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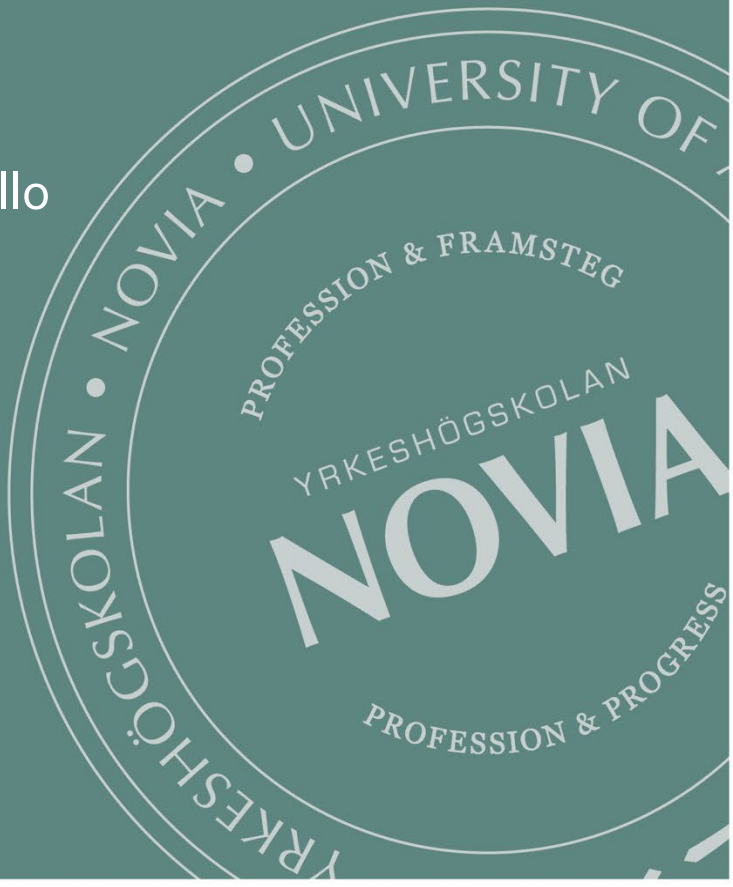
Methodology for Land Suitability Analysis:

Mapping of Suitable areas for growing Early-potato, Apples, Pastures (Grazing Land) and Cultural Grains in Uusimaa

Eduardo Grisales-Jaramillo



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Eduardo Grisales-Jaramillo, Novia University of Applied Sciences

Methodology for Land Suitability Analysis: Mapping of Suitable areas for growing Early-potato, Apples, Pastures (Grazing Land) and Cultural Grains in Uusimaa

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Contents

Introduction

This document describes a methodology integrating Geographical Information Systems (GIS) and a Multi-criteria Evaluation (MCE) applied to the identification of suitable areas for growing early-potatoes, apples, pastures (grazing land) and cultural grains. These crops are within the range of crops that can be cultivated in Uusimaa and reinforce a sustainable food- system and the local economy. The analysis and classification of the fields is divided in three categories: highly suitable areas, acceptable areas, and areas with low suitability for the cultivation of the crops mentioned above.

The criteria for analysing each crop can be different, but they all relate to soil and climate conditions. These soil and climate aspects are adapted from studies with similar approach and conditions. The literature helps to identify the type of data needed and to set threshold values for the criteria. The importance of each criterion in the analysis might vary from crop to crop. For instance, one crop can tolerate colder temperatures than others, in this case, temperature as a parameter does not have the same weight in the prioritisation process. The value of certain parameter is given according to the needs of that crop.

The GIS software is used to process all input data and to standardise variables of different scales. The resulting fields are preferably displayed in a traffic-light classification. Ideally, one map per crop. The type of data, its processing and sources, the parameters/criteria will be explained further down in this document.

Data collection and sources

CORINE Land Cover 2018

It is an inventory of satellite images (mosaics) and spatial data on land use covering the whole of Finland. SYKE has been producing the latest material with high accuracy. Data can be retrieved from the following link:

https://www.syke.fi/en-US/Open_information/Spatial_datasets/Downloadable_spatial_dataset

Land Surface Temperature (LST)

The LST measures the emission of thermal radiance from the land surface where the incoming solar energy interacts with and heats the ground, or the surface of the canopy in vegetated areas. This quality makes LST a good indicator of energy.

In contrast to surface temperature is air temperature, which is measured at a standard height of 1.2 m (4.0 ft) above the ground surface. Air temperature can be quite different from surface temperature. In general, air temperatures above a surface reflect the same trends as ground surface temperatures, but ground temperatures are likely to be more extreme.

