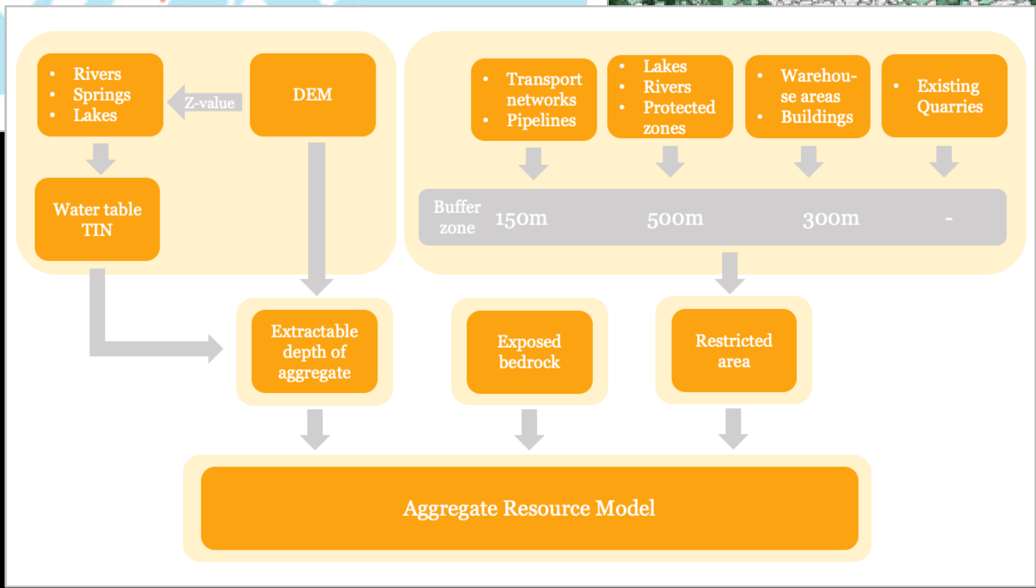

2019 DEPARTMENT OF GEOSCIENCES AND GEOGRAPHY C17

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KUJALA, S. & MUUKKONEN, P. (Eds.)

GIS applications in teaching and research:

Final report of MSc course at the Department of Geosciences and Geography, University of Helsinki, spring 2019

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UNIVERSITY OF HELSINKI
FACULTY OF SCIENCE

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Preface

GIS experts' journey from university to working life: the role of university education

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Geoinformatics, GIS, GIScience, or geomatics. We can call methodology and science related to locational, spatial, and geographical information with many names. It doesn't matter what name we call it (geoinformatics), but it's agreeable that nowadays its role in the profession of the geographer is greater than ever. We have noticed that term the "geoinformatics" is often related to the profession of geographers. Maybe we've managed to brand ourselves. Thus, demands of working life, especially in the public sector, is great about skilful people who can collect spatial data, do spatial analyses, can consider data quality, and can even visualize their outputs as beautiful but informative maps.

Our role here in the university is to give students a diverse and solid base of knowledge and skills over geoinformatics. We cannot cover all themes and skills, but we can build a solid base, which can act as a core to build further skills. It' s a well-known fact that learning continues after the university as well. One of those skills is general project management skills related especially to GIS projects. In a successful GIS project, there are many core skills. First, a GIS expert should gather GIS data needed in the GIS project, it can be downloaded from open access archives and databases or collected from the field. An expert should know what kind of data is needed for that specific purpose. Secondly, an expert should know how to manage data- and analyses workflow. This means that an expert should know how to build a system of steps, analyses, and tools following each other, sometimes this might build a complex model or work-flow-chart. Thirdly, a skilful GIS expert should know how to visualize work-flow and outputs to end-users. Finally, a skilful GIS expert needs to manage this all. Therefore, we state that project working skills are important.

To answer this demand, the Department of Geosciences and Geography, University of Helsinki, has established a specific graduate-level course to teach general project management skills related to GIS project working. This is now the second time the course GEOG-G303 GIS Project Work is organized. During the spring term, 2018 was the first time this course was available (Tyystjärvi & Muukkonen 2018). The current course was held during the spring term of 2019. In this collection of articles, we are publishing final articles of each project. All projects are jointly executed together with geography students and senior researchers. Now, we had a diverse collection of a different kind of project works varying from the higher education and science education to the GIS analyses studying natural resources in Finland. In **Chapter I**, Brendell et al. (2019) write how one can combine various open-access GIS data sources to study and model rock aggregate resources, which are important bulk building material in the growing society. They have concentrated on the Pirkanmaa region in south-west Finland. **Chapter II** shows a graduate-level e-learning course for 3D analyses (Kujala et al. 2019). In their chapter, Kujala et al. (2019) provide a pedagogical reasoning and an overall structure and content of that GIS e-learning course. In **Chapter III**, Järvinen et al. (2019) discuss how one can develop GIS learning material for the science education to be used in the elementary or high school level teaching (prior the university level). This chapter is mainly in Finnish because the audience of this article is mainly Finnish geography teachers. Finally, **Chapter IV** written by Ruikkala et al. (2019) shows a methodology on how one should calculate derived GIS-based variables for ditching density in wetland forests. Wetland forests play an important in the boreal forest ecosystem and have a high economic value in the forestry.

During these GIS project works, done in close co-operation with research projects, researchers and teachers, graduate-level geography students have learned important project management skills. They have learned to plan a GIS project, to schedule project's tasks and goals, to develop project's communication within the project participants and even to end-users and to the audience, and they have also learned to report the project work-flow and main outcomes (oral presentations, poster, and written documents. We see that these general skills are beneficial when one is leaving university and head to work life.

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Chapter I

Open source modelling of rock aggregate resources in the Pirkanmaa Region

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Abstract

Aggregate rock has a constant demand in urban areas as a construction material for infrastructure. To be economically viable, the extraction sites for this resource should be located close to the construction sites, which can be complicated due to conflicting land uses. In this research, rock aggregate resources were modelled for the Pirkanmaa region in Western Finland with an open source GIS-approach, using free and open software and data. The resulting model shows the quantities of rock aggregate resources in Pirkanmaa municipalities, as well as the spatial distribution of the resource in the area.

Keywords: rock aggregate; GIS; open source; modelling, Pirkanmaa

1. Background

Rocks are a key material when constructing buildings and roads, and particular when establishing the foundation. This role leads to a high demand in expanding regions undergoing urbanization. Due to the scale and weight of the material, the extraction areas of rock aggregate are optimally located near the areas of deployment (Poulin et al., 1994). This is complicated by the competition of other land uses such as national parks, housing or other human infrastructure which conflict with the extraction areas (Mäkelä, 2018). A map depicting the rock resources and their volume helps regional planners and decision-makers in identifying the optimal location for extraction. The objective of this work was to create such cartographic visualization by using open source geographical information systems (GIS).

The needed shape of rock for construction is aggregate (Smith & Collis, 1993). Therefore, loose sand or gravel would be the most profitable source since solid rock needs to be crushed for the extraction while sands and gravel can just be shovelled. However, lucrative sand and gravel sources are on their way of depletion. In addition, these areas serve another important task as they provide fresh groundwater or recreational areas (Britschgi, 2001; Räisänen, 2004; Lonka et al., 2015). Due to this reason, solid rock as a source for rock aggregate is rising in significance in areas of high demand (Rintala, 2003; Räisänen, 2004; Lonka et al., 2015). Furthermore, the costlier extraction and processing is countered by the decrease of the carriage distance (Brown, 2012; Lonka et al., 2015).

Many factors have to be considered when mapping rock aggregate resources. They range from social, environmental to economic issues where preservation acts against profitable growth (Ross & Bobrowsky, 2002; Mäkelä 2018). When you add the consideration that the sought rock resources have to be located as close as possible to the deployment site, the extraction site has to compete against other land uses in the urban region (Bobrowsky & Manson, 1998; Brown, 2012; Dahl et al., 2012). City planners have to take this into consideration, still, without the knowledge of an approximate amount of the available amount of rock, it is difficult to create a futureproof city plan. Our work is addressing this problem by providing insights into the location and volume of solid rock resources usable for rock aggregate extraction.

The approach used in this research is based on Mäkelä’s (2018) previous study in the Helsinki metropolitan area. Due to the fact that this model worked for the Helsinki metropolitan area, we are replicating and applying this method for another region. The emphasis is on providing a complication-free reproducibility with an open source approach.

2. Open GIS

Recent decades have witnessed a growing interest in open GIS practices (Steiniger 2012; Sui 2014), reflecting a wider trend of openness in social and technological environments. According to Sui (2014), open GIS should include open data, open software, open hardware, open standards, open research collaboration, open publication, open funding, and open education/learning. This approach is seen beneficial as it can improve GIS products and practices through decentralized development, but also because it can facilitate new applications and approaches in GIS research. The rock aggregate resource model (Mäkelä 2018) used in this research project is based on utilizing both sources of open data and open software environments.

3. Data

Data for the model included topographical features derived from the topographic database (Maastotietokohteet, 2018) by National Land Survey of Finland (NLS), elevation model by NLS (Korkeusmalli 10m, 2016) and exposed bedrock derived from superficial deposits data by Geological Survey of Finland (GSF) (Maaperä 1:20 000, 2015). Description of all the used data is shown in Table 1. All the data are free and have an open license.

Topographic database by NLS, from which topographical data was derived, is a dataset of Finland's topographical features, covering the entire country (Maastotietokohteet, 2018). The information is thoroughly updated every 3-10 years, depending on the area. Some of the information, such as transport networks, are updated more frequently, with the aim to keep them up to date. Another dataset by NLS, 10 m elevation model, is currently the most accurate digital elevation model for the entire country, with 1.4 m precision (Korkeusmalli 10m, 2016).

Superficial deposits datasets by GSF, from which the exposed bedrock data was extracted, was produced during 1972-2007 for land use planning, mapping and inventory of natural resources as well as for environmental management and scientific research (Maaperä 1:20 000, 2015). Deposit type is defined from the basal deposit at a depth of one meter; thus, exposed bedrock class includes all the exposed bedrocks and areas with less than 1 m of topsoil.

Table 1. Description of all the data used in the rock aggregate model (NLS = National Land Survey of Finland; GSF = Geological Survey of Finland).

