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Chapter IV

Applying open GIS data to study wetland forests and ditches in Finland

Ruikkala, T. [1], Aalto, I. [2], Peltoniemi, M. [3] & Salmivaara, A. [4], Tuominen, S. [5] & Muukkonen, P. [6]

[1] *toni.ruikkala@helsinki.fi, University of Helsinki*
[2] *iris.aalto@helsinki.fi, University of Helsinki*
[3] *mikko.peltoniemi@luke.fi, Natural Resources Institute Finland (Luke)*
[4] *aura.salmivaara@luke.fi, Natural Resources Institute Finland (Luke)*
[5] *sakari.tuominen@luke.fi, Natural Resources Institute Finland (Luke)*
[6] *petteri.muukkonen@helsinki.fi, University of Helsinki*

Abstract

Open GIS data enables calculations and analysation of ditch related variables in drained forest areas. Gathering and combining all this information can be a laborious but it helps and improves modelling related to ditching and carbon fluxes. Finnish Natural Resource Institute's SOMPA-project tries to find more ecologically sustainable methods for forestry and a major part of carbon fluxes are contributed by peatlands, ditched or not. This study demonstrates and highlights that it is possible to calculate ditch densities and gather ditch-related data from the national open GIS data. This study also provides a work-flow on how to calculate these variables.

Keywords: ditch; ditch density; forestry; geoinformatics; GIS; natural resources; MS-NFI

1. Introduction

More than half of Finnish peatlands have been drained for forestry use since the 1960s (Laiho et al, 2016). Today the total wetland area in Finland is 8.7 million hectares of which around 4.6 million hectares are drained for forestry and agricultural use (Korhonen et al., 2017)**.** Of the total forest area in Finland, drained wetland forests make up one third. In addition, it has been showed that all ditches do not necessarily support flow (Hasselquist et al., 2018). This means that ditch networks do not work with full effort. Yet, the former mires have become well-producing and fertile grounds for both forestry and agricultural use. Still, the impacts on climate are not as convenient.

The lowering groundwater level creates aerobic conditions in the soil surface layer which causes the aerobic decomposition of plant material. This, in turn, increases carbon dioxide emissions. The carbon balance of drained wetlands is negative, however, forests growing on these sites compensate the emissions by sequestering carbon. (Ministry of Agriculture and Forestry of Finland, 2007; Vanhatalo et al., 2015; Penttilä et al., 2018) The Natural Resources Institute Finland (Luke) is carrying out a six-year project (SOMPA, 2018–2023) with an aim to develop methods for improving management strategies for drained peatlands to mitigate climate change.

To survey national forest resources and forest land in Finland the first National Forest Inventory (NFI) was carried out in Finland with the aim to systematically monitor forest resources regionally and in the whole country since 1921. Ever since the inventories have been carried out with 5–10-year rotations. The national forest inventory produces information about volume and growth of growing stock, silvicultural quality of forests, land use and ownership, forest health, biodiversity, and carbon reserves. The results are based on versatile field measurements on field plots. (Mäkisara et al., 2019). The Multi-Source National Forest Inventory (MS-NFI) combines the measurements of NFI sample plots to additional information (Tomppo et al. 2008). This additional information is topographical maps and remote sensing data such as satellite images. With these data, the inventory can be interpolated for smaller areas than what was possible with only field-based measurements. The first MS-NFI results were published in 1990, and in 1994 there were results covering the whole country. The latest published MS-NFI is from 2017 (see https://www.luke.fi/tietoa-luonnonvaroista/metsa/metsavarat-ja-metsasuunnittelu/metsavarakartat-ja-kuntatilastot/).

In this project, our aim was to derive new variables from open GIS sources to be used with the newest MS-NFI data by Luke. These new variables can be used in modelling and research purposes for wetland forests in Finland.

Figure 1. The study area is in Ostrobothnia, where drained wetlands are a common landscape.

2. Data

2.1 Study area and data sources

The study area covers a 12.0 km ×12.0 km rectangle corresponding to map sheet P4212R located near the municipality of Lappajärvi in Ostrobothnia (Figure 1). The selection of the study area was based on a high proportion of drained forest in the area. In addition, we limited our calculations to the smaller study area due the need for processing speed and power to carry all our calculations. That is why selected this small test area for our calculations.