The European Space Agency (ESA) maintains satellites in orbit with different instruments for measuring components of the climate, atmosphere, etc. The Sentinel-3 offers a variety of products; the LST is one of them. The LST is collected twice a day for the Satellite, and it is available from the Open Access Hub in the following link:

https://scihub.copernicus.eu/

The datasets can be extracted and processed in Rstudio with the package rOpenGov, The R software can be downloaded for free from its own website. The Sentinel Application Platform (SNAP). The SNAP architecture is also useful for Earth Observation processing and analysis and can be downloaded from the following link:

https://step.esa.int/main/toolboxes/snap/

https://www.r-project.org/

Digital Elevation Model (DEM)

It is a 3D representation of a terrain's surface. This dataset is a raster file, and it is essential to obtain aspect and slope of a terrain.

Source: National Land Survey of Finland (free download services). Grid

Resolution: 10x10

Link: https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta?lang=en

Soil type

The soil type describes the texture of the soil. The dataset comprises 2 layers: topsoil and subsoil. This final maps only included the topsoil data, which has a depth of 1 meter approximately and a minimum polygon size of 4 hectares. The main mapping scale is 1:10000.

Source: Geological Survey of Finland / Geology Research Centre.

Scale: 1/10 000 – 1/50 000

Link: https://hakku.gtk.fi/en/locations/search?location_id=1

Topography Components (water bodies and roads)

Two layers are needed from the whole component of topography, water bodies and roads. The Geological Survey of Finland allows to download the whole topography at different scales, after downloading the dataset, it is possible to extract the two layers needed (layers named in Finnish). The dataset can be downloaded from the following link:

https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta?lang=en

Data processing

It is important to mention that all data was extracted from open sources. Some datasets were used in multiples maps, for instance, the Land Surface Temperature dataset was used in the potato map, apples map and cultural cereals map, it is a sensible aspect for those crops.

The data processing is almost the same for the four maps. There are some variations of the values of criteria according to the crop needs.

The previous GIS software (ArcMap) presented difficulties when processing certain raster formats and the license for data interoperability function was not active. At the same time, due to technical limitations (low RAM in the computer), the processing time was taken long periods in ArcMap, often crashing when executing a function with a large dataset. Therefore, the option was to switch to ArcGIS PRO 2.6.

The following section explains the data processing. As mentioned before, different datasets were processed in the same manner and used for different crops. Therefore, the processing of one dataset can contain two or more crops in the same explanation, the only difference is the threshold values and the weight or importance attached to that parameter.

DEM (Potato – Apple – Pastures – Cultural Grains)

The DEM was added into the ArcGIS PRO with a raster cell size of 10x10 m. The extracted mosaics must be merged with the Merge Mosaic Dataset Items function from the data management tool. It groups multiple items in a mosaic dataset together as one item, the new output dataset. The tool can be found by typing merge mosaic in the search toolbox (Ctrl+F) (figure 1).

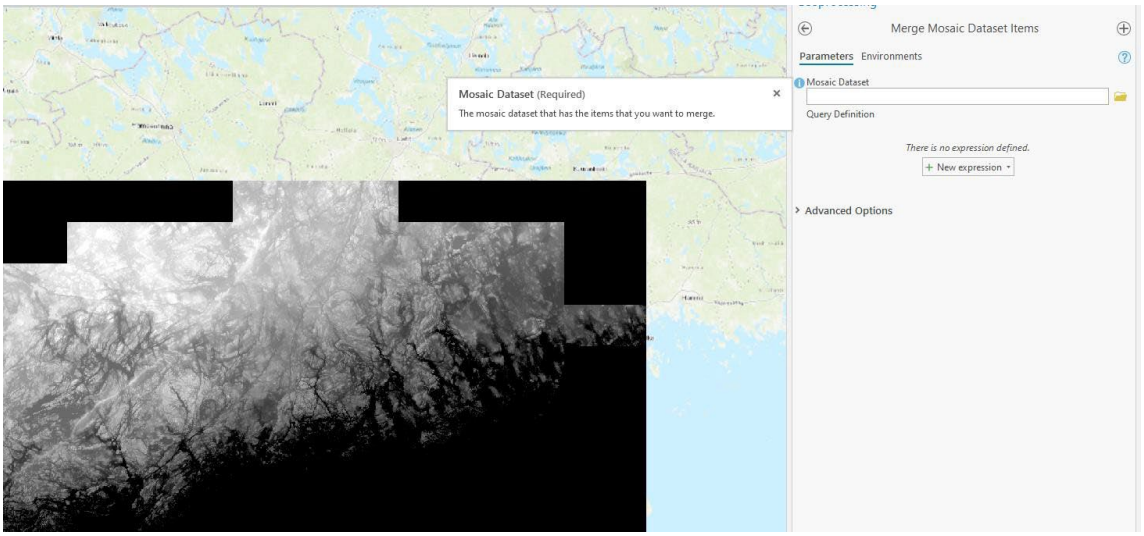

Figure 1. Merge Mosaic Dataset tool from the Data Management functions.