Data	Source	Name	Type	Scale	License	Acquired
Elevation	NLS	Elevation model 10m	Raster	Grid size 10 m	CC/BY4.0 / NLS	28.3.2019

Transport network	NLS	Topographic database	Vector line / polygon	1:20 000	CC/BY4.0 / NLS	23.3.2019
Pipelines	NLS	Topographic database	Vector line	1:20 000	CC/BY4.0 / NLS	23.3.2019
Lakes	NLS	Topographic database	Vector polygon	1:20 000	CC/BY4.0 / NLS	23.3.2019
Warehouse areas	NLS	Topographic database	Vector polygon	1:20 000	CC/BY4.0 / NLS	23.3.2019
Buildings	NLS	Topographic database	Vector polygon	1:20 000	CC/BY4.0 / NLS	23.3.2019
Military areas	NLS	Topographic database	Vector polygon	1:20 000	CC/BY4.0 / NLS	23.3.2019
Protected areas	NLS	Topographic database	Vector polygon	1:20 000	CC/BY4.0 / NLS	23.3.2019
Protected objects	NLS	Topographic database	Vector polygon / point	1:20 000	CC/BY4.0 / NLS	23.3.2019
Exposed bedrock	GSF	Superficial deposits	Vector polygon	1:20 000	Modified data, © GTK 2019	29.3.2019

4. Study area

The model used in this research has previously been tested for the metropolitan area of Helsinki (Mäkelä, 2018) which is the most populated region in Finland. Second, comes Tampere Central Region, which has been one of the fastest-growing regions in Finland in the last five years with Oulu and Helsinki and should, therefore, have a high demand for rock aggregate (Population growth by sub-regional, 2019). Thus, Pirkanmaa sub-region where Tampere is located was chosen as the target area.

5. Preparing the data

Handling the sorting of the data manually would have been laborious and time-consuming as the number of files in our dataset exceeded three figures. Thus, we wrote Python scripts to handle the data. Each individual shapefile had a descriptive code in the name. First, a script unzipped each individual tile:

```
import zipfile,fnmatch,os
def unzip():
    rootPath = r"./data/realsuomi/Varsinais-"
    pattern = '*.zip'
    for root, dirs, files in os.walk(rootPath):
    for filename in fnmatch.filter(files, pattern):
    print(os.path.join(root, filename))
    zipfile.ZipFile(os.path.join(root, filename)).extractall(os.path.join(root,
filename.split(".")[0]))
unzip()
```

Next, another script iterated over the folders, subfolders and files and moved the files according to their descriptive code at the beginning of the filename to their designated folders:

```
import os
import shutil
fullpath = os.path.join
buildings = "./data/realsuomi/bufflayers/Buildings"
pipelines = "./data/realsuomi/bufflayers/Pipelines"
protected = "./data/realsuomi/bufflayers/Protected"
...

def sorting():
    for dirname, dirnames, filenames in os.walk(rawdata_directory):
    for filename in filenames:
    source = fullpath(dirname, filename)
    if filename.startswith("j_"):
    shutil.move(source, fullpath(pipelines, filename))
    elif filename.startswith("r_"):
    shutil.move(source, fullpath(buildings, filename))
        elif filename.startswith("s_"):
    shutil.move(source, fullpath(protected, filename))
        …
sorting()
```

Then another script merged the files in each individual folder according to their descriptive code at the end of the file name which indicated the type of shape (Polygons, vectors, points):

```
def merge():
    folder = path.Path("./data/bufflayers/Water")
    destination = path.Path("./data/bufflayers/Merged/Water")
    shapefiles = folder.glob("*v.shp")
    gdf = pandas.concat([
    gpd.read_file(shp)
    for shp in shapefiles
    ]).pipe(gpd.GeoDataFrame)
    gdf.to_file(destination / 'river.shp')

merge()
```

Some files still included attributes that we had to filter. This task was done with GDAL (Geospatial Data Abstraction Library). This command goes over the attributes of the shapefile and creates a new shapefile containing only the rows of the needed attribute:

```
ogr2ogr -where LUOKKA=36100 36100.shp springs.shp
```

The raster data for the DEM was also provided in tiles which had to be merged. On this problem we used a Python script containing a GDAL command:

```
import glob
import os
file_list = glob.glob("*.tif")
files_string = " ".join(file_list)
command = "gdal_merge.py -o output.tif -of gtiff " + files_string
os.system(command)
```

6. Workflow

The workflow for the model is shown in figure 1. The model consists of a limitation layer, the exposed bedrock and the volume of the extractable rock aggregate. The area of the limitation layer was defined by creating a buffer zone around areas and objects from the topographic database that restrict mining activities. Lengths of the buffer zones are based on legislations and industry standards (Mäkelä 2018). Once the limitation layer was established, it was used for an overlay analysis (difference) with the exposed bedrock to define areas suitable for rock extraction.

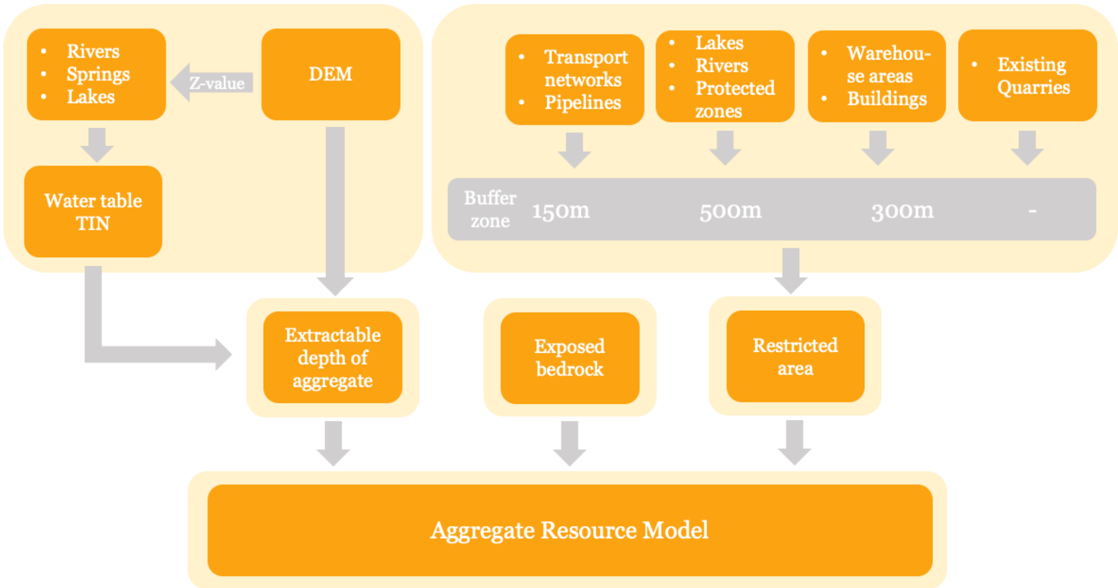

Figure 1. Workflow for the rock aggregate modelling.

To calculate the volume of extractable rock aggregates, upper and lower limit of the non-restricted bedrocks were estimated. The upper limit was extracted from the elevation model. The lower limit is based on the estimated level of groundwater. This level was modelled by first adding an elevation value from the elevation model to the centroids of all lakes, springs and rivers and then creating a Triangulated Irregular Network (TIN) layer from these centroids. The resulting lower limit was then subtracted from the upper limit to get the extractable depth of the exposed bedrocks.

The extractable volumes of the rock aggregates were then estimated by calculating the mean depth of the aggregate polygons and multiplying it by the area of the polygon. Furthermore, the total volume of the rock aggregate resources was calculated for each municipality.

7. Results

Generally, Pirkanmaa has large quantities of rock aggregate resources available. Yet, the resources and possible extraction sites are unevenly distributed among municipalities (Figure 2; Figure 3). While Ruovesi and Orivesi have over 5000 M m3 of rock aggregate resources, Valkeakoski, Pirkkala, and Akaa do not have a utilisable amount of rock resources available (Figure 2).

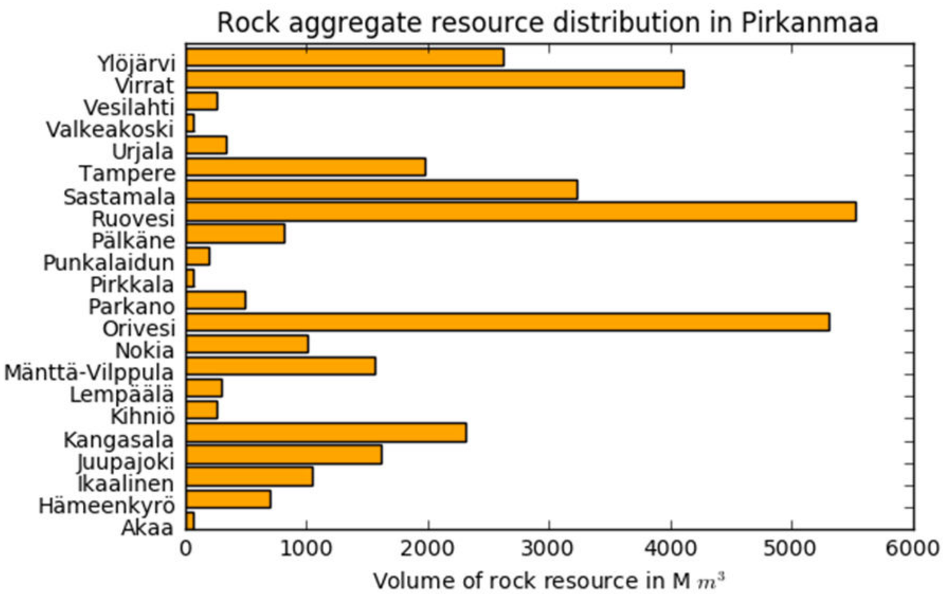

Figure 2. Quantities of the rock aggregate resources in the Pirkanmaa municipalities.

