YRKESHÖGSKOLAN NOVIA

Suitable Land for Potato Cultivation in the Västra Nyland Region

A GIS Method Template for Field Selection

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Abstract

The Västra Nyland Region, located in the south of Finland, is known for the early-potato production, The region aims to strengthen the Food Strategy Plan by consolidating existing areas dedicated to potato cultivation and finding suitable alternatives for the same purpose. Suitable fields for potato cultivation require certain soil and climatic conditions.

The current work proposes a methodology for identifying highly suitable soils for potato cultivation in the Västra Nyland region. The method applied is a multicriteria analysis based on literature review that will support threshold values definition for the physical conditions of the soils such as land use, soil type, slope and aspect.

Geographical data of the study area was collected for performing land suitability and selection.

The data processing software produced maps with highly suitable areas for potato cultivation. Some of those areas were already in use for agricultural purposes which confirms, to some extent, the chosen criteria and thresholds as a valid methodology for site selection.

Data on detailed climatic conditions would significantly improve the accuracy of this work. For instance, the variables with significant impact on microclimates such as rainfall, temperature, wind, etc., could positively influence an area, making it highly suitable. Another improvement can be derived from soil tests, in order to identify patterns in the chemical composition of soils with great conditions for growing potatoes and include them as criteria in the site selection methodology.

Language: English Key words: GIS, Multi-criteria Analysis, Soil, Climatic Conditions

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1 Introduction

In Finland, every spring brings high expectations for the early potato season and it is normal; the Finnish potato is one of the tastiest in the world. New potatoes have traditionally been a delicacy which price above average. By the time when early potatoes begin to be harvested, some warehouses are almost empty. However, stored potatoes from the previous season are sufficient and will be preserved thanks to good stocks, there might be other reasons for the expectation; early potatoes are a clear sign of summer, since Finland moves from a long winter to a summer with a relatively short spring. Potatoes similar to Finnish early potatoes are imported mainly from Sweden, but also from Denmark. Swedish potatoes arrive in stores a few weeks before domestic ones do.

Farmers from the south of Finland start the soil preparations for sowing in the last week of February or beginning of March. The selection of land for cultivation purposes requires an analysis of different characteristics. Different crops have different requirements regarding the soil chemical and physical properties. Moreover, variables like rainfall, temperature, sunlight and altitude-latitude are an essential complement to the soil properties and for making a field suitable for cultivation.

The contrast of climate variables in recent years has changed the circumstances for some farmers in the region. For instance, few believed that early potatoes could be planted this spring in early March (2020). The rainfall in the region has been almost constant since the autumn, and flooding has penetrated flatter and shallowest fields (2). Farmers might need to migrate their plantations to steeper fields (as long as the crop production conditions are not affected).

This thesis work proposes a methodology for analysing the soil physical conditions and define suitable areas for potato (*Solanum tuberosum*) cultivation in the Västra Nyland Region in Finland. Using Geographical Information Systems (GIS), which is a computer-based system that offers data processing and space analysis functions for land suitability analysis.

The identification of soil types in the region as well as the use they have, will contribute to elaborate a criteria analysis for site selection.

A soil analysis is often used to know the components or nutrients the soil has for cultivation, it can be very extensive and include many parameters. Those parameters can be adjustable, some crops do not require strict soil properties, and they grow in a wide range of soil and climatic conditions.

The template will serve as a tool and as a method to compare and assess the current selection procedures for potato cultivation. The Västra Nyland region is an area of high importance for potato production, especially for the fresh "early potato" production; although nowadays, there are fewer large potato fields in the Region. According to information from the Ministry of Agriculture and Forestry, potatoes are cultivated on about 300 hectares throughout Uusimaa Region (1).

This model can display alternative options as the available land with suitable conditions can be visualised in the final map. It is also possible to modify the thresholds for whichever requirements are more favourable for the crop.

2 Historical Background

Potato is a tuber originating from South America that has been consumed for more than 8000 years. It was brought to Europe by the Spanish in the 16th century. Its cultivation expanded in the same century to England and Holland as an ornamental and consumption plant for poor people, but it was at the end of the 18th century that its cultivation and consumption spread around the world, including Asia, Africa and Oceania (3).