Slope

The purpose of having a DEM is to obtain the slope and aspect of the fields. The slope identifies the gradient or steepness from each cell of a raster. It is obtained by running the slope function from the spatial analyst; as before, it can be found in the search toolbox. The input raster will be the raster dataset from where the slope is derived, meaning the DEM (figure 2). The output measurement can be either in degrees or percentage.

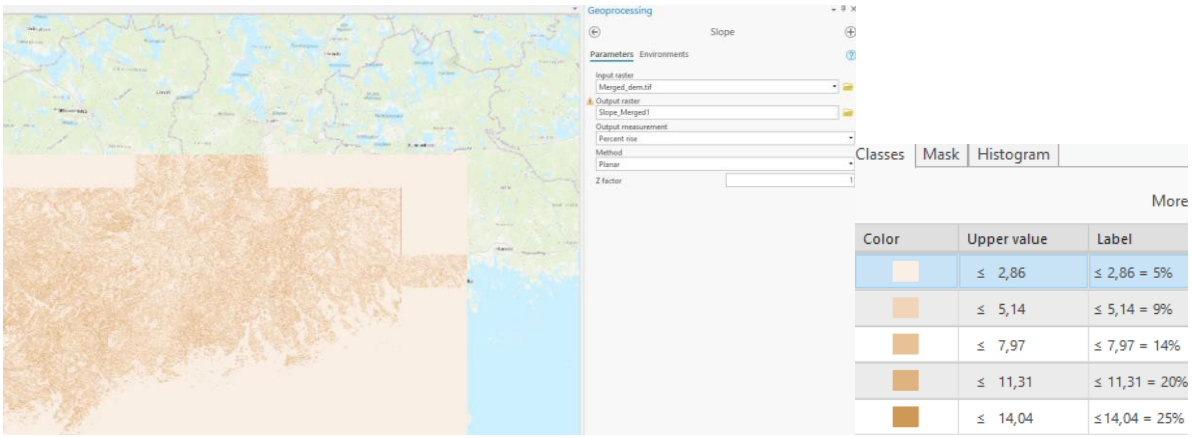

Figure 2. Slope tool from the Spatial Analyst functions. Accessed from the search toolbox (Ctrl+F) – The classification of the slope is divided in 5 categories as shown.

Table 1. Slope: classification of the values in 3 categories.

Slope classification in downhill percentage %	Potatoes	Apples	Pastures	Grains
Highly Suitable	=< 5	=<7	=<15	=<5
Acceptable	=< 9	=<10	=<20	=<9
Low Suitability	>9	=<15	>20	=>14

Aspect

The aspect identifies the compass direction that the downhill slope faces for each location. This function is based on the DEM and can be found by typing aspect in the search toolbox (figure 3). As before, the input raster is the DEM.

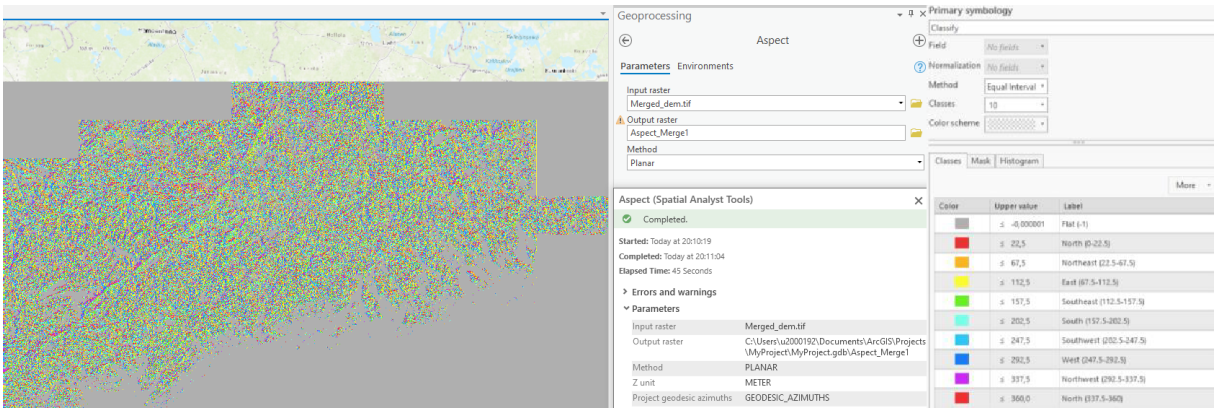

Figure 3. Aspect tool from the Spatial Analyst functions.