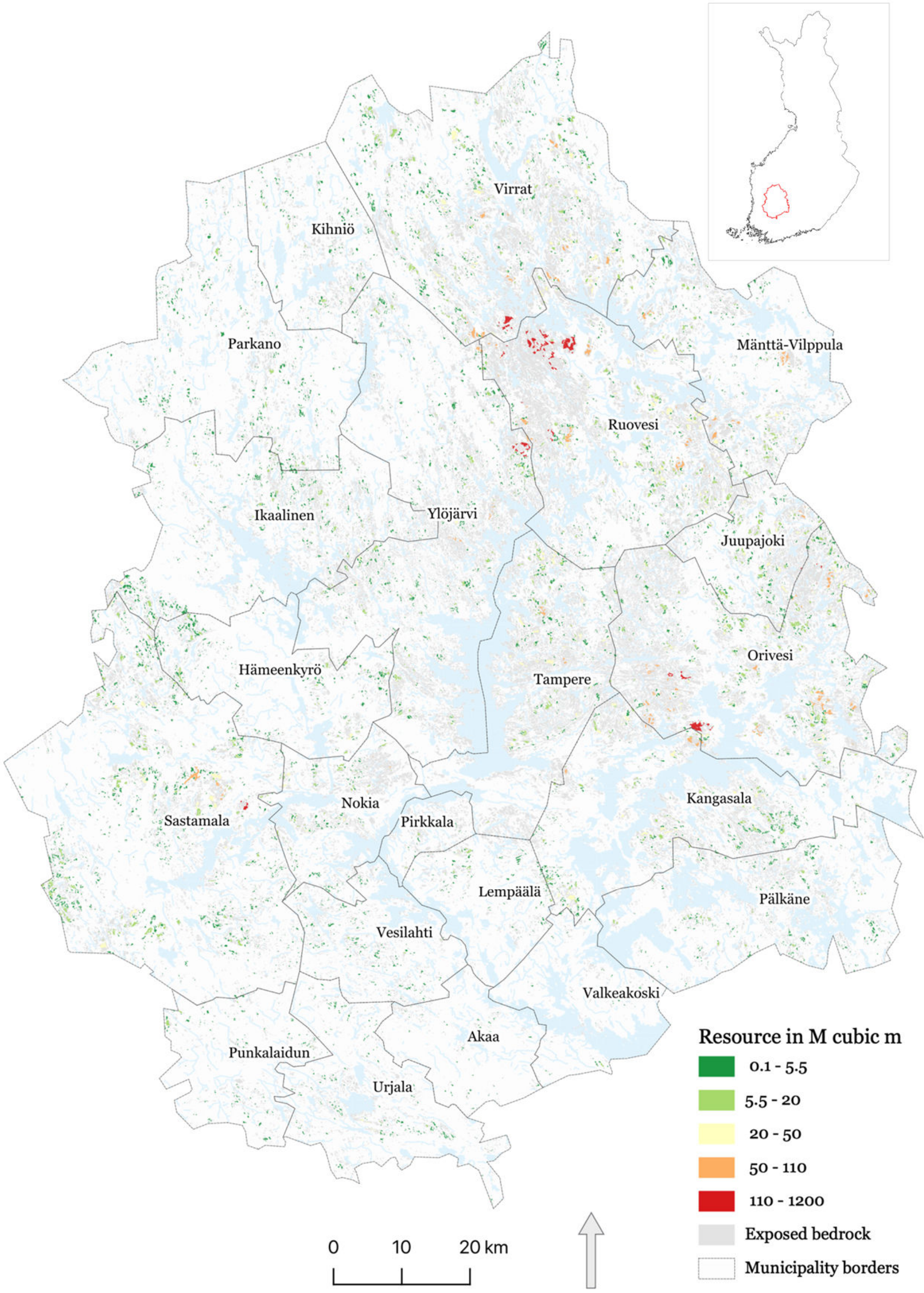

Figure 3. A map showing the spatial distribution of rock aggregate resources in the Pirkanmaa area.

8. Discussion

The Geological Survey of Finland has its own dataset for the available rock resources in the whole of Finland. Most of the results here are in line with this data, but our model shows more resource areas. This could be due to filtration of smaller areas by the Geological Survey for their dataset. In addition to the volumes, the bedrock aggregate dataset by GSF offers information about the rock type and point data about test results of the rock in many areas.

For calculating the expected groundwater table, we used a Triangulated Irregular Network (TIN) with rivers and seas as a source. The result of the TIN only gives us a rough estimation of the groundwater table, thus, providing an accurate volume of extractable rock is not possible with our data. Enhancing the quality of the estimation is possible if a more accurate dataset for the groundwater table is used.

While our model can give an approximate estimate of the number of rock resources, rock quality has to be determined in field studies at the respective sites. However, the rock quality is not a big concern in Finland as most of the Finnish bedrock consists of plutonic or high-grade metamorphic rocks (Mäkelä, 2018; Härme, 1980; Laitala, 1991; Grönholm, 2000a, 2000b; Vuokko, 2004).

Not included in our model are regional plans as they are not yet implemented and can, therefore, be changed. For instance, one huge possible extraction site may be sterilized by a plan for a motocross track. Evaluating the importance of each land use is an errand city planners and decision-makers have to do. Also not included are regional plans' important biodiversity areas which should be preserved. City planners and decision-makers should avoid these areas as locations for quarries.

9. Web Map

For easy accessibility, we created a web map of our results. It is produced in Python with the Bokeh library. The code for the web map can be found in appendix 1 while the web map can be found on this website: https://brenchri.github.io/rockaggregate.html.

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Appendix 1

```
# Necessary libraries

import bokeh.layouts
import geopandas as gpd
import pandas as pd
import pandas_bokeh
pandas_bokeh.output_notebook()
import bokeh
from bokeh.plotting import save, figure
from bokeh.transform import transform

# Importing the data for the creation of the interactive map

rock = "./data/pirkanmaa_rock_aggregate.shp"
mun_source = "./Pirkanmaa/Municipalities/pirkanmaa_muncipalities.shp"

df_mun = gpd.read_file(mun_source)
df_rock = gpd.read_file(rock)

df_rock = df_rock.rename(columns={'rock': 'Aggregate volume in M cubic
metre'})

# Bokeh command for plotting the municipality borders

figure = df_mun.plot_bokeh(title="Resource map",
simplify_shapes=10,fill_alpha=None, fill_color=None,
line_color="black", show_figure=False)

# Bokeh command for plotting the rock resource data
```

```
df_rock.plot_bokeh(simplify_shapes=500,
                    figure=figure,
                    category="Aggregate volume in M cubic metre",
                    line_color=None,
                    show_colorbar=True,
                    colormap="Spectral",
                    colormap_uselog=True, legend=True)

# Command for scaling the plot according to the website design

figure.sizing_mode = 'scale_width'

# Output filepath

outfp = r"./data/test_map.html"

# Save the map
save(figure, outfp)
```

Chapter II

Developing a higher education e-learning GIS course for 3D analyses in geography

Kujala, S. [1], Lämsä, S. [2], Määttänen, A-M. [3] & Muukkonen, P. [4]

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Abstract

In this paper, we are showing how we designed and implemented a graduate-level GIS e-learning course for 3D analyses in GIS and geoinformatics. This work was done in the GIS project work course in the Department of Geosciences and Geography, University of Helsinki. In the developed e-learning course students can study independently on the e-learning platform. We based a lot of own prior experience towards the design of the course, and we justified our decisions with topical pedagogical scientific knowledge about GIS teaching. The main aim was to make a challenging but interesting overview of the topic 3D in GIS. The course combines readings, practices, and final essay on a chosen topic. The course is divided into six different areas under 3D. After these, the final essay measures the learning within a form of deeper thinking skills. Course's goal is to teach the student to use their own knowledge and skills on data processing methods later the future in their working life. In addition, self-motivated learning is highly encouraged throughout this e-learning course.

Keywords: 3DGIS; distance studies; e-learning; geography teaching; higher education; online studies

1. Introduction

1.1 Background

We wanted to design a new GIS course for graduate geography students. The aim was to fulfil a need to introduce geographers into the possibilities of three-dimensional (3D) GIS and its analyses. The requirement for the project work was to make the course completely into an online-self-study course that can be completed as distance studies at any time depending on a student's own preferences. In this way, they will have a less formal studying atmosphere with the course, since they can complete it from anywhere at any time (Harris 2003; Şeremet & Chalkley 2015; Robinson et al. 2015). The course uses one of the four approaches of the usage of ICT (information and communications technology) based learning, called fully online learning (Lynch 2008). The course does not need attendance at the campus, but students will follow an online curriculum. Due to an increased need for 3D GIS analyses skills in general, we decided to create an online course about the topic, and we also decided that the course would use an e-learning platform Moodle and the completion would be up to the students themselves. We created a course that would be interesting for the present and future graduate-level geography students. The "non-cookbook" practical style encourages deep learning within the students (Şeremet & Chalkley 2015; Argles 2017). One of the goals was also to create a course that can last at least some upcoming years without too drastic changes or need for updating into the structure of the course. Naturally, this course will be improved in the future due to the rapid improvements in the field of GIS, 3D GIS, and computer sciences.

The course is divided into six sections of practical topics and into a final scientific essay (see Figure 1). The topics of the course will guide the student through different topics of 3D GIS and the possibilities of 3D visualization in mapping. These topics were notified to be the core of this theme. The overall goal was to give a good overview of interesting topics in the field of the 3D GIS analyses and visualisation in geography.

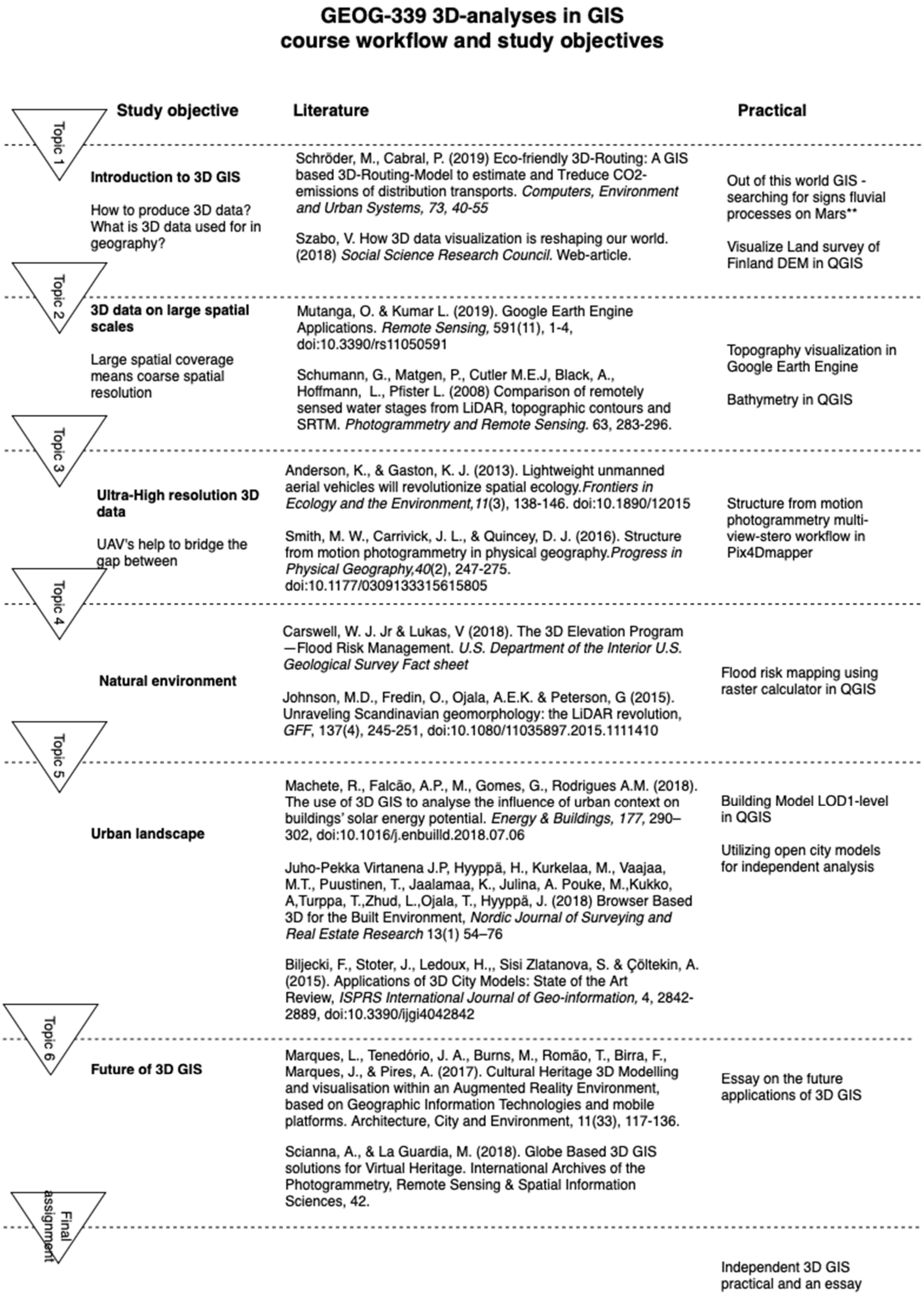

Figure 1. Workflow and course literature of the 3D course.

