Mervi Kokkila
Antti Peltola

Using GIS and harvester data to improve mechanized wood harvesting on sensitive sites.

Introduction

This study is part of an Ecowood project, which is to develop a protocol for ecoefficient wood harvesting on "sensitive" sites that matches the machines to the sites and integrates the stages in the wood harvesting chain from cutting the trees to their extraction from the forest. The aim is to achieve cost effective, ecoefficient operations, which at the same time are ergonomically and socially sound.

Site disturbances cannot be fully avoided in harvesting operations. Areas with the highest risks for damage can, however, be located with careful planning. One objective of the ECOWOOD project is to develop GIS-based (geographic information systems) planning methods for harvesting in sensitive sites.

In this case study the aim was to test how the GPS-located harvester data combined with spatial terrain data could be use to help forwarder operations. This could include both to improve the operations productivity and to avoid damage to the stand.

This is not the first attempt to study how the spatial terrain data or harvester data could be used to improve forwarder operations. E.g. Reisinger and Davis (1986), Nearhood (1992), Eichrodt (2000) and Orava (2000) have made GIS-based terrain trafficability analyses. Although they have used DEMs in slope calculations, the other uses of DEMs haven’t been included. Skogforsk and Linköping University have studied forwarder route optimisation (Ericksson, et. al 1999, Forsberg 2001).

In this case the approach in routing was a bit different. The aim was to study the information accuracy and how to visualize the data so, that operator could be the decision maker. The system would just produce information the operator needs and requests.

Use of GIS in terrain trafficability analysis

The current harvest planning methods do not fully utilise the possibilities of geographic information systems (GIS). Harvest plans are based on topographic maps, forest plans and data collected during the field surveys. Topographic map is by nature a static visualisation of the terrain. Though it contains information about site topography and site wetness, it is a generalisation and a simplification of the terrain. Forest plans describe the site as a whole and the outlines are often marked based on the forest cover. Thus they might not give a proper view about the variability in the terrain properties. Use of a GIS allows an easy way to gather up all the available information, to analyse it and to visualise it in the most illustrative way.

Digital elevation model (DEM) describes site topography numerically and is one of the basic models in GIS environment. It allows easy quantification of the landform attributes like slope, aspect and specific catchment area. These terrain attributes can be used when assessing e.g. the influences of slopes on the machine performance and routes in the harvesting site or when evaluating the differences in site wetness and thus also in site trafficability.

Wetness indices are the most widely used DEM-based attributes to describe how topography affects on the distribution of soil moisture in a landscape level. The calculation of the index is based on logical ideas of downslope water movement and accumulation of water at the base of slopes and in depressions. Although the approach in the wetness index calculation is simple, it includes topography, which is seen as a key factor regulating the soil water system behaviour. It may thus provide a quick way to assess the relative differences in the soil moisture between the sites and within the site and thus also a way to assess the relative differences in trafficability.

In this study the main interest in terrain attributes was put into slope and wetness index as those might be the most useful ones in characterizing the site variability in forest harvesting.

Adding harvester data on the map

The use of information technology has changed the wood harvesting operations dramatically during the last 10 years. So far the main development areas have been the use of GIS and wireless data transfer to lower the supervision costs, transportation logistics to minimize the trucking costs and use of wireless telecommunication for fast update of timber storage status. The changes have been quite dramatic. However, still we are in very initial phase at this moment. Although it is important to avoid collecting information just because it is possible, there is unused potential still.

A modern harvester collects a large amount of data during the work process. As it passes through the cut block it is capable to collect new information of the terrain and trees processed. This could open totally new opportunities for control of other machines in the wood harvesting chain and further update the maps and geographic information.

The new IT time in harvesters has improved their operations, but surprisingly it has made the forwarder operations more difficult. Forwarder (operator) is only an information producer, not a receiver. This situation is shown in the figure 1.