For the aspect layer, the terrains facing north correspond to 0° and 360°. Therefore, as it goes clockwise, 90° is east, 180° is south and 270° is west. The following table describes suitable downhill direction for each crop:

Table 2. Aspect/downhill direction: classification in 3 categories.

Aspect classification in degrees	Potatoes	Apples	Pastures	Grains
Highly Suitable	115 - 235	115 - 235	-	100 – 260
Acceptable	90 – 114 / 236 - 270	90 – 114 / 236 - 270	-	80 – 99 / 261 - 300
Low Suitability	0 – 89 / 271 - 360	0 – 89 / 271 - 360	-	0 – 79 / 301 - 360

Soil Type

The soil type and EU Official subsidised fields data were converted from polygon format to raster datasets with the polygon to raster conversion tool as shown in figure 5. The conversion of files into a single format is necessary to operate the raster calculator.

Table 3. Soil type suitability classification

Soil Type Categories	Potatoes	Apples	Pastures	Grains
Highly Suitable	Loam-sand + Moraine	Loam-sand + Clay / Moraine	-	Sandy - Loam
Acceptable	Sand + Clay	Sand + Clay	-	Sand – Clay / Silt
Low Suitability	Clay + Silt / Sand	Clay + Silt / Sand	-	Clay – Silt / Sand

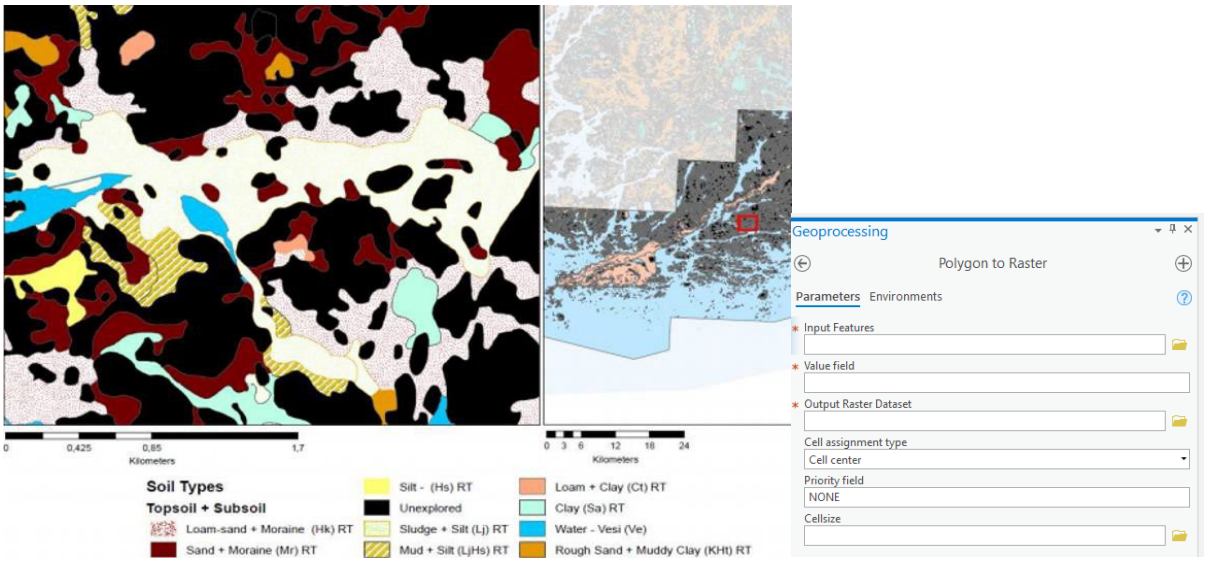

Figure 5. Polygon to raster conversion tool. Converts polygon features to a raster dataset.

Land Surface Temperature

The LST datasets are downloaded from the ESA Open Hub and processed in ArcGIS PRO. The previous GIS software (ArcMap) used for processing data, did not allow to import data directly from Sentinel-3 Open Hub, therefore, it was necessary to download The Sentinel Application Platform SNAP for processing all LST data.

One dataset per day was downloaded from April 1st to April 20th, during the years 2018, 2019 and 2020. It was possible to choose morning hours, from 5 am to 8 am, where frost is most likely to happen.

Each dataset has different spectral bands, they differ in wavelength and spatial resolution. The band needed is LST with a spatial resolution of 1 Km. The data images can be accessed from Rstudio with the package getSpatialData, this package enables generic access to multiple data distributors with a common syntax for 159 products.

If the datasets are being visualised in a different GIS software that does not allow the direct import, as mentioned before, it is also possible to process the images in SNAP. Once the dataset is downloaded and unzipped, it can be imported to SNAP, where the image is cropped as shown in figure 7. It is important to note that in this case, the dataset must be reprojected in the coordinate system WGS84. The reprojection is necessary to be able to project them in

ArcGIS PRO as shown in the figure 6. The applied changes significantly reduced the size of the file.