This 3D GIS course is a five-credit (5 ECTS) course that requires a good basis of existing extensive knowledge of geoinformatics, GIS, and its systems. Pre-course requirements for completion of this course are at least Introduction to Advanced Geoinformatics at the University of Helsinki, however, any other more advanced GIS courses give a valid basis for completion of this 3 D course. Students will work independently a lot, so it's recommended to have confidence in doing their own research with materials and methods in the field of GIS. The learning outcomes for the course are in a way that the students will have a broad overview of varied topics in 3D GIS. Students will also have increased skills in searching for more information and using open software in their research. Each study credit is equivalent to approximately 27 hours of work, in total, the course is designed to take approximately 135–140 hours of working time consisting of readings, practicals (material research, GIS analysis, and writing), and a final essay. It is intended that each practical would take approximately 8 to 10 hours to complete, and a student can use the remaining time to do the final project and essay that takes a little bit longer to complete.

1.2 Why do we need a 3D GIS online course?

We perceive our surroundings in three dimensions; the Earth is not flat, and neither are the events occurring on it. Three-dimensional (3D) data is essential for accurate descriptions, analysis, and predictions of both natural and man-made phenomena. In a typical GIS application, it is usual that at least two of these dimensions (x and y) are spatial extents in a known coordinate system and the third (z) is elevation data. The third dimension can, however, represent some other attribute as well, e.g. the concentration of a chemical or the literacy rate of a given area.

3D data can be divided into two main types: surface and objects (Abdul-Rahman & Pilouk 2007). A surface is a representation of an attribute in three-dimensional space, and its format is most commonly raster, triangulated mesh or some other continuous digital surface. An object is discrete and is usually represented in a vector format. These vectors can be a point, polygons, and polylines in a three-dimensional space.

A need for different 3D applications methods is increasing in the field of GIS. This course will improve student basic knowledge from 2D to 3D. The study program of geography, University of Helsinki, is currently lacking a course that will study GIS purely from the viewpoint of 3D. Now, the array of GIS courses offered by the department is scattered from the standpoint of 3D. This new online course offers a clear-cut and more in-depth perspective to 3D data and 3D analysis in GIS.

2. The study material of the course

2.1 Study structure

Each topic is based on different spatial extents or perspectives of 3D data applications, were learning the objective is to deepen knowledge in separate 3D spatial data areas. The course includes six topics:

1. What is 3D GIS?
2. Large spatial scale 3D mapping
3. Ultra-high-resolution 3D
4. Natural environment
5. Urban landscape and urban environment
6. Future of 3D

Each topic introduces applications within the main topic where some are scientific articles, and some are practicals. The course workflow is categorized by accurate spatial extents: spaceborne for large spatial extents, aerial for landscape, and in-situ and unmanned aerial vehicles or a low aerial for local spatial extents.

The course uses the Moodle e-learning platform. This platform was chosen because it is familiar to the students of the University of Helsinki and it is suitable for varying number of participants.

2.2 Topic 1: What is 3DGIS

The first topic introduces the basic elements of 3D data and its main types: surfaces and objects. The student is challenged to think outside-the-box by scientific reading. For example, the article by Schröder and Cabral (2019) introduces 3D visualization of CO^2 emissions of transport. The aim of this is to underline that the z-coordinate can represent other parameters than the only elevation. The main aim is to teach basic knowledge about 3D GIS and the vast array of different data types, and how they relate to the spatial extent of coverage. Different platforms are described briefly in Figure 2. Students will get familiar with several observation platforms that can be used when producing 3D GIS data (Figure 2).

The first practical will be an easy visualization practical using the 2-meter resolution Lidar-derived DEM provided by the National Land Survey of Finland. The data is open access data and it is free to use. The student will also learn basics through question list. Answers should be included to report.

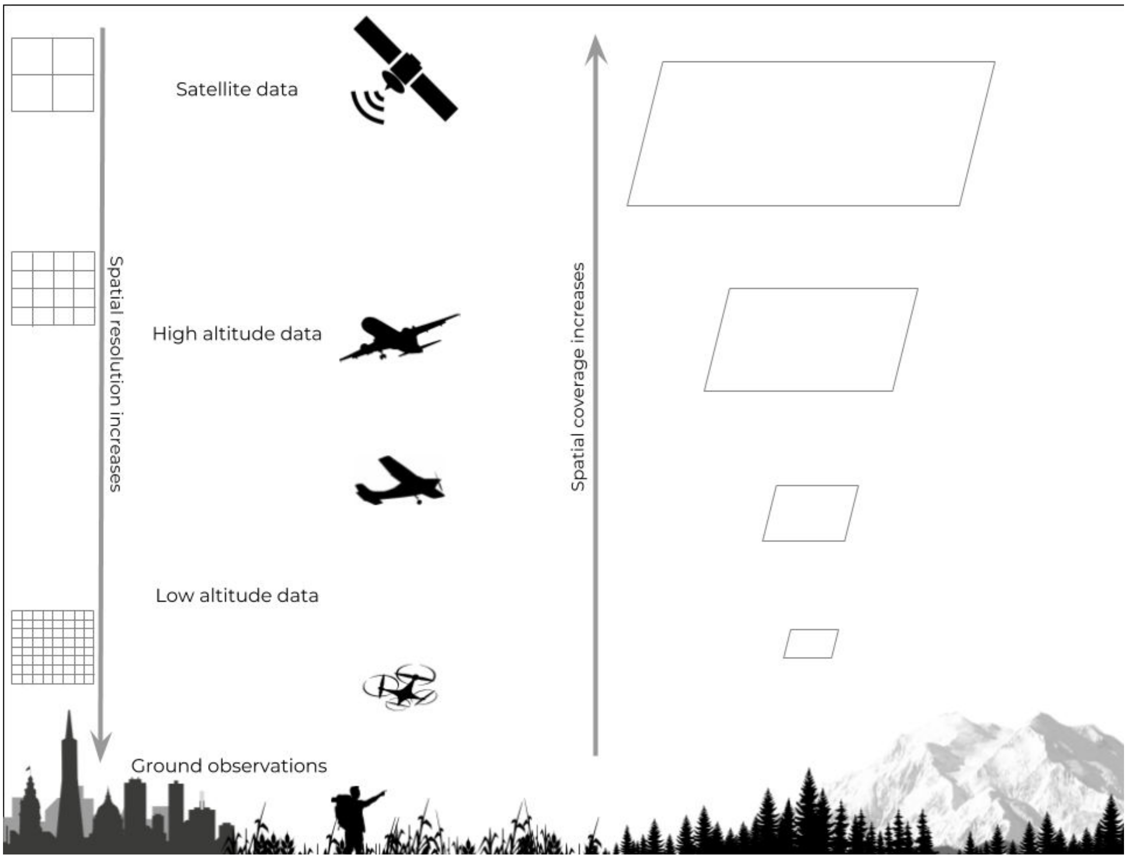

Figure 2. Different 3D data gathering platforms and their relation to spatial coverage and spatial resolution. (drawing: A-M. Määttänen)

2.3 Topic 2: Large spatial scale 3D mapping

Here we introduce the main data sources for near-global scale topographic data and discuss the trade-offs in data quality versus spatial coverage. The main data source discussed is the near-global coverage Shuttle Radar Topographic Mission (SRTM) by NASA. Global investigation of topography is crucial because elevation constitutes one of the most important boundary conditions (Schumann et al. 2007). The global coverage topography data enables investigation of different fluxes of material and understanding global patterns of for example species distribution. It is evident, that these large scale and large extent data sets require a lot of storage space and processing power, the students will go through a demo of Google's Earth Engine (GEE) remote sensing data processing interface. GEE is a geodatabase with an impressive assemblage of different remote sensing data, i.e. the complete LANDSAT archive (Mutanga & Kumar 2019). Students will use GEE to run a short script that visualizes SRTM topographic data using Google's processing resources. The practical will introduce students to bathymetry and underwater 3D applications.

2.4 Topic 3: Ultra-high-resolution 3D

UAV (unmanned aerial vehicle) methods have closed the resolution gap between field observations and remote sensing data (Anderson & Gaston 2013). Together with novel computer vision algorithms, these methods have democratized the availability of 3D spatial data. This topic is focused on Structure from Motions (SfM) and its potential in ecosystem-scale GIS problems. The literature introduces SfM and the practical is a basic SfM workflow. The practical is carried out with a commercial software Pix4Dmapper. The rationale behind the decision of using commercial software instead of an open one is that there are licences available for this software in the department and the graphical user interface logical.

2.5 Topic 4: Natural environment

We wanted to differentiate the 3D GIS applications for urban areas and the natural environment because the modelling of the movements of energy and metrical on the earth is different in natural landscapes compared to environments that have been heavily shaped by humans. Furthermore, the questions that arise are usually different between the two environments. We acknowledge, that human activity is a pronounced geomorphic process and this division simplifies complex systems (Tarolli & Sofia 2016). This division was made on the account of simplicity and because students might want to treat these environments as separate due to their field of specialization under the geography discipline.