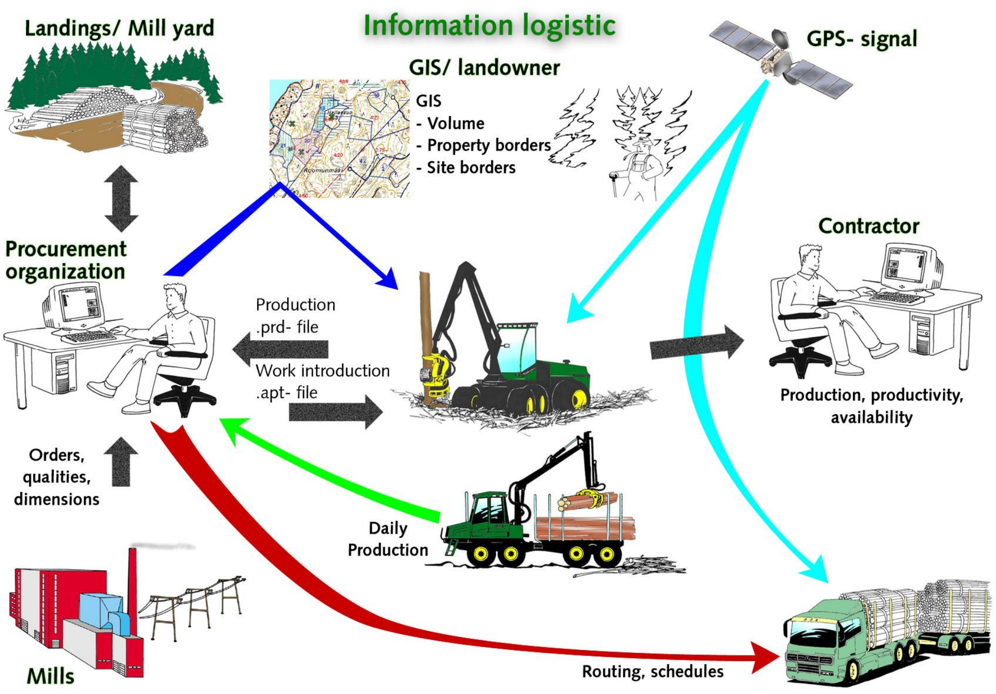

Figure 1. Information logistic in wood procurement

A big question is, that should we try to be accurate or informative – or can we be both. In this case this means that should we be interested in single logs or look at bigger units. In this study a decision was made to look at the different ways to produce information for the forwarder operator. The map could be static or interactive. During the tests we wanted to confirm also the possibilities and restrictions of location data for this purpose.

Material and methods

Five small harvesting sites, which were used to demonstrate the usability of terrain analysis data in forest harvesting operation, were located in central Finland (61.56˚ N, 24.30˚ E). Harvester data was collected in all sites, while terrain trafficability was studied only in one site.

Site sensitivity in all sites was assessed based on geomorphological knowledge, soil type map, contour dataset and datasets of rocks and peatlands. A raster DEM over the area was constructed with Arc/Info topogridtool based on the contour datasets of NLS. The resolution of the model was 10 m. Terrain attributes were calculated with the program TAPES-G.

The site for trafficability analysis was chosen based on the differences in the soil moisture classes between the topographic map and the wetness index map. Based on the topographic map, the site was a normal mineral soil site without peat-cover. However, in the wetness index map the index values in the lower part of the site were quite high indicating quite wet soil conditions