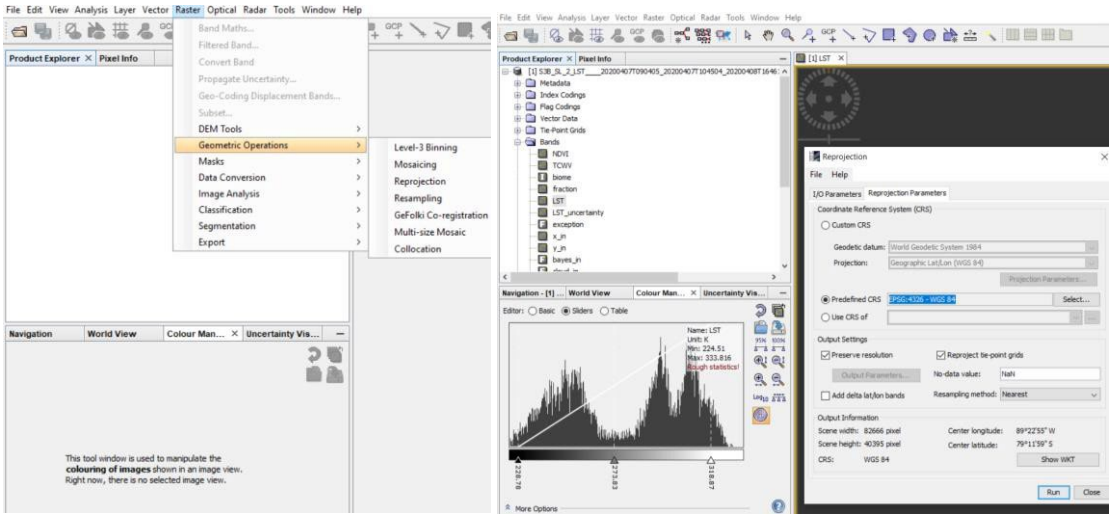

Figure 6 Reprojection of the dataset

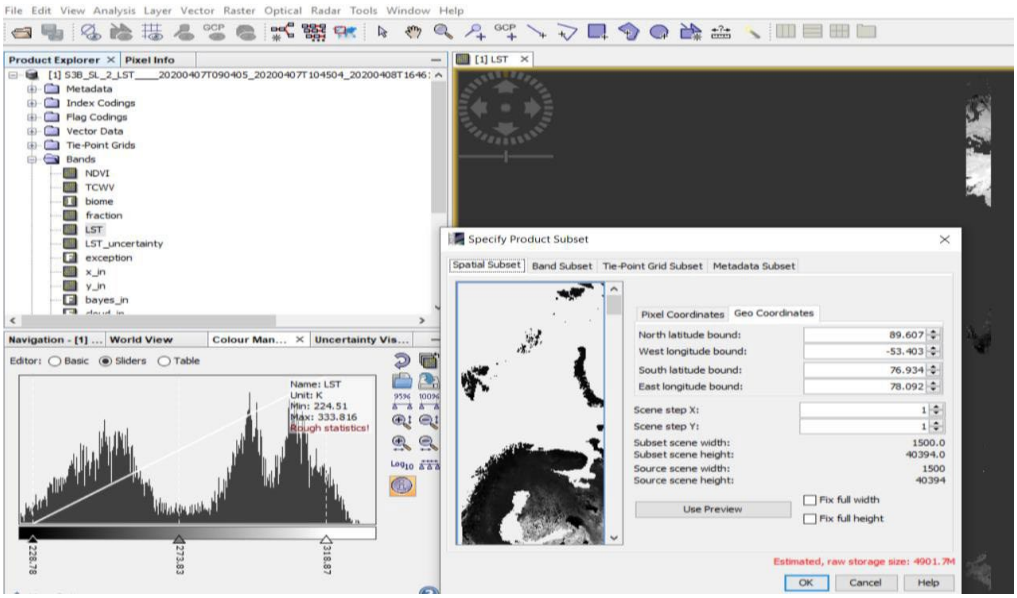

Figure 7. Subset of the LST band

From the file tab in the main menu of SNAP, the images can be exported to ArcMAP.

Once the datasets are exported to GIS Software, the mean values are calculated per year, this could potentially show which areas have higher temperature in the selected time frame and combined with the standard deviation, it is possible to find areas where the variation is low from year to year. These calculations are done with the Cell Statistics tool.

Land Surface Temperature is classified in 3 categories according to each crop temperature requirements:

Table 4. Classification of LST thresholds

LST values per category in Celsius	Potatoes	Apples	Pastures	Grains
Highly Suitable	3 to 10	0 to 12	-10 to 10 or more	0 to 5 or more
Acceptable	0 to 2	-4 to -1		-5 to -1
Low Suitability	=< -1	=< -5		=< -6

Water proximity and road accessibility (Grazing land)

These criteria are applied only to the grazing land map. Beef cattle may graze in one area but move to another area to rest or to drink water. For that, the road accessibility and water sources are determining criteria in this assessment.