The natural environment topic introduces some focal applications of 3D GIS like geomorphometry, 3D change detection (Quin et al. 2016), and risk evaluation, especially from flood map point of view (Carswell & Lukas 2018). These topics are approached in the literature via different datasets. Johnson et al. (2015) review how LiDaR has revolutionized the way Scandinavian geomorphology is studied. The practical is a sea-level rise risk map using OpenTopography data and raster calculator. A simple analysis of how the coastline will be submerged in different sea-level rise scenarios.

2.6 Topic 5: Urban landscape and urban environment

Urban areas are also a big topic in the 3D GIS. Several cities have created detailed 3D city models which are improving their decision making and urban planning. Through this section, the student will deepen their knowledge about 3D city models and cityGMLstandards. Additionally, the students will learn how to gather 3D data from urban areas, depending is it object-based or more detailed model. Practical includes basic building exercise, where learning outcome is to create LOD1 (Level-of-detail) model from the city. Another practical task is to create own urban application analysis, which depends on the student own interests. The student will have a few tips on how to do their own analysis.

2.7 Topic 6: Future of 3D

The topic of the future of 3D GIS was chosen on the basis that the rapid technological evolution will take the field of 3D even further into different fields in science. We wanted to have the last topic to be a bit different from other practicals so we decided to make a freeform essay on a chosen field of possibilities of 3D GIS in the future.

Marques et al. (2015) utilized 3D GIS application in AR (augmented reality) for cultural heritage modelling and Jazbinšek and Hren (2018) also used AR and 3D GIS to create a new way to visualize GIS data. In the practical, the students will read about three different uses for future 3D GIS and one ESRI article on the usage of their CityEngine in research (Fabricius 2018).

2.8 Topic 7 – Final assignment

The main learning objective of having a final assignment is to have students to prove their knowledge on gathered concepts and realize learning in the form of a written report. By writing the assignment on free-to-choose topics we can ensure that the students are motivated and interested in their own topic. Şeremet and Chalkley (2015) also found out that by using GIS on bigger phenomena the students improve other skills aside from GIS as well. For example, students showed an increase in spatial learning and ecology knowledge after producing maps on forestry. Final essays are also a common way to assess the combined knowledge from learned theory and finished practicals, although it had also been argued that the students experience the essay-based assessments to be not as useful as other course practicals (Şeremet & Chalkley 2015). Despite this, after a small survey and discussions with graduate-level geography students we decided to apply some essay-based elements to this course.

2.9 Providing course feedback

After the course, students are required to fill out a feedback questionnaire before the completion of this course. The e-learning nature of the course demands that course should evolve and grow to fill into the users' needs. It is obvious that feedback is required and needed for the future of the course. Sack and Roth (2017) used the term exit survey to describe their online course feedback survey. According to the survey of Sack and Roth (2017), students answered several questions on the topics relating to the content of the course and possible improvements to them.

The first questions ask students how well they felt that the learning objectives were articulated and how well the provided literature and practicals helped to reach these targets. The next questions were aimed at finding out if the students liked how the course was organized and whether the independent form of studying was considered to be helpful in terms of learning. These questions are essential for course development and will be used as the initial measure of how well we, as a group, performed in creating an online 3D GIS course.

The next three questions in the survey are meant for self-reflection. One asks if the amount of work required for completion of the course corresponding to the five credit. The other two questions ask if the student felt that the topics were interesting and if they felt that they gained some useful knowledge and skills during the course.

All the questions described above were scaled from ***Completely agree*** to ***Completely disagree*** on a four-point scale. At the end of the survey, there are two open questions. These are aimed for any feedback or course-development ideas that may have arisen during competition of the course.

Before launching the course available to all students, we used the initial feedback from the few students who tested the course. Feedback was a pivotal part of course development. In addition, it was important because this course was developed as project work in the graduate-level course. Therefore, the role of feedback in the early stages of the developing was even more pronounced.

3. Discussion

Lynch (2008) argued over ten years ago that technology will change the future and work life, which it indeed did. A rise in the popularity of e-learning within and outside of higher education institutions has been increasingly noticeable in recent years. We argue that this is since information is more accessible now than ever and, in addition, learning is becoming more scattered.

One possible threat to e-learning is that students are dropping e-learning courses more often than traditional lecture-based courses (Robinson et al. 2015). Our goal was to avoid this by making the topics varied and this way more suitable for students with varying interests in the field of 3D GIS. Students are also given the freedom to decide their final report from different topics throughout the course to work on.

The students not having excessively detailed instructions to the practicals might cause some students to end up having to go through several unproductive searches online for help and answers to the practicals (Lynch 2008). However, this varies a lot from student to student, since it's tied to their prior skill level and knowledge on GIS programs and open data search. The solution for this could be turning the course into a larger open MOOC (Massive Open Online Course) course, where students could learn more from each other as Robinson et al. (2015), found out in their research. One possible solution would also be to encourage students to create study groups for the completion of the course.

It was discussed a lot within the team that our project group had almost no prior knowledge of how to produce a university course other than from the student's perspective. We conducted several overlooks to the methodology of GIS teaching on the university level and found that our own views on a good lecture series matched to scientific research in several cases (Harris 2003; Lynch 2008; Robinson et al. 2015; Şeremet & Chalkley 2015; Argles 2017).

It was discussed that there might be problems with some used programs during the course, for example, our program of choice, QGIS, changes very rapidly (Argles 2017), which could turn out to be problematic for the completion of some of the practicals. However, this should not be a big problem since the instructions to the practicals are not too detailed. In case the software will change during the course or during the next years, we highly encourage students to search additional information from the user forums of the programs since they have proven to be very reliable in most of the cases. In the case of bigger problems with completion, the students can always turn to the help of the course instructor. To preserve the integrity of the learning materials we created them to be more open and leaning towards self-studying methods. Our aim was to find as new articles as possible that will stay actual longer. Topic 6 was left a bit more open since it is almost impossible to predict the future possibilities of 3D GIS, but the topic was included since we believe that 3D GIS will be more prominent in the field of GIS.

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Chapter III

GIS-opetusmateriaalien kehittäminen tiedekasvatuksen käyttöön

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Tiivistelmä

Uudessa opetussuunnitelmassa geomedia, eli maantieteellisen tiedon erilaiset hankinta- ja esitystavat, kasvatti osuuttaan sekä peruskoulun että lukiotason maantieteen opetuksessa. Erityisesti lukion opetussuunnitelmassa tuodaan esille geomedia-käsitteen mukainen paikkatieto-opetus sekä paikkatietomenetelmien soveltaminen maantieteellisessä tutkimuksessa. Helsingin yliopiston Tiedekasvatuskeskuksen alaisuudessa toimiva maantieteen Geopiste tuottaa avoimesti saatavilla olevia maantieteen opetusmateriaaleja ja järjestää esittelyjä ja oppitunteja vieraileville koululaisryhmille. Geopisteen materiaalipankkiin luotiin keväällä 2019 yhteensä kahdeksan uutta paikkatietoaiheista tehtäväpakettia. Materiaalit luotiin tukemaan opetussuunnitelman mukaista opetusta, ja niitä voidaan käyttää joko vierailuilla Geopisteessä tai opettajat voivat käyttää niitä luokkaopetuksessa. Tarjoamalla laadukkaita materiaaleja ja opetusta voidaan tarjota ratkaisua koulujen paikkatieto-opetukseen liittyviin ongelmiin, jotka johtuvat usein materiaalien, teknisten resurssien tai asiantuntevan ohjauksen puutteeseen.

Avainsanat: avoimet oppimateriaalit; GIS; GIS-opetus; paikkatieto; tiedekasvatus

Abstract

The current curriculum of the Finnish senior high school requires skills to use various sources of geomedia. In the Finnish school system, geomedia means all sources of geographical data. Typically this is understood as geoinformatics, GID, and maps, but it includes also photos, news, text sources, diagrams, statistics, videos etc. This is recognised also by the geography science education and learning centre "Geopiste" at the University of Helsinki. In this article, we are showing and reasoning several open-access GIS exercises that geography teachers can use in their own teaching or those can be used when school groups are visiting in the Geopiste learning centre. Here are totally eight new GIS exercises, which were produced according to the newest Finnish curriculum for the level of upper high school. There is an urgent need for this kind of open access exercises due to technical challenges.

Keywords: geoinformatics; GIS; open-access learning material; science education

1. Johdanto

Paikkatietojärjestelmien ja paikkatiedon (GIS, *geographic information system*) avulla voidaan säilyttää ja käsitellä tiettyyn kohteeseen sidottua spatiaalista dataa eli paikkatietoa (Burrough et al. 2015). Yli 40 vuotta kestäneen kehityksen tuloksena paikkatietojärjestelmiä hyödynnetään maailmanlaajuisesti kaikilla julkisilla ja yksityisillä sektoreilla, ja 1990-luvulta lähtien sitä on hyödynnetty myös kouluopetuksessa (Kerski et al. 2013; Burrough et al. 2015). Suomessa paikkatietoa on hyödynnetty perus- ja lukio-opetuksessa 1990-luvun lopulta lähtien; aluksi pioneereina toimineiden opettajien ansiosta, mutta nykyään jo selkeänä osana lukion opetussuunnitelmaa (Johansson 2011; Opetushallitus 2015).

GIS-ohjelmistoja ja -tekniikoita hyödyntävien harjoitusten ja projektien on havaittu olevan toimiva pohja monialaiselle ja ongelmanratkaisupohjaiselle opetukselle peruskoulu- ja lukio-opetuksessa (Rød et al. 2010; Demirci et al. 2013; Kerski et al. 2013). GIS-pohjaisen työskentely auttaa kehittämään spatiaalista ajattelutapaa ja ymmärrystä nostamalla esiin kysymyksiä ilmiöiden sijoittumisesta ja sijoittumisen syystä (Fitzpatrick 2001; Oldakowski 2001). GIS-harjoitusten avulla voidaan yhdistää oppiaineiden sisältöä monialaisiksi kokonaisuuksiksi, ja tarkastella todellisen maailman ilmiöitä oppilaskeskeisen opetuksen avulla (Kerski et al. 2013).