Potato is one of the most important food crops in developing countries, as well as in developed countries. Due to its importance in Europe as a cheap product for human and animal food, and as a source of starch and alcohol during the industrial revolution, the production and use of the crop was considered restricted only to industrialized nations. Developing countries today produce about 30% of the world's total potatoes, and production in these countries is expanding more rapidly than other food crops production. As a result, potato cultivation has been an important source of rural employment, income, and food for growing populations. In monetary terms, potatoes are now the fourth most important crop among food crops in the developing world. Potato cultivation policies are becoming increasingly important in developing areas. Unfortunately, the information required for proper policy decisions is usually not readily available, because it is disseminated in numerous textbooks, scientific papers, statistical reports, and unpublished

documents. In the case of the Nordic Countries and developed countries in general, established associations and institutions have gathered and structured databases with detailed data. Most developing countries are following but much of the information available is outdated or misleading because it was written with industrialized nations in mind. Since development program managers may not be clear on the differences between food systems and technology needs in rich and poor countries, these programs often seek to "transfer" inappropriate technology to developing countries. A better understanding of the current and potential role of potatoes in the food systems of developing countries can help researchers, planners and development agencies to avoid these problems in the future (3, p. 5-11).

2.1 Potatoes in Finland

The potato came to Fagervik (Finland) from Germany in the 1730s with the mill's workers from Saxony. When the soldiers returned from the Pomeranian War (1757-62), they contributed to the spread of potatoes. In the 1750s, the plant was almost unknown in the remotest parts of the country, even though The Crown introduced potatoes to the country in the 1740s. The chaplain of Asikkala Axel Laurell (d. 1790), published a guide on the subject, a short description of potato or ground pear plantation (1773) (4).

The Finnish Economic Society, founded in 1797, also played an important role in the spread of potatoes. The Society emphasized the importance of potatoes on many occasions.

The popularity of potatoes in Finland continued to grow as its use as a raw material for distillation became more widespread.

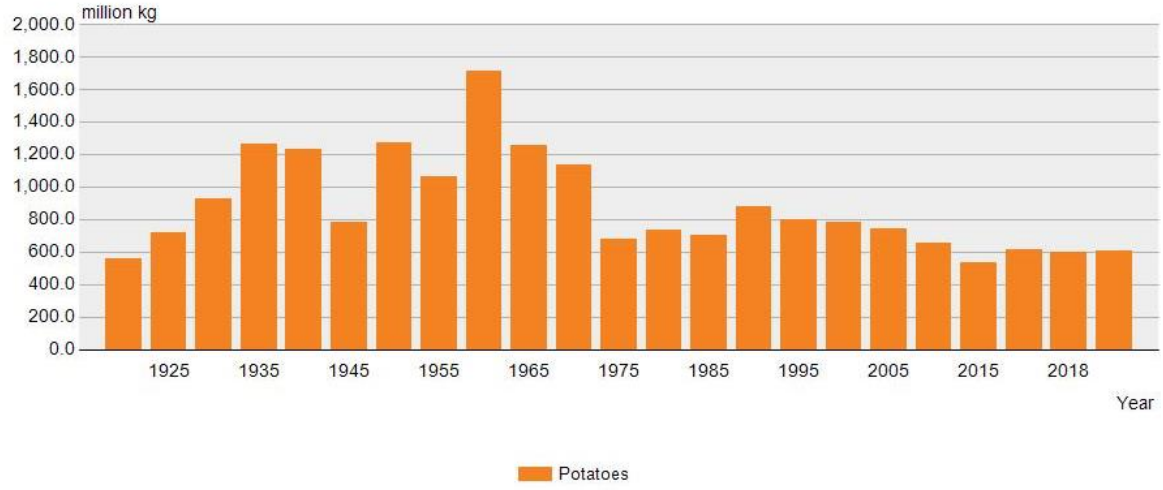
Once upon a time, potatoes played an important role in the northern countries, especially during the winter and spring months, when it was difficult to get fresh vegetarian food. Potato was important, especially as an anti-sclerosis agent.

A special potato committee was formed at the Finnish Economic Society, which, with the help of state funding, distributed seed potatoes to growers free of charge and encouraged farmers with cash prizes. According to the Society, potato cultivation had already spread in Finland in 1807, so that special measures were needed only in Savo and Karelia (4).

The potato had spread to the whole of Finland. However, differences in cultivation varied considerably between regions. Potato was especially good for small farmers, as it produced more food per area than cereals. It could be cultivated by someone who did not have any cultivated land. Potatoes improved the malnutrition status of the people, contributing to the rapid population growth since the late 18th century.

In addition to nutrition, potatoes played an important role, especially preventing scurvy, which was very common before potatoes were used. This was very important for the health of the seafarers during long voyages on the sea and during the bleak winter and spring months when it was difficult to get fresh root vegetables (4).