The selection by location tool allows to choose a method of selection. The goal is to select those non- agricultural fields and agroforestry areas with broad-leaved trees (indicator of soil fertility and nutrient rich forest) which contain, intersect, touch a boundary or are within a close distance from the target element (freshwater bodies and dirt roads, small roads, and animal routes).

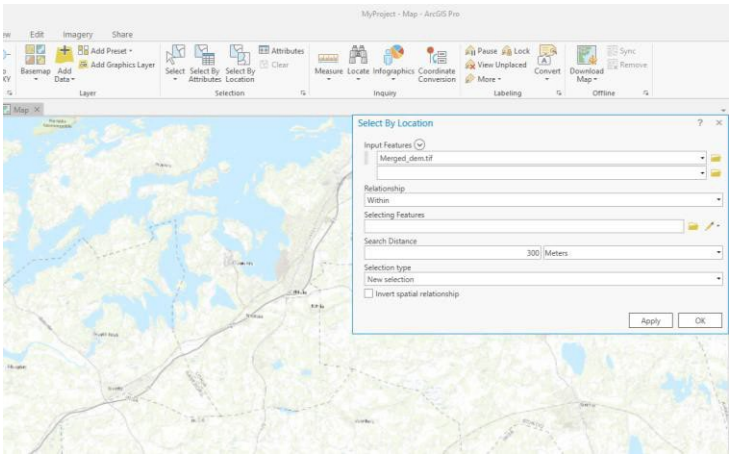

Figure 8. Select by location tool. The features that will be evaluated against the Selecting Features parameter. The selection will be applied to these features.

Table 5. Classification in 3 categories

	Roads	Proximity to water bodies
Highly Suitable	Direct access	Within the field
Acceptable	Within a distance of 500m	Within the field or 300m
Low Suitability	>500m	>300m

Raster Calculator Execution

The raster calculator builds and executes a single map algebra expression using Python syntax in calculator-like interface. This tool from the spatial analyst function can be found in the search toolbox.

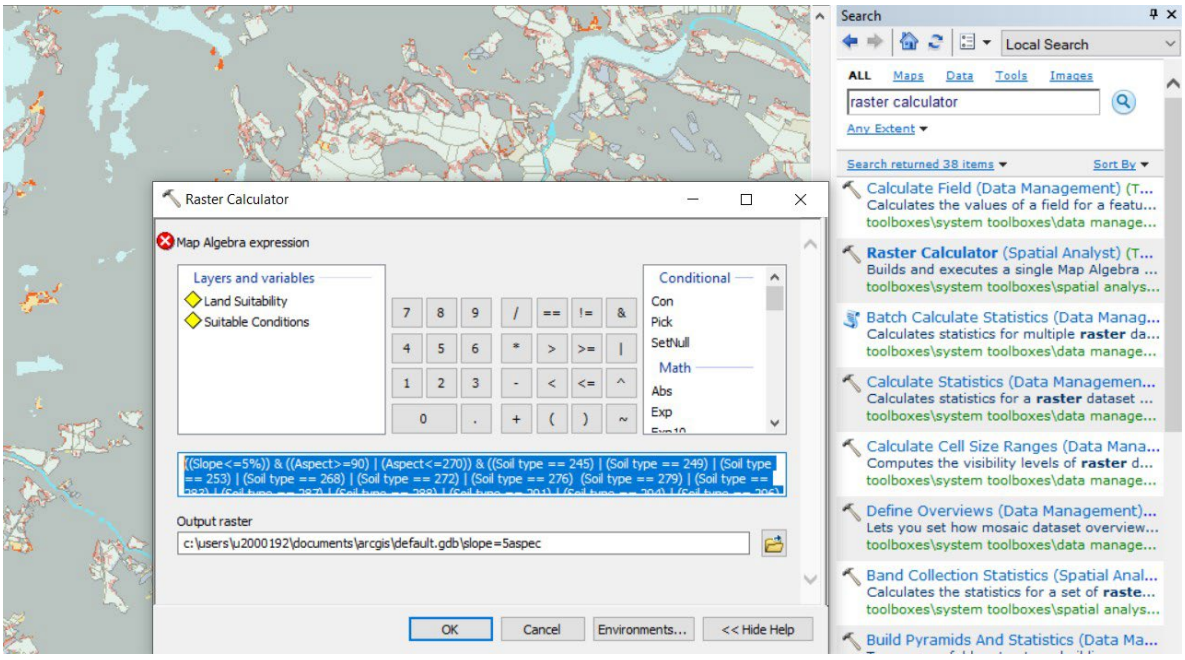

Figure 9. Raster calculator tool.