Suomen uusimmassa opetussuunnitelmassa sekä peruskoulun että lukion maantieteen opetukseen on vahvasti integroitu tuore käsite geomedia, jolla viitataan erilaisiin maantieteellisiin tiedon hankinta- ja esitystapoihin, kuten karttoihin, tilastoihin, videoihin, uutisiin ja kuviin, ja niiden käyttöön (Opetushallitus 2015). Paikkatieto mainitaan terminä ainoastaan lukion opetussuunnitelmassa, mutta myös peruskoulun opetussuunnitelmaan kuuluvat geomedia-teeman alla karttojen tulkinta- ja laadintataidot. Opetussuunnitelmissa tuodaan esille, että geomedia tulee opetuksessa yhdistää maantieteellisen tiedon käsittelyyn, analyysiin ja visualisointiin, eikä paikkatieto-opetus ole vain GIS:stä oppimista, vaan sen avulla oppimista. Onkin havaittu, että paikkatietomenetelmien ja -projektien käyttö opetuksessa tukee ymmärrystä maantieteellisestä ongelmanratkaisusta, kun taas opettajakeskeinen, paikkatiedosta luennoiva opetus keskittyy lähinnä GIS:n tekniseen puoleen – ja tästä syystä monissa tutkimuksissa on päädytty yhtenevään tulokseen siitä, että paikkatieto-opetus kannattaa toteuttaa kouluissa oppilaskeskeisellä tavalla, GIS:n avulla oppien (Baker 2005; Rød et al. 2010).

Peruskoulu- ja lukioasteen paikkatieto-opetuksen järjestämisen ongelmakohdiksi osoittautuvat usein samat tekijät, joista eniten nousee esille opettajien puutteelliset GIS-taidot. Peruskoulu- ja lukioasteen paikkatieto-opetuksen organisointiin liittyvät ongelmat linkittyvät usein juuri opettajien puutteelliseen paikkatietoalan harjautuneisuuteen, mutta myös käytettävissä olevan ajan vähäisyyteen sekä opetusresursseihin (Bernardz 2004; Rød et al. 2010; Milson & Kerski 2012). Tämä voi rajoittaa mahdollisuuksia monipuolisen opetuksen järjestämiseen, koska se luo ongelmia opetusaineistojen kehittämisessä ja tarpeeksi asiantuntevan ohjauksen antamisessa. Yhteistyö yliopistojen kanssa onkin yksi mahdollinen ratkaisu ongelmaan, niin Suomessa kuin muuallakin maailmassa. Yliopistojen asiantuntijoiden tarjoamat materiaalit, koulutukset ja oppituntien ohjaus mahdollistavat syvällisemmän GIS-opetuksen, vaikka koulun omat resurssit eivät riittäisikään syvällisemmän paikkatieto-opetuksen järjestämiseen (Kerski 2003; Bernarz 2004; Rød et al. 2010).

Helsingin yliopiston Tiedekasvatuskeskuksen alainen, Kumpulan kampuksella toimiva Geopiste on maantieteen alan oppimiskeskus, joka tarjoaa opettajien käyttöön maantieteen opetusmateriaaleja ja järjestää kampuksella vieraileville ryhmille paikkatietoaiheisia oppitunteja. Oppitunneilla vierailevat ryhmät saavat käyttöönsä yliopiston tietokoneet ja kaikki tarpeelliset ohjelmistot, ja harjoitusten ohjaajina toimivat yliopiston opettajat ja opiskelijat, joten oppilasryhmien omien opettajien paikkatieto-osaamisen tasolla ei ole oppituntien onnistumisen kannalta väliä.

Maantieteen maisteriohjelman kurssilla *GEOG-G303 GIS Project Work* kehitettiin kevään 2019 aikana uusia paikkatietoharjoituksia Geopisteen materiaalipankkiin. Tämä artikkeli käsittelee näiden uusia harjoituksien luomista sekä niitä opetuksellisia ja oppimisen perusteita ja tietämystä, joita alan tutkijat ovat tutkimuksissaan havainneet. Lisäksi artikkelissa esitetään nyt luotujen uusien harjoitustehtävien yhteyttä uusimpiin peruskoulun ja lukion maantieteen opetusohjelmiin.

2. Paikkatietoharjoitukset

2.1 Tausta

Uusia GIS-harjoituksia kehitettiin kurssin aikana yhteensä kahdeksan kappaletta. Kuhunkin harjoituspakettiin kuuluu pdf-muotoinen harjoitusohje sekä kaikki harjoituksessa tarvittavat aineistot GIS-aineistojen käsittelyyn tarvittavia ohjelmia lukuun ottamatta. Harjoituspaketit kehitettiin Geopisteen nettisivuilla avoimesti jaettaviksi, ja niitä suunniteltaessa noudatettiin seuraavia ohjesääntöjä:

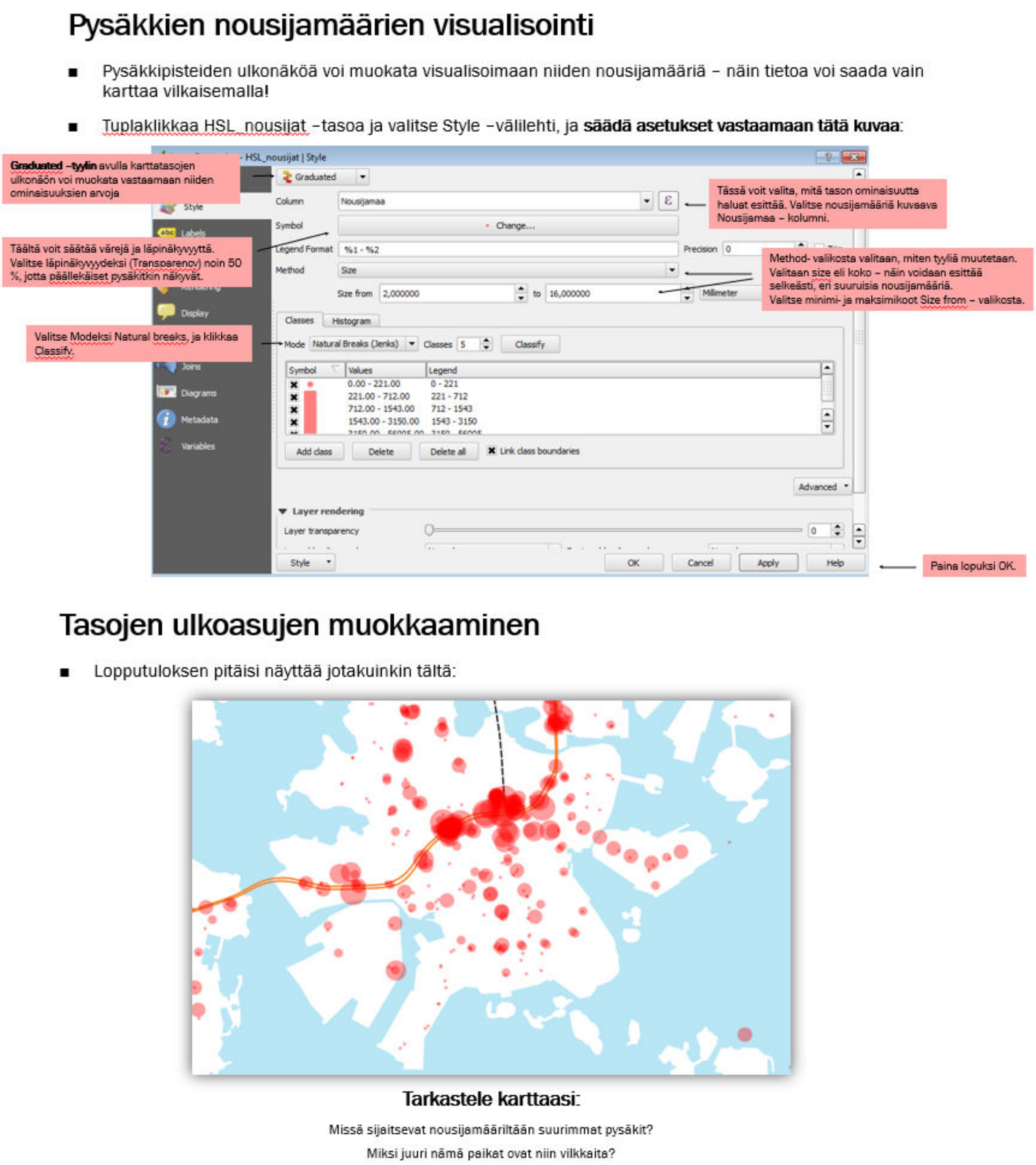
(1) **Yhteys opetussuunnitelmaan**:
GIS-ohjelmia käyttävät harjoitukset linkittyvät luonnollisesti opetussuunnitelmien geomedia- ja paikkatieto-osuuksiin. Jokaisella harjoituksella on myös oma teemansa, maantieteen osa-alue, joka voi tukea harjoituksen tekevän opiskelijan maantieteellisen ymmärryksen jäsentymistä aiheesta.

(2) **Selkeys**:
Monet Geopiste-vierailijat ovat kokemattomia paikkatieto-ohjelmien käyttämisessä. Jokainen harjoitus alkaa perusasioista ja soveltuu kaiken tasoisille oppijoille. Vaikka erityisesti QGIS-paikkatieto-ohjelmalla suoritettavat harjoitukset on kehitetty Geopiste-vierailuja varten, niiden ohjeista on pyritty tekemään mahdollisimman selkeät, jotta niitä voitaisiin käyttää myös tavallisessa luokkaopetuksessa kouluissa.

(3) **Avoimuus**:
Kaikki harjoituksissa käytetyt tietoaineistot ovat avoimia, ja aineistojen alkuperäiset lataussivustot on linkitetty harjoitusohjeisiin. Varsinaisilla GIS-ohjelmilla suoritettavat harjoitukset on kehitetty QGIS-paikkatieto-ohjelmalle, joka on ilmainen avoimen lähdekoodin paikkatieto-ohjelma ja kaikkien vapaasti ladattavissa. Selaimella tehtävät harjoitukset suoritetaan Paikkatietoikkuna-palvelussa, joka on Maanmittauslaitoksen vapaasti käytettävissä oleva internetin karttapalvelu.

2.2 Harjoitusten aineistot

Harjoituksia varten on koottu aineistoa monesta eri lähteestä, ja jokainen harjoitusohje sisältää linkit aineistojen lataussivustoihin. Kaikki harjoituksissa käytettävä data on avointa, mikä mahdollistaa alkuperäisten aineistojen helpon hankinnan ja tarkastelun. Tämä voi myös auttaa opiskelijoita ymmärtämään avoimen datan potentiaalin ja sen, ettei paikkatiedon käsittelyyn missään tapauksessa tarvitse aina käyttää kalliita ohjelmia ja maksullisia aineistoja. Käytettävät aineistot on hankittu monista eri lähteistä, ja tuottajia ovat muun muassa Tilastokeskus ja Maanmittauslaitos, mutta monissa tapauksissa myös jokin vapaaehtoisjärjestö tai muu epävirallisempi taho. Epävirallisten tahojen tuottamat aineistot saattavat olla joskus puutteellisia tai epätarkkoja, eivätkä niistä saadut tulokset ole vertailukelpoisia. Esimerkiksi uudessa harjoituksessa *Konflikteja Afrikassa* käytetty pisteaineisto sisältää duplikaatteja, ja aineiston luokittelu on tehty paikoittain epäjohdonmukaisesti. Kehitettyjen harjoitusten idea on kuitenkin toimia opetusmateriaaleina eikä korkealaatuisen tutkimuksen pohjana, joten tarkoilla lopputuloksilla ei ole tässä tapauksessa merkitystä. Jokainen aineisto on käyty läpi ja arvioitu, ja sen takia ne soveltuvat epätarkkuuksista huolimatta erinomaisesti eri ilmiöiden havainnollistamiseen.