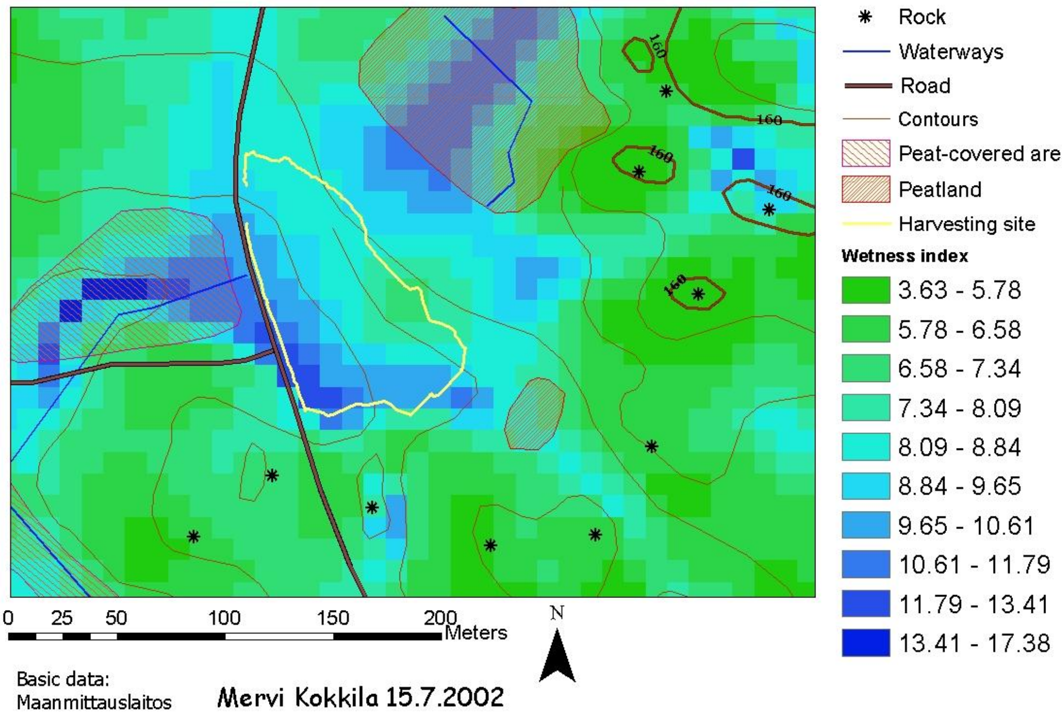

Figure 2. Wetness index values in raster format and terrain information from a topographic map

Measurement points were positioned regularly over the 0,5 ha-sized site. Penetration resistance and gravimetric soil moisture content were determined in those points before the harvesting event. After the harvesting the locations of the ruts were determined and rut depths measured.

The harvester was equipped with two GPS receives, one with differential correction one without correction. Special software was recording the machine location in 2 seconds intervals. In addition to that each felled stem and processed log was registered with location information from the DGPS receiver. The data the harvester produced was analysed with Arcview program.

Results:

Variation in terrain conditions was large even in such a small-sized site as 0,5 ha. Some measurement points were located in rocks with a thin mineral soil cover while some points were in peatland and others in podzolic mineral soil. The gravimetric soil moisture content, (θ_m), indicates this variation well. Mass wetness (θ_m) varied in peatland (or peat-covered) samples from 74 % to 890 % and in mineral soil samples from 6 % to 77 %.

The relationship between wetness index and measured soil moisture content is described in Figure 3. Peat deposits indicate that there has been surplus water in soil for a long time. Wetness index describes the same thing, as index values are high in flat areas at a base of slope where water moves slowly and where there is surplus water in soil due to the large upslope catchment area. This connection between wetness index and peat deposits is clearly seen in the figure.

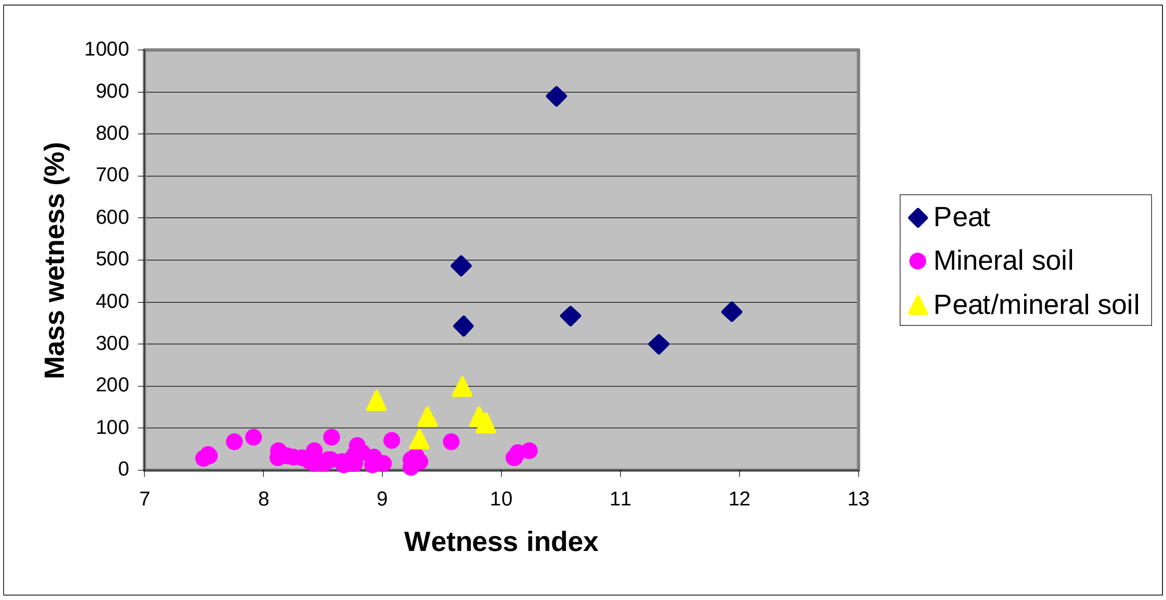

Figure 3. The relationship between mass wetness and wetness index for different soil samples

The data collection in harvester succeeded without problems. One interesting issue was to compare the data from GPS and DGPS receivers. The nature of machine operations is that the machine moves slowly and stays in one location several minutes. This appears to be a source of inaccuracy. In visual interpretation it seems that GPS signal is not as accurate/reliable as it should be if we wish to handle single logs for route optimisation.