The basis for the study is the Multi-Source National Forest Inventory (MS-NFI) *data provided* by *the Natural Resources Institute, Finland (*Luke*)*. The open MS-NFI data consist of thematic forest maps in the form of raster layers. On the basis of the raster format MS-NFI maps, automatic delineation of forest stands has been carried out by automatic image segmentation. In addition to MS-NFI map data, peatland drainage maps and forest estate borders have been used in the delineation of the segments. These forest segments are based on the inventory and real estate borders, but because it is based on raster format the data does not fully follow real vector format borders of real estate objects but depends about the spatial resolution of the raster data. In the whole of Finland, there are a total of approximately 20 million identified forest segments and each segment is identified with an individual ID. In the inventory, the country is divided into five parts: eastern, western and southern Finland, Lapland, and Åland Islands.

The variables combined and developed were ditch density, ditch length, surface soil type, peat depth, drainage state, fertility class, and topographic wetness index (TWI). More info about the variables can be found later in the chapter. The main priority was to calculate the new ditch related variables. Luke is also calculating Depth-to-Water (DTW), but this was not available for the whole of Finland at the time of the study.

We also added some other variables from Open data that we thought could be of usage. All the variables that were joined to the attribute table of MS-NFI forest segments are presented in table 2. All the data were vector files except the MS-NFI files which were in raster format. From the Topographical database, we only needed the vector layer that contained ditches. From the forest resource data by the Finnish Forest Centre (Metsäkeskus, metsään.fi), we downloaded four smaller UTM10 map sheets that together covered the map sheet P4212R. TWI could not be downloaded for separate areas, therefore we downloaded it for the whole of Finland and clipped it for the area of interest.

During this study, an updated 2019 version of the Topographical database was published. We decided to continue using the one we already had downloaded from the year 2016 since there appeared to be no major changes at least in our study area. When applying the methods developed in this study for the whole of Finland, we suggest that the latest 2019 version of the Topographical database should be used. After the data was gathered, a transformation of segmented MS-NFI data to vector polygon format was needed. The conversion was made in order to be able to join new data and modify the existing data in the raster layer. Tree volume and height was from the previous MS-NFI that was available for download.

Table 2. The GIS data used in this study (for more information, see attachment 1).

Variable / data	Source	Producer	Year of production	Date of download
Ditches as polylines *Estate borders*	Topographical database	National Land Survey of Finland	2016	7.3.2019
Soil type *Peat depth*	Hakku.fi	Geological Survey of Finland	2002–2009	25.3.2019
Fertility class *Drainage state* *Tree species* *Ditching year*	Metsään.fi	Finnish Forest Centre	2018	27.3.2019
Topographic Wetness Index	Paituli.fi	Natural Resources Institute Finland	2016	4.4.2019
Tree height *Tree volume*	Natural Resources Institute Finland	Natural Resources Institute Finland	2015	5.4.2019
Topographic Wetness Index (TWI)	Natural Resources Institute Finland	Laura Salmivaara, Pers. comm.		

2.2 Description of variables and their relevance in the study

The soil type -variable shows us the mode soil type per polygon. Soil type affects the soil's ability to retain water which in turn has an impact on forest growth. Drainage of wetlands aims to optimize the soil's water availability for trees. Mineral soils in general have lower water retention capacity compared to organic soils. Organic soils, such as peat and mould, are dominant soil types in drained wetlands. In our study area, the most dominant soil type was peat of different thickness. Peat depth and drainage affect also the release or sequestration of carbon.

Peat depth indicates the thickness of the peat layer on a polygon. The thicker the peat layer is, the more carbon is captured in the soil. Peat is a soil type that is formed in wetlands under anaerobic conditions. Drainage decreases peat depth layer and allows quick aerobic decomposition of the peat. In this process, carbon dioxide is released to the atmosphere. Thick peat layers in natural wetlands release methane, but this is a slower process than the sequestration of carbon through decomposition. In drained wetlands, the goal is to protect thick peat soils. (Penttilä et al., 2018).