Kuva 1. Sivuja harjoituksen Joukkoliikenteen nousijat pääkaupunkiseudulla ohjeista. Ohjeet sisältävät työntekoa helpottavia selitteitä ja ohjeita muokkausten tekoon, sekä pohdiskelua helpottavia kysymyksiä.

2.3 Harjoitusten sisältö ja rakenne

Jokainen uusi harjoitus on suunniteltu toimimaan mahdollisena ensikosketuksena paikkatietoon, muttei toimia teoriaoppituntina. Harjoitusohjeessa aloitetaan käytännöllisistä perusasioista, ja siirrytään sen jälkeen käyttämään paikkatieto-ohjelmien toimintoja selkeiden ja visuaalisten ohjeiden avulla (Kuva 1). Visuaalisten ohjeiden on havaittu toimivan hyvin GIS-harjoituksissa, sillä niiden avulla tutkittavan ongelman voi ymmärtää helposti, ja tekniset ohjeet ovat helpommin lähestyttäviä (Hall-Wallace & McAuliffe 2002). GIS:n tekniseen puoleen saadaan harjoituksissa pintaraapaisu, mutta tämä osa-alue toimii lähinnä aiemman tai tulevan teoriaopetuksen tukena, ja harjoitusten varsinainen tehtävä on tutustuttaa opiskelijoita paikkatieto-ohjelmien käyttöön aitojen tutkimusaiheiden tarkastelussa.

Harjoitukset on suunniteltu suoritettaviksi yhden oppitunnin aikana, ja niiden suorittamisen kesto vaihtelee 45 ja 90 minuutin välillä. Suoritusaikaan vaikuttavat myös muun muassa opetusryhmän koko ja luokka-aste. Uusista harjoituksista kuusi on suunniteltu QGIS-paikkatieto-ohjelmalle ja kaksi internetselaimessa toimivaan Maanmittaus-laitoksen Paikkatietoikkunaan.

2.4 Harjoitukset suhteessa opetussuunnitelmaan

Lukion opetussuunnitelmassa paikkatieto on yksi kokonaisuuksista, ja siihen paneudutaan neljännessä maantieteen kurssissa, jonka aihe on geomedia (Opetushallitus 2015). Peruskoulun opetussuunnitelmassa sanaa paikkatieto ei mainita, mutta kartanlu-ku-, kartantuottamis- ja geomediataidot kuuluvat myös yläkoulun opetukseen (Opetushallitus 2014).

Kehitetyt GIS-harjoitukset luonnollisesti tukevat opetusta ja oppilaiden ymmärrystä paikkatiedosta. Paikkatiedon lisäksi jokainen uusi harjoitus on suunniteltu tukemaan muutakin maantieteen opetusta – uusia harjoituksia tehtiin muun muassa riskeihin, luonnonmaantieteeseen ja ihmismaantieteeseen liittyen. Aineistoja käsitellään harjoituksissa siihen muotoon, että niiden pohjalta voi tehdä johtopäätöksiä. Harjoituksissa päästään yhdessä harjoituksessa muun muassa visualisoimaan biodiversiteetin Hot Spot -alueita ja toisessa harjoituksessa tekemään reittilaskelmia oppilaalle tutuilla alueilla. Harjoitukset ja niiden yhteys opetussuunnitelmaan esitellään tarkemmin taulukossa 1. Koska lukion opetussuunnitelmassa aiheet käsitellään ja eritellään yksityiskohtaisemmin, harjoitusten aiheet on merkitty Taulukkoon 1 vähintään kurssin tarkkuudella. Peruskoulun opetussuunnitelma ei syvenny maantieteellisiin aiheisiin samalla tavalla kuin lukion opetussuunnitelma, vaan se auttaa oppilaita luomaan maailmankuvaansa, ja samoja teemoja käsitellään useiden usealla kurssilla. Tästä syystä peruskoulun opetuksen ja uusien Geopiste-harjoitusten välinen yhteys määritellään vain yleisemmällä tasolla.

Taulukko 1. Uusien GIS-harjoitusten teemat ja niiden yhteys opetussuunnitelmiin (L = lukion opetussuunnitelma, Y = peruskoulun yläluokkien 7–9 opetussuunnitelma).

HARJOITUS	TEEMA	OPETUS-SUUNNITELMA
JOUKKOLIIKENTEEN NOUSIJAT PÄÄKAUPUNKISEUDULLA	TARKASTELLAAN HSL:N NOUSIJADATAA, ESITÄÄN HOTSPOTEJA JA VISUALISOIDAAN MATKUSTAJAMÄÄRIÄ	L GE3: JULKINEN LIIKENNE JA IHMISTEN LIIKKUMINEN Y: IHMIS/KAUPUNKIMAANTIEDE
OPTIMAALISTEN REITTIEN LASKENTA	LASKETAAN OPTIMAALISIA REITTEJÄ QGIS:N JA SEN LISÄOSIEN AVULLA	L GE3: LIIKENNE JA TIEVERKOSTOT Y: IHMIS/KAUPUNKIMAANTIEDE
MERTEN LAJIRUNSAUS JA BIODIVERSITEETTI	VISUALISOIDAAN MERTEN LAJIRUNSAUTTA JA KORALLIRIUTTOJA JA NIIHIN KOHDISTUVAA VAHINKOA	GE1: ILMASTONMUUTOS JA LAJIEN HÄVIÄMINEN, BIODIVERSITEETTI Y: ILMASTONMUUTOS JA BIODIVERSITEETTI
KORKEUSMALLIT JA 3D-KARTTAESITYKSET	HARJOITELLAAN KORKEUSMALLIEN KÄSITTELYÄ JA VISUALISOINTIA JA LUODAAN 3D-KARTTA	L GE2: GEOMORFOLOGIA JA MAISEMANTULKINTA Y: GEOMORFOLOGIA
KONFLIKTIT AFRIKASSA	VISUALISOIDAAN KONFLIKTIPISTEITÄ JA HARJOITELLAAN ANIMOITUJEN KARTTOJEN TEKOA	L GE1: TERRORISMI JA ALUEELLISET RISKIT Y: IHMIS/RISKIMAANTIEDE
VÄESTÖKARTTOJA PAIKKATIETOIKKUNASSA	PAIKKATIETOIKKUNAN PERUSKÄYTTÖ JA TEEMAKARTTOJEN LUOMINEN	L GE3: VÄESTÖN SIJOITTUMINEN MAANTIETEELLISESTI Y: SUOMEN MAANTIEDE, VÄESTÖ
GIS-ANALYYSI PAIKKATIETOIKKUNASSA	GIS-ANALYYSIT PAIKKATIETOIKKUNAN AVULLA	L GE4: PAIKKATIETOANALYYSI Y: GEOMEDIA& KARTAT

3. Keskustelu

Tämän projektin aikana luotiin Geopisteelle uusia harjoituksia vanhojen, osittain materiaaleiltaan vanhentuneiden harjoitusten tilalle ja rinnalle. Kaikki uudet harjoitusohjeet noudattavat samaa muotoilua ja etenemisrakennetta. Koska kaikki harjoitukset ovat uusia, niitä kaikkia ei ole ehditty vielä testaamaan vierailevien koululaisten kanssa. Harjoitus *Joukkoliikenteen nousijamäärät pääkaupunkiseudulla* on jo kokeiltu keväällä 2019 kahden luokan kanssa. Harjoitus sai hyvää palautetta, ja sen ohjeisiin tehtiin pieniä korjauksia tulevan opetuksen avuksi. Kun harjoituksia aloitetaan käyttää enemmän, niiden sisältöä ja ohjeita voidaan muokata entisestään ohjaajilta ja oppilailta kerätyn palautteen perusteella. Yleisimpiä ongelmakohtia GIS-opetuksessa on useimmiten varsinkin ohjauksessa (joka tässä tapauksessa linkittyy voimakkaasti ohjeiden selkeyteen) ja aineistojen ja ohjelmien käsittelyssä (Demirci et al. 2013; Kerski 2003).

Yksi tärkeä tekijä, joka tuli ottaa huomioon uusia harjoituksia luodessa oli niiden yhteys opetussuunnitelmaan. Koska resurssien puutteellisuuden tai muiden tekijöiden takia kaikissa oppilaitoksissa ei ole realistisia mahdollisuuksia järjestää käytännön paikkatieto-opetusta, nyt luodut uudet harjoitukset haluttiin liittää opetussuunnitelmien teemoihin mahdollisimman toimivasti. Tämä edesauttaa mahdollisuuksia paikkatietoaiheiden syvempään ymmärtämiseen, kun luodaan yhteyksiä ja näkökulmia tuttuihin aiheisiin liittyvien ongelmien ratkaisemiseen, ja tällöin GIS-opetus voi tuntua asiaan perehtymättömällekin luontevalta eikä suinkaan aiemmin opittuun verrattuna erilliseltä (Rød et al. 2010). Tämäkin on aihe, josta voisi olla aiheellista kerätä palautetta ja mielipiteitä oppilailta, koska oppimateriaaleja kehittämällä voidaan näin pyrkiä luomaan mahdollisimman hyvin oppimista tukeva kokonaisuus. Tarjoamalla akateemisten maantieteen asiantuntijoiden ohjaamaa ja hyvin muuhun opetukseen linkitettyä opetusta voidaan erityisesti tukea niitä opettajia, joiden tekninen osaaminen paikkatiedossa rajoittaa aiheen laadukasta opetusta (Bernarz 2004; Kerski 2003; Rød et al. 2010).

Tämän projektin myötä Geopisteen GIS-harjoitusten materiaalipankki moninkertaistui. Tulevaisuudessa nyt luotuja materiaaleja voidaan kehittää entisestään, ja uusia harjoituksia voidaan luoda lisää, esimerkiksi muidenkin maantieteen yliopistokurssien lopputyönä. Luomalla aineistoja ja tarjoamalla opetusta ja koulutusta voidaan syventää yliopistojen ja muiden oppilaitosten välistä yhteistyötä, mikä mahdollistaa useammassa oppilaitoksessa laadukkaan ja heidän omista resursseistaan riippumattoman GIS-opetuksen.