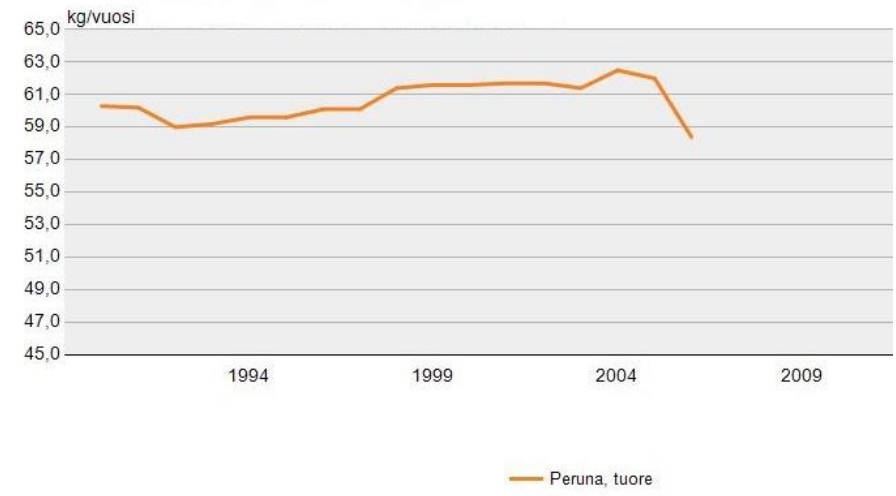
Potatoes began to be appreciated especially in the years when the frost was damaged cereal plantations but generally left the potatoes in good condition. Potatoes have also been available in wartime, although potatoes were subject to regulation due to decreasing potato yields during World War II. Finland has not been dependent on the import of potatoes; therefore, it has been a secure commodity during difficult times. Especially during the Second World War, people were encouraged to diversify the use of potatoes and introduce new cultivated lands through various educational campaigns. For example, in wartime in the early 1940s hospitals were required to start growing potatoes and other vegetables in their gardens and lawns (4).



Source: OSF: Natural Resources Institute Finland, Crop production statistics

Figure 1 – Potato production in Finland. Widely produced from 1925 to 1970 with a decline in the Second World War years. It greatly recovered after the end of the war but from 1975 production has been fluctuating until now.

The potato played an important role from the 1950s, as shown in the figure 1, the whole decade had in average one of the highest productions rates until now. It started to decline steadily in the 1990s. In the beginning, the transformation of society through urbanisation, rising incomes and increased tourism had also changed the importance of potatoes as a raw material. Throughout the years, Finnish potato consumption has fallen significantly, changes in the population's economic structure, housing and habits have also affected potato consumption. While in 1950 an average person ate more than 140 kilos of potatoes a year, the corresponding figure in 2016 was 46 kilos. The popularity of potatoes might be declining in terms of consumption. For instance, in the figure 2, it is possible to observe a rapid decline in consumption between 2005 and 2006. However, potato is still an important commodity in the country, therefore, the Food Strategy Plan in the region is developing a project for better utilisation of the market. This methodology for selecting fields will be extended to the whole Uusimaa region and integrated into the project with the purpose of finding potential alternative areas for cultivation of different crops.



Lähde: Luonnonvarakeskus, Ravintotase

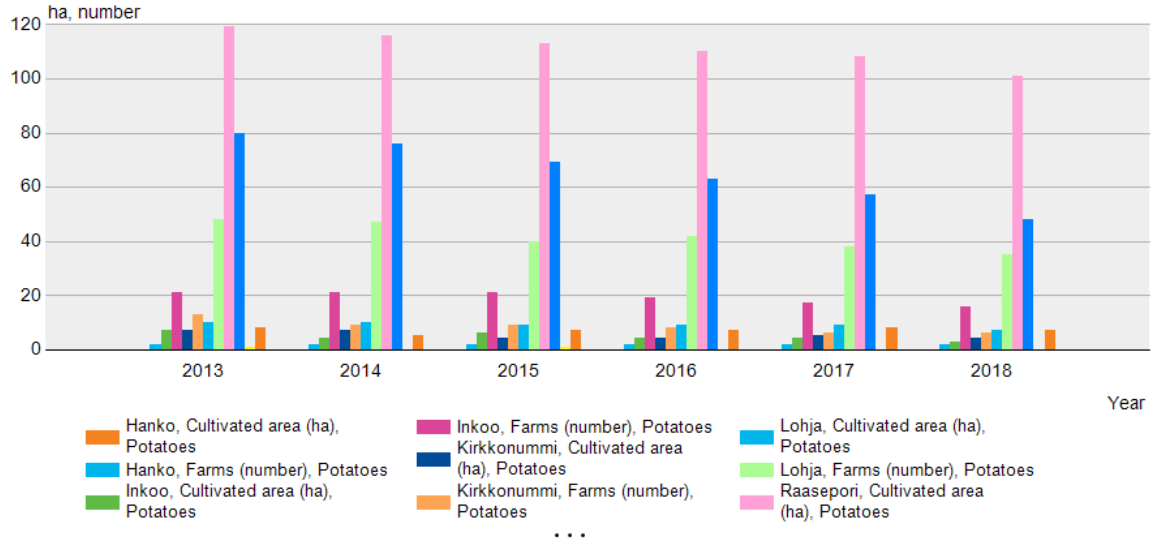
Figure 2 – Potato consumption per capita in Finland. It shows a decline after 2004.

