as well as the procedure of delineation of micro stands for different tree species. There is not yet complete application available at this moment.

Technical readiness (TRL 5) (++)

Tree species selection tool has been tested in practical forestry with one operator.

Fit for purpose (+++)

In the tested case stands tree species selection tool fitted well for the purpose to determine and localize the variation of growth potential within a large regeneration area.

Complexity (-)

Tree species selection tool uses harvester data and forest data as input. Procedure to determine local growth potential and to delineate of micro stands for different tree species can be quite easily automated.

Maintenance (-)

When this tool is integrated in the operational systems the maintenance operations can be estimated to be quite minimal.

Validity of the predictions (++)

Prediction in tree species selection method is now based on harvester data and forest data. The validity of predictions might be improved with using ALS-data (or two ALS-data from different time points) when determining local site index. Also if the age of trees could be defined more precisely from the dominant trees at harvesting operation it might also improve the results.

IPR

Tree species selection method procedures have been developed in Luke with co-operation with MetsäGroup company.

3.4 Plant order tool

Summary

Today decision on the most important factors of regeneration such as selections of tree species and density of seedlings to be planted (stems/ha) is typically done with similar manner for the whole site. This does not take into consideration variation of growth conditions within the site. Depending on the landscape and the area of the regeneration site, there might be rather large variations in site index (SI) indicating variation of optimal management and tree species.

Data on past growth, collected by the harvester can be used not only for selecting the right tree species but also to analyse the right planting intensity and the properties required from the planting material. The harvester data (hpr-data) can be augmented by other precision forestry data such as digital terrain models (DTM) and depth to water models (DTW).

If higher precision could be used in regeneration and silviculture there is much to gain both concerning sustainability aspects and vitality of the forests and thereby protection against insects, fungi and climate changes, but also concerning forest production and profitability of the forest sector.

In EFFORTE we have developed a methodology where harvester data is combined with topographical data to facilitate a higher resolution in forest planning in order to optimize choice of tree species, density of the stand and environmental aspects.

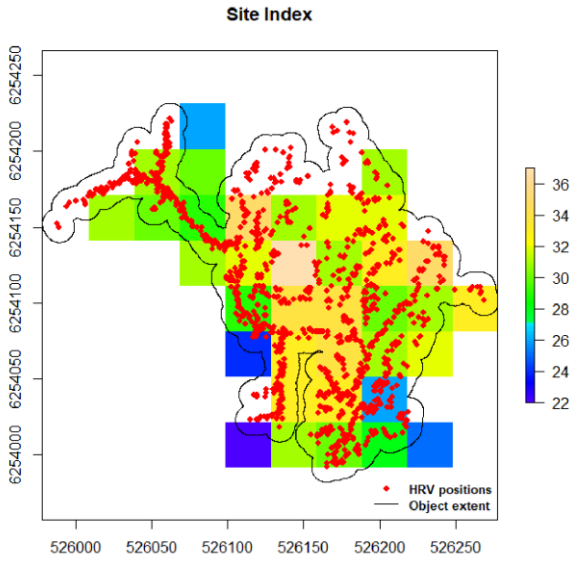

Figure 2. Site index (SI) in object derived from harvester data. Resolution 30x30m^2.

The results show clear correlations between SI derived from harvester data and topography, the SI-topo relationship, which means that it makes good sense to continue another step towards a planning tool for regeneration planners. Even when no harvester data is available, it would be possible to get at good hint about SI variations in a certain area, either by known SI-topo relationships in the same region, or just from the high-resolution terrain model itself and more general knowledge about SI-variation.

Status of the application at the end of the project

This planning tool is only in the test level. It has been discussed with planning managers at different companies, but not tested in operational forestry. The next step is to test the model on a bigger selection of clear-cut sites and try to actually combine hpr-data with topographic data in the model.

Technical readiness (TRL 2)

Plant order tool has been tested in practical forestry.

Fit for purpose (++)

A decision tool for silviculture and regeneration is most needed in the forestry. This will facilitate sustainability, healthy forests and high forest production which will secure delivery of forest product to a bio-based society. The key is to develop this tool in cooperation with the users and to find a good adjustment between complexity, robustness and user friendliness.

Complexity (--)

This kind of tool will be rather complex with a complex model and calculation. In addition we need to consider how the information should be presented for the end user (e.g. in digital maps or other applications).

Maintenance (-)

This kind of tool will need constant development to fit into operational forestry.

Validity of the predictions (+)

The first tests have showed quite valid predictions, but we will continue with further tests.

IPR

Hpr-files and some of the map layers might be confidential or subject to a fee. Hence this is something to consider in the further development of the tool.

4. Discussion and summary of the developed tools

Most tools and methods summarized in this report are in rather early phase of development. The idea of utilising harvester data, laser canning data and topographical data also in augmenting silvicultural operations is rather new since most efforts so far in this field has been focused on improving efficiency and in protecting environment in logging operations. It is rather obvious that we will see in the future huge development in utilising various digital information to enhance planning of silvicultural operations. The evaluation summary of system validations is presented in table 4.

Table 4. Tool validation summary. Tools and systems, which are developed and /or tested within the Efforte-project.

Tool	Description	Technical readiness	Fit for purpose	Complexity	Mainte-nance	Validity of the predictions
Regeneration method tool	Tool for selecting regeneration method	+	+++	-	-	+
Identification of high conservation values	A methodology to identify areas with high conservation values	+	++	-	-	+
Tree species selection tool	Tree species selection tool based on local growth potential determined using harvester data and forest data as input.	++	+++	-	-	++
Plant order tool	A methodology to analyze SI and define density of the seedlings to be planted	+	++	--	-	+

All of these tools and systems are in testing phase and they need more piloting before largescale operational use. At the moment these tools are individual components and they need to be integrated to the normal silvicultural planning process before they can be used in an efficient way. However there is a large potential to improve precision silviculture with these tools.