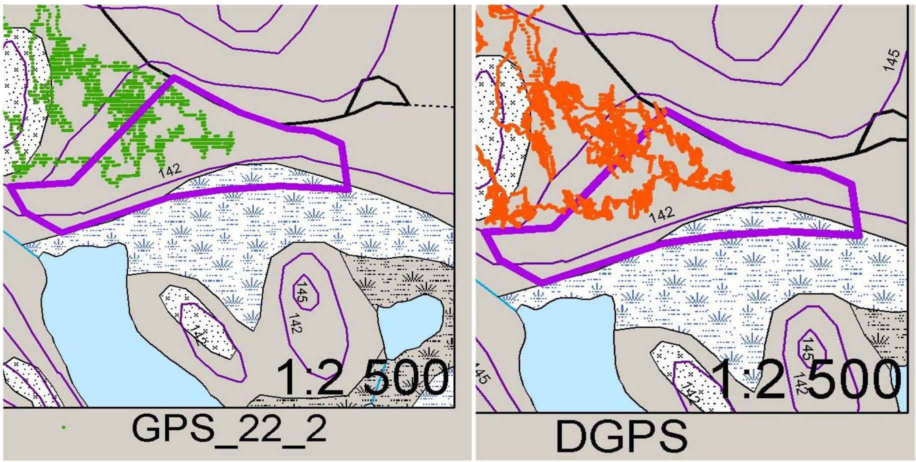

Figure 4. Harvester route recorded by DGPS and GPS receivers.

One way to handle this source of inaccuracy is to increase the scale. The following example shows the way to divide the cut block to subdivisions. The size of sub-blocks depends on the conditions, harvesting method and machinery. The idea of sub-blocks is that instead of looking for a single log or pile we visualize the wood volumes inside these areas and let the operator plan his routes. This seems to be a reasonable compromise in the beginning.

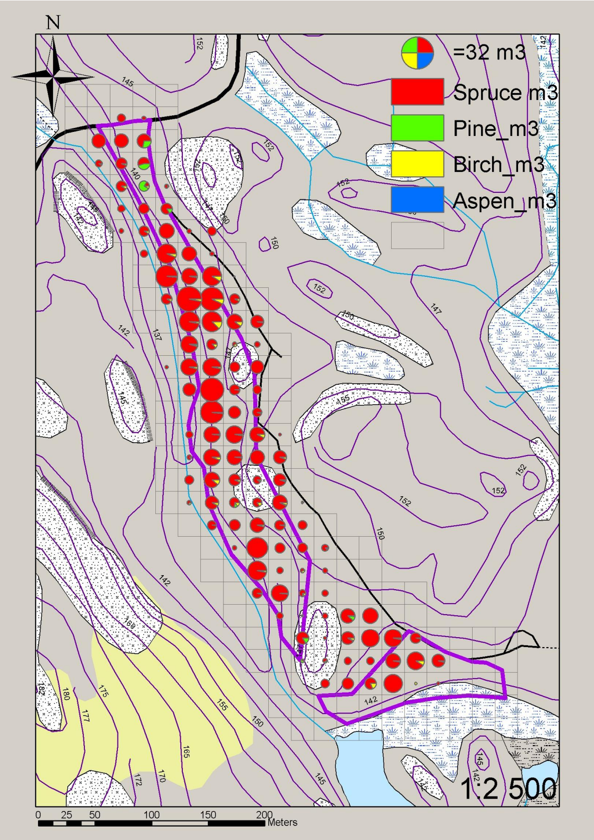

Figure 5. Volumes available for forwarding.

Conclusions and discussion

The wood harvesting operations have changed dramatically with GIS and wireless data transfer. In this case study we wanted to verify what potential still is in the digital maps and if the machines could add new applicable data. In the Ecowood project this knowledge is used to improve operations on sensitive sites. The results show that both information sources still have a lot of unused potential. With the map analyses it seems to be possible to locate spots that are sensitive because of wetness or slopeness.

With the harvester data the forwarder operator can have a static or interactive map as he/she arrives at the cut block. This is now first time forwarder operator can have a map and plan his operations. Especially in thinning or when the amount of different assortments is high the map certainly will help to plan the routes to minimize unproductive driving.

It is important to remember that he possibilities to collect stem and log data with a location “stamp” do not end to machine operations. It has potential and value also in:

- Forest management planning
- Disease mapping
- Certificate of origin

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