Tree species -variable shows the most common tree species on a polygon. This is specified by determining if the forest is deciduous or coniferous and then defining the most dominant species in terms of tree volume (Hökkä et al., 2002). Different tree species have different requirements of water and nutrients and the availability of these depend mostly on the habitat and soil type. Optimal growing circumstances enable maximum growth of a tree, which correlates with economic profitability (Vanhatalo et al., 2015). Fertility class describes the forest habitat type. The habitat types have different fertility levels which has a direct effect on tree growth and production (Hökkä et al., 2002).

Drainage year -variable shows the year a specific polygon was drained. In the 1960's, the use of machinery to drain wetlands for agricultural and forestry purposes started. To keep the wetland forests productive, ditches need to be retrieved every 20–40 years (Sarkkola et al., 2013; Vanhatalo et al., 2015). Forestry drainage has not in all cases had the desired effect on tree productivity and thus not all ditches should be kept open. This is because ditching also has an enormous effect on the ecosystem (Aapala et al., 2013). Drainage state classifies forest segments into ditched and non-ditched, and the former further to different drainage states that describe the vegetation and tree growth in the area (Hökkä et al., 2002).

Topographic wetness index (TWI) is typically used to quantify the effect of topography to hydrological phenomena (Sørensen et al. 2005). Topography affects the spatial water distribution of an area, soil moisture and groundwater flow (Beven and Kirkby, 1979).

Tree height is a growth indicator and relates to the age and productivity of a tree. Tree volume is reported in m^3/ha. It is an important factor in determining the management practices to be done in the forest. Tree volume can be later converted to tree biomass (Somogyi et al., 2007).

Depth to water (DTW), which was not yet available in our study area, is a central attribute when it comes to the climate impact of drained wetlands, since the top layer above the water table determines much of the greenhouse gas emissions from the soil (Vanhatalo et al., 2015; Penttilä et al., 2018). Yet, this variable is important in forest drainage studies and it should be considered when forest drainage and its effects are under consideration. The optimum depth to water in a drained wetland forest is 30–40 cm (Aukia, 2019) which allows enough air for tree roots but does not cause massive carbon emissions (Vanhatalo et al., 2015; Penttilä et al., 2018).

3. Methods

In this study, we derived new ditch related variables to describe amount and density of ditches in the drained wetlands in the boreal forests in Finland. Firstly, we made the ditch-layer from NLS's topographic database (for calculation workflow see Figure 2). We used only features with codes 36311 (ditches less than 2 meters wide) and 36312 (ditches 2–5 meters wide). Secondly, the newly made ditch layer was then combined with the polygons of the MS-NFI layer with ArcGIS software's Intersect-tool. Thirdly, each forest segment's ditches were combined using Summary Statistics -tool into a total ditch length for a specific polygon.