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Chapter IV

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

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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.

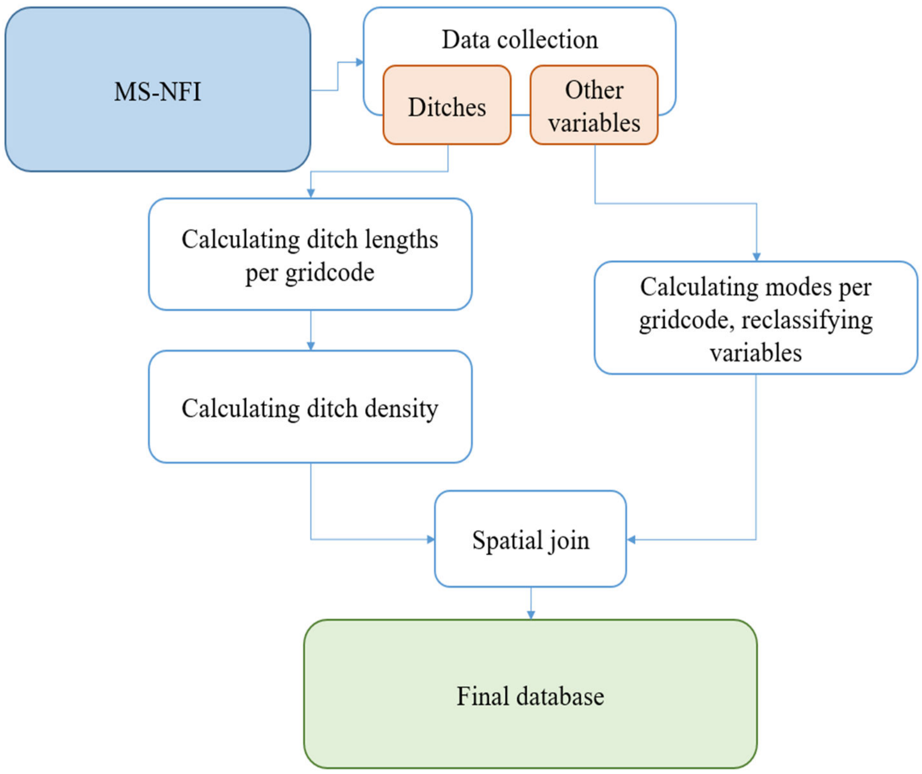

Figure 2. Workflow chart of GIS analyses.

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.

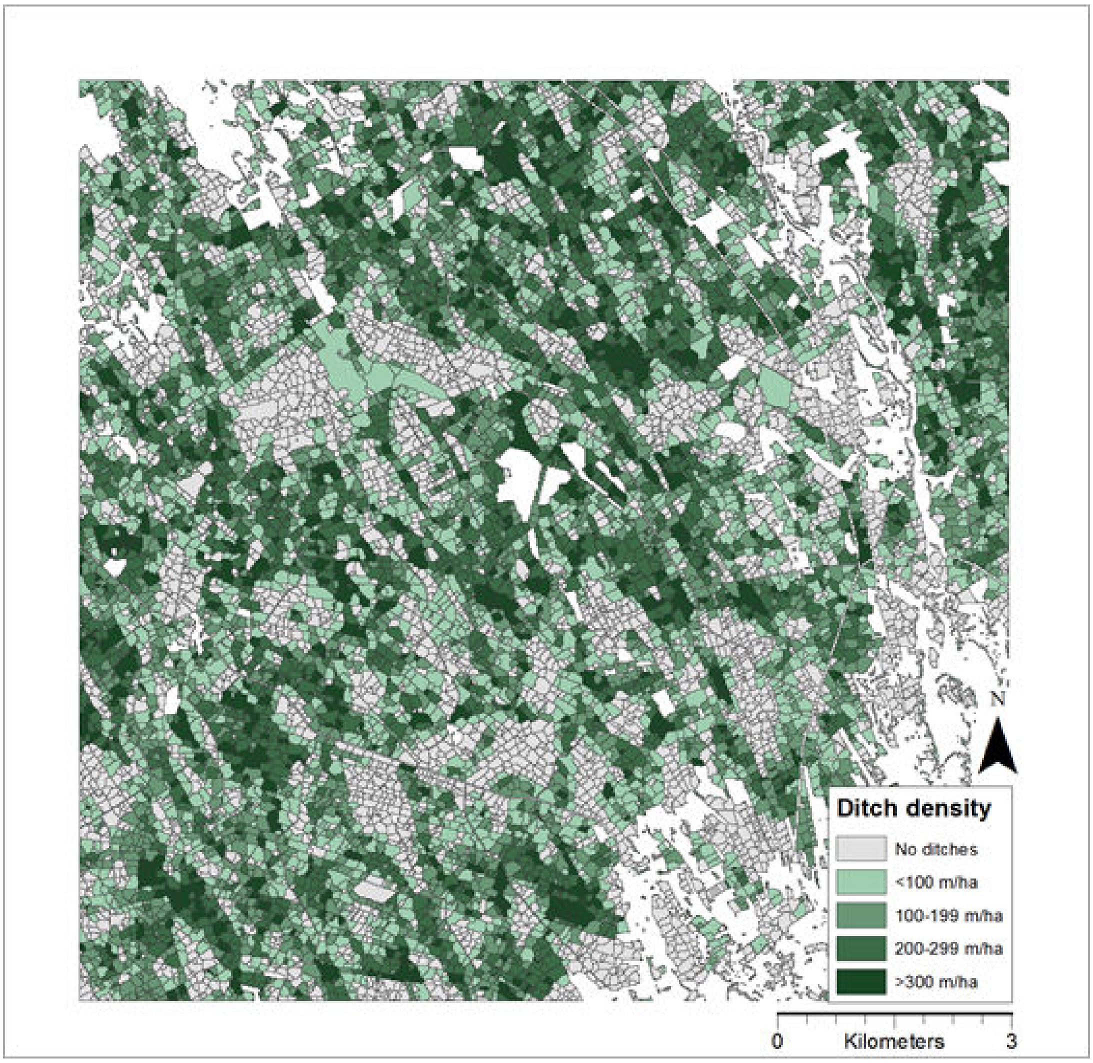

Figure 3. Ditch density (m/ha) describes the ditching state of forest segments.

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.

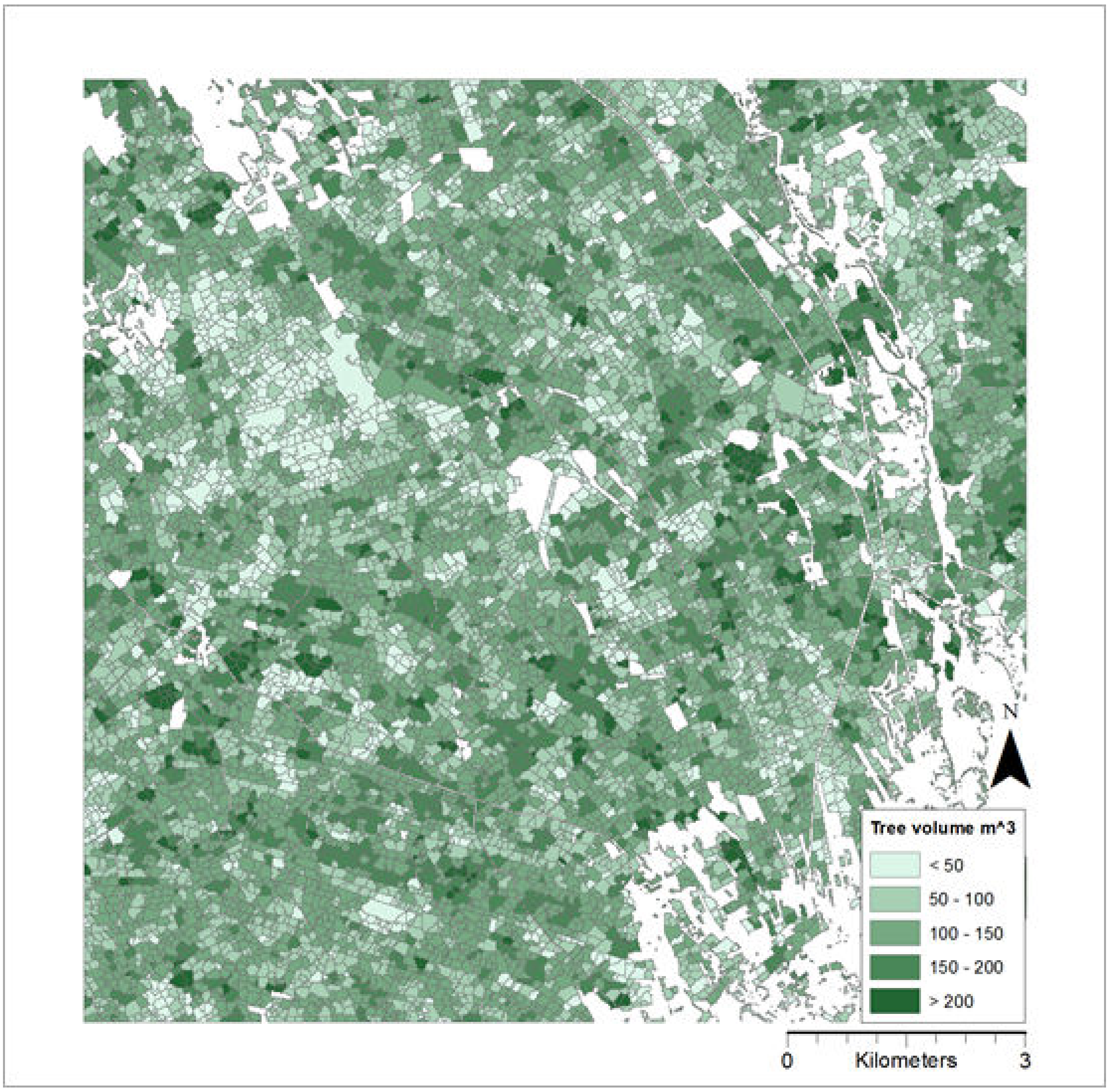

Figure 4. Tree volume (m^3/ha) per forest segment.

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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GIS applications in teaching and research presents the outcomes of a graduate level course *GEOG-G303 GIS project work*. The course was conducted in small working groups, each of which was assigned a separate project topic. The topics came from different research groups or teachers in the Department of Geosciences and Geography and vary from research tasks to building a teaching content. These articles are written in close co-operation with researchers and teachers.

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