The syntax expression used for obtaining the outcome raster map for each crop included all criteria or variables described above and their threshold values described before. The expressions as follows:

Potato	*((Slope<=5)) & ((Aspect>=90) & (Aspect<=270)) & ((Soil type == 245) & (Soil type == 249) & (Soil type == 253) & (Soil type == 268) (Soil type == 272) & (Soil type == 276) (Soil type == 279) & (Soil type == 283) & (Soil type == 287) & (Soil type == 288) & (Soil type == 291) & (Soil type == 294) & (Soil type == 296) & (Soil type == 301)) & ((Land Cover == 17) & (Land cover == 21) & (Land cover == 22)) & ((LST-mean >= 0) & (LST-STD <=5))*
Apple	*((Slope=<7)) & ((Aspect=>90) & (Aspect=<270)) & ((Soil type == 245) & (Soil type == 249) & (Soil type == 253) & (Soil type == 268) (Soil type == 272) & (Soil type == 276) (Soil type == 279) & (Soil type == 283) & (Soil type == 287) & (Soil type == 288) & (Soil type == 291) & (Soil type == 294) & (Soil type == 296) & (Soil type == 301)) & ((Land Cover == 17) & (Land cover == 21) & (Land cover == 22)) & ((LST-mean >= 0) & (LST-STD <=12))*
Pastures	*((Slope=<15)) & ((Aspect=>90) & (Aspect=<270)) & ((Soil type == 245) & (Soil type == 249) & (Soil type == 253) & (Soil type == 268) (Soil type == 272) & (Soil type == 276) (Soil type == 279) & (Soil type == 283) & (Soil type == 287) & (Soil type == 288) & (Soil type == 291) & (Soil type == 294) & (Soil type == 296) & (Soil type == 301)) & ((Land Cover == 17) & (Land cover == 21) & (Land cover == 22)) & ((LST-mean => -10) & (LST-STD =<10))*
Grains	*((Slope<=6)) & ((Aspect>=90) & (Aspect<=270)) & ((Soil type == 245) & (Soil type == 249) & (Soil type == 253) & (Soil type == 268) (Soil type == 272) & (Soil type == 276) (Soil type == 279) & (Soil type == 283) & (Soil type == 287) & (Soil type == 288) & (Soil type == 291) & (Soil type == 294) & (Soil type == 296) & (Soil type == 301)) & ((Land Cover == 17) & (Land cover == 21) & (Land cover == 22)) & ((LST-mean >= 0) & (LST-STD <=5))*

ArcGIS Online

It is a cloud-based mapping service in which is possible to share maps from ArcGIS PRO amongst other services.

Before sharing a map, it is essential to have an account in ArcGIS Online. The account can be created by the administrator of the license. By signing-in to ArcGIS PRO, the map can be published as a service in the ArcGIS Online. The service is hosted by Yrekeshögskolan Novia

In the ArcGIS PRO service editor, it is required to fill-in features such as item description, capabilities of the service and sharing attributes as shown in figure 10. The following describes how the service was set:

-Capabilities: Tiled service

-Cache settings - Tiling Scheme: ArcGIS Online, Bing Maps, Google Maps.

Level of detail: minimum and maximum scales for this tiled map/image service. The chosen levels 7 to 19 were cached. The size of the cache is calculated before the service is published. Therefore, it is necessary to make sure there is enough space in the hosting cloud server.