3 Research and Procedures

3.1 Research Purpose

The figure 3 displays the most important municipalities regarding potato cultivation in the Västra Nyland region. Some of them are utilising a great portion of arable land, meanwhile other municipalities have a small participation in the cultivation of potatoes. There could be several reasons for such differences amongst municipalities, for instance, the land is

cultivated with other crops, the land is inappropriate for potato cultivation or the land is simply not in use, but it is suitable.



Source: OSF: Natural Resources Institute Finland, Utilized agricultural area

Figure 3 – Utilised agricultural area for potato cultivation by municipality in the Västra Nyland region.

This project proposes a Multi-Criteria Analysis based on Geographical Information Systems (GIS) for finding available suitable areas for potato cultivation in the region. The georeferenced data collected from different sources contains spatial information of different variables included in this model. The data processing is done in the ArcGIS software. Information retrieved from the literature serves to classify and establish thresholds. Finally, the maps display sites within the Västra Nyland Region fulfilling the criteria analysis and its considerations for selecting suitable areas for potato cultivation.

The aim of this work is to provide small/medium farms, educational projects, researchers, and any institution or individual with a simple method template for selecting suitable fields for potato cultivation. The initial template can be modified; the same approach can also be used for other crops.

4 Methods

The study area has an extension of 4058 km², it may slightly differ depending on the definition of the total land area according to the National Land Survey. It comprehends the municipalities of Hanko, Rasepoori, Lohja, Inkoo, Kirkkonummi and Siuntio; and a total of 143.311 inhabitants.

4.1 Literature Review

4.1.1 Theoretical review

This thesis work is based on a survey of peer reviewed scientific articles and non-peer reviewed articles as well as personal communication with experts. The chosen method allows to take a deep look into similar projects developed in the areas of comparable conditions. Thus, this theoretical review might benefit the implementation of future land suitability models or further developments of the present one.

4.1.2 Conditions and Requirements for Land Suitability

Potato is predominantly a temperate climate crop, although it can be grown in subtropical and tropical climates. Currently, potatoes are cultivated worldwide in areas with cold, temperate and warm climates, due to the development of varieties, the crop can adapt to those type of climates.

Regional climatic differences are decisive for potatoes production in the growing season; sometimes while in the north it can be rainy, the drought is severe in the south. The areas close the archipelago present the driest growing locations in Finland. The impact of these conditions will be reflected on the harvest quality and quantity of any crop (5).

In commercial potato production, the selection and the preparation of the soil to be cultivated affect the production and quality of the tubers. On the other hand, different agronomic factors have great importance in the production costs of the crop. For example, the yields and potential quality of tubers will be lower in those soils with drainage problems compaction (because of the soil structure), plant light absorption, low availability of nutrients, acids and/or with high levels of aluminium. Therefore, any increase in production yield will imply the improvement of the physical-chemical conditions of the

soil, through crop breeding, increasing production costs. On the contrary, soils with good physical-chemical conditions will achieve high yields at a lower production cost (5).

For development of the plant and production of potato, the crop has requirements in terms of climate (temperature, length of daylight, etc.), soil and topography, water and fertilisers. Within the climate variables, temperature is one of the most preponderant requirements, it should be noted that these requirements need to be according to the phonological phases, since in each phase the plant tends to develop certain types of organs (6).

The reviewed literature converges in most requirements or concepts regarding the threshold values for the chosen variables. A summary of the most relevant literature here:

Table 1. Peer reviewed and non-peer reviewed references

Source → Variable ↓	Food and Agriculture Organisation – The Potato Factsheets 2008 (9).	H.P. Beukema & D.E. Van der Zaag Introduction to Potato Production (17).	D. Horton Potatoes. Production, Marketing and Programs for Developing Countries (3).	R. Navarre & M. J. Pavek The Potato, Botany, Production and Uses (18).
Land Use/Cover	Cultivated land under crop rotation		Irrigated arable land system	Fields with crop rotation systems in agricultural land.
Soil Type	loam, sandy loam, silt loam and clay loam.	Light soils, composition: 50% sand, 40% silt and 10% silt.	Composition varies, loose soils are ideal with a sandy loam structure.	Non-compacted soil, coarsed-textured soils: silt loams, loams and sandy loams.
Slope	Slopes from 0% to 5% and to 9% with engineering conservation measures.	Flat fields with loose soils, slope can vary according to the soil structure.	Slope range: 0% - 14%. It depends on the soil preparation and sowing direction	5% slope prevents the soil from erosion and water bodies from runoffs.