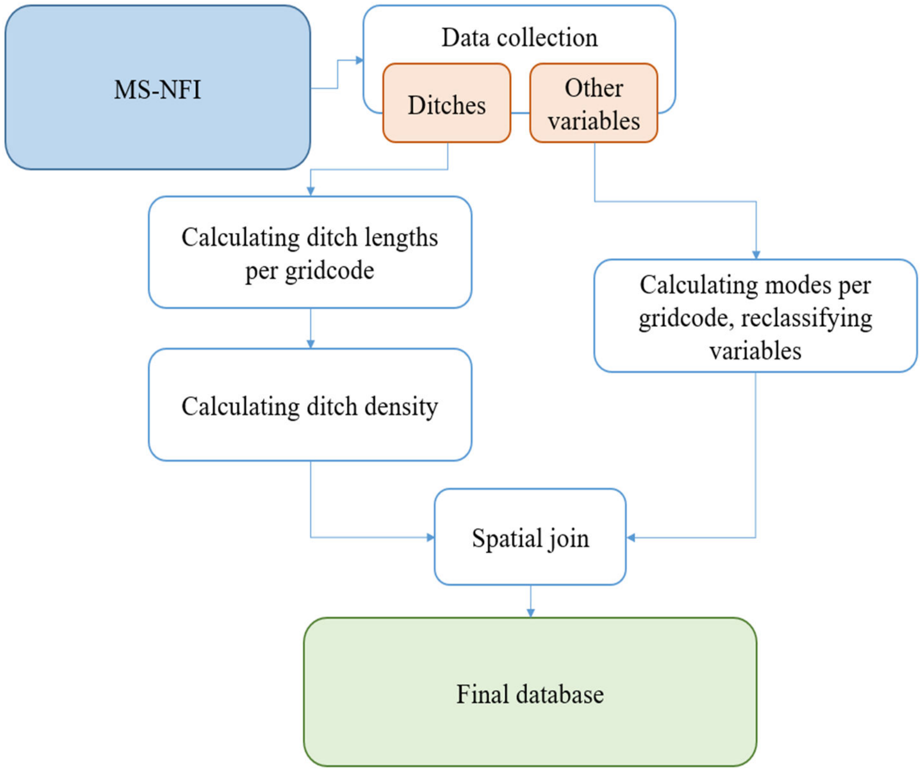

Figure 2. Workflow chart of GIS analyses.

Ditch density was calculated using the drainage density formula **D = L/A** by Dingman (1978), where **D** is a ditch density, **L** is a total length of ditches, and **A** is an area. Using drainage density formula for calculating ditch density has some limitations but despite these limitations, it worked well when calculating ditch density in the area. Ditch density was calculated in meters per hectare. Final classification for ditching density was made by calculating the average distance between ditches in a hectare. These density class values were “no ditches”, “less than 100 m/ha”, “100–199 m/ha”, “200–299 m/ha”, and “more than 300 m/ha” (for ditch density map see Figure 3). In calculations, this makes it so that if a polygon had totally more than 300 meters of ditches per hectare, the distance between ditches were less than 30 meters. For the 200–299 m/ha class, distance between ditches were 30–50 m, for 100–199 m/ha distance was more than 50 meters. This calculation does not take the possibility of intersecting ditches into account. Nevertheless, it still gives a good estimate of the ditching state of the segments.

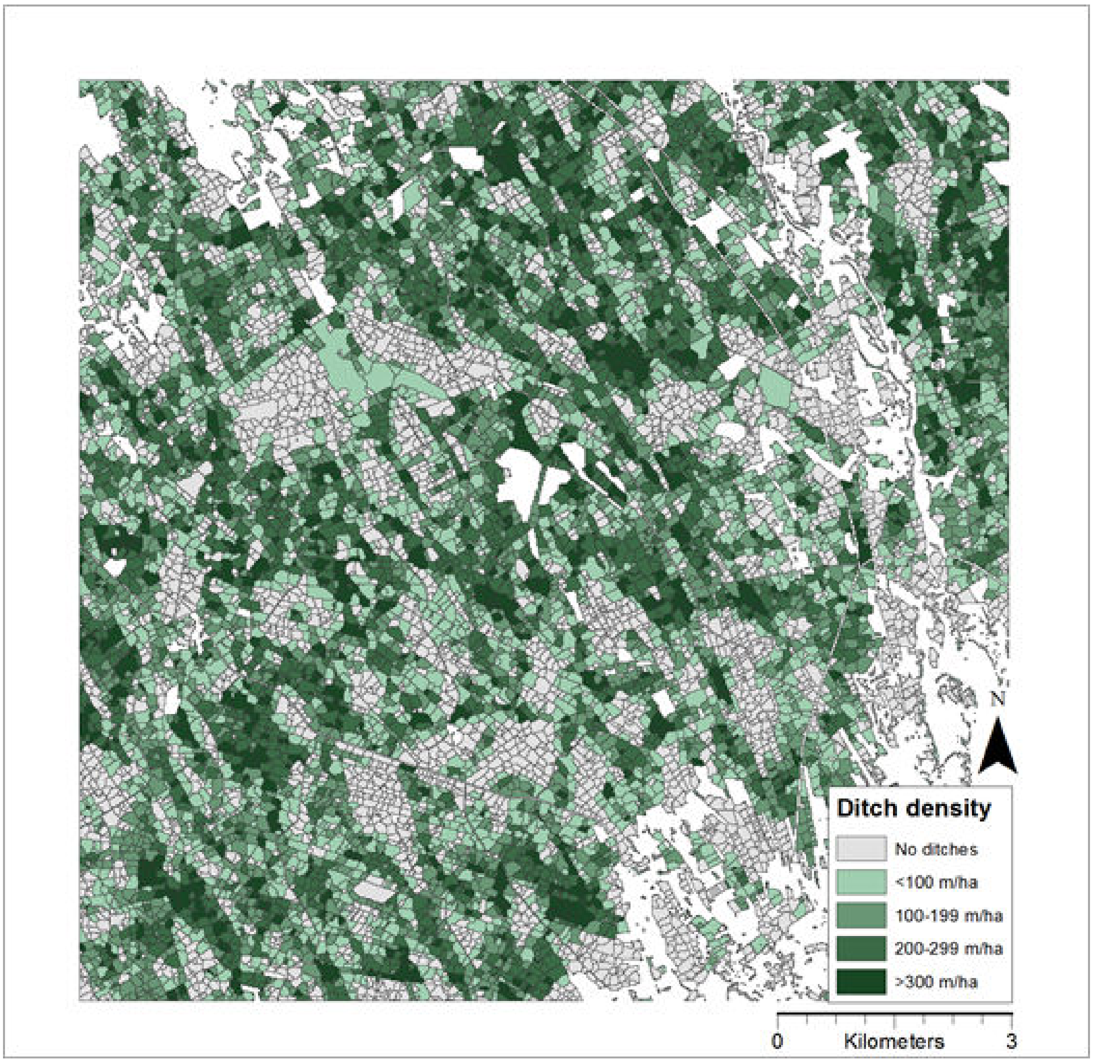

Figure 3. Ditch density (m/ha) describes the ditching state of forest segments.

For other forest variables, we calculated with intersect tool descriptive statistics within each segment polygons (see Figure 4 for example of another forest variable, tree volume). This was done with the Zonal statistics -tool. For zonal statistics, the polygon layers had to be converted to raster format. After the conversion, Zonal statistics was made with the Majority -setting in order to get the mode value for each forest segment polygon. Raster layers were then converted back to polygon. We had to classify peat depth map layer for easier interpretation, and we changed the codes to correspond depth values. We chose the minimum values of each class to represent the different depths (0.6 meters and 1 meter). This is a notable simplification, but we also didn’t have precise peat depth-data at our disposal. The process for other variables was straightforward since it did not require much extra work.

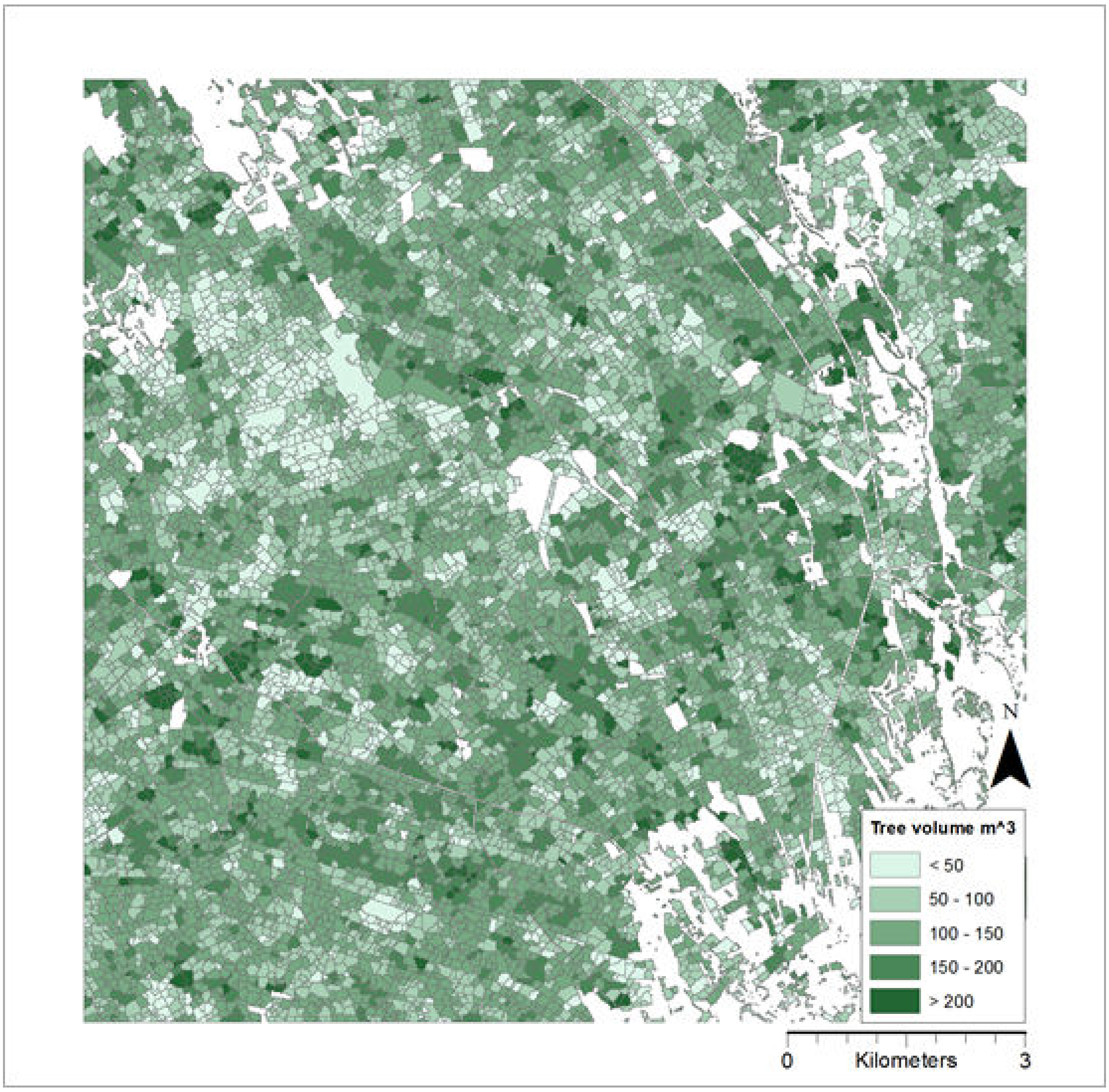

Figure 4. Tree volume (m^3/ha) per forest segment.

4. Conclusions

The main aim of this study was to derive new variables and search and collect open GIS data for Luke to use in modelling and research. **This study demonstrates and highlights that it is possible to calculate ditch densities and gather ditch-related data from the national open GIS data.** New variables include ditching density and ditching density class. Our test study area was Southern Ostrobothnia and the area is heavily ditched and modified by humans (Figure 3). In our study area the average size of an MS-NFI polygon was 0.88 hectares and contained 108 meters of ditches. Average ditching density in the area was 114.66 meters of ditches per hectare. The total length of ditches in the study area was 1461 kilometres.

We calculated the ditch density with the drainage density formula by Dingman (1978). The formula is meant for calculating drainage density in large basins, but we found it suitable for ditch density as well. However, considering the small size of majority of the forest segments, drainage density might be a slightly misleading concept. For instance, the smallest segments were only a few square meters in area and could have a ditch density of several hundred meters per hectare, which gives an impression of very dense ditching in the area. This is however not necessarily the case since in the neighbouring segments there might not be any ditches at all.

Ditching forested areas and wetlands might improve growing and soil conditions but it also may have environmental impacts. Especially water quality and quantity might get affected (Prevost et al., 1999). Areas with higher drainage density experiences increased summer flows and greater pH. Ditching also stops the production of peat and peatland flora will eventually vanish when more generic forest vegetation becomes dominant. In future studies it would be necessary to calculate ditch density variables for whole Finland. Then one should compare ditch variables against other forest variables to detect possible correlations and relationships between variables.

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