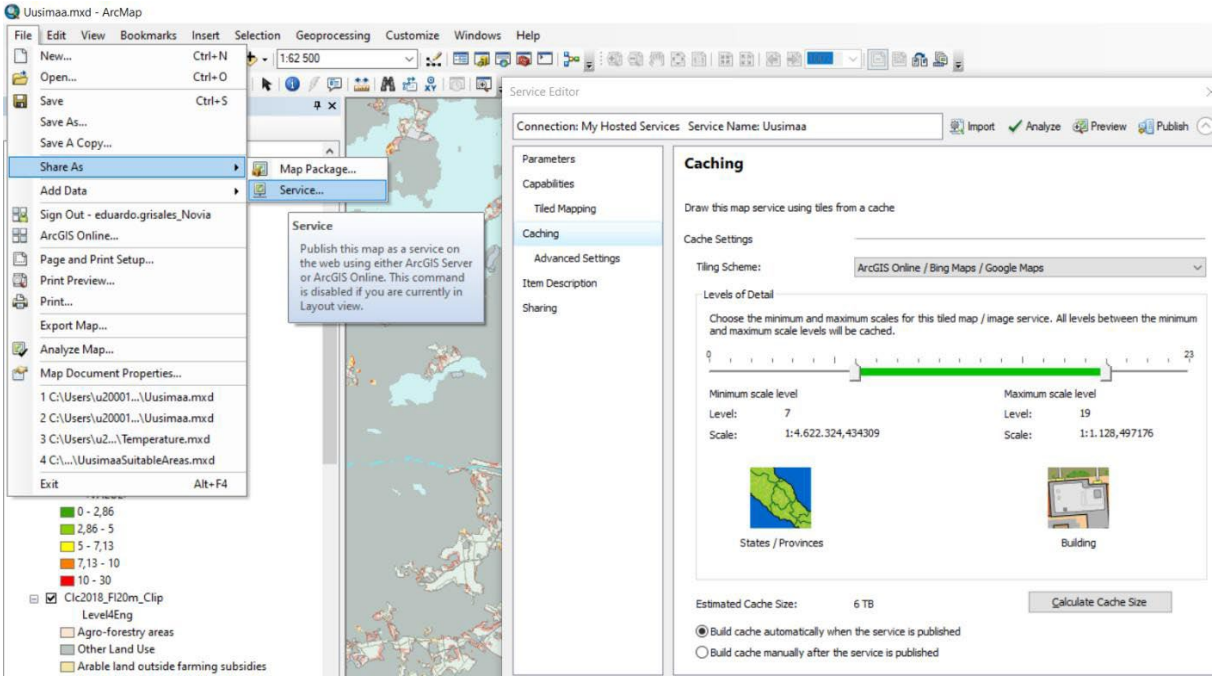

Figure 10. Map shared as tiled service.

The map can be viewed in ArcGIS Online and shared with other users within the organisation and/or everyone as shown in figure 10.

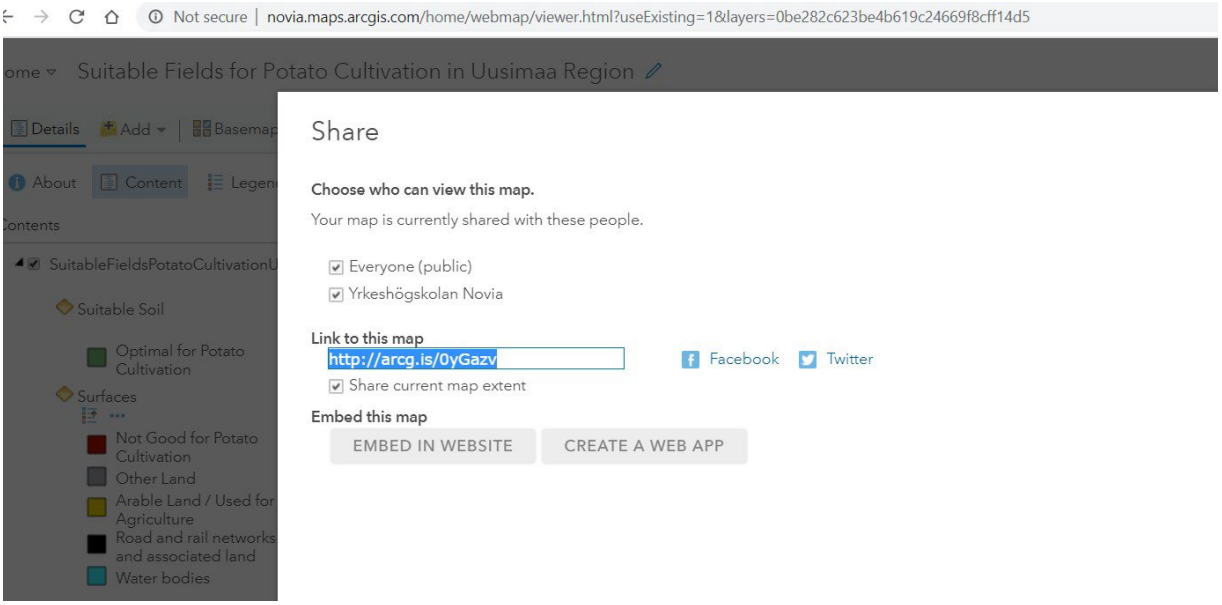

Figure 11. ArcGIS Online. Sharing attributes of an online tiled service.

Links to the Maps

Early-potato => https://arcg.is/1Xfmfq0

Apples => https://arcg.is/1y80GO1

Pastures => https://arcg.is/1Kni5j0

Cultural Grains => https://arcg.is/1S4rGj

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Yrkeshögskolan Novia
Rektorat
Wolffskavägen 31
65200 Vasa, Finland
Tfn +358 (0)6 328 5000 (växel),
www.novia.fi

Antagningsservice
Wolffskavägen 33
65200 Vasa
antagningsservice@novia.fi
admissions@novia.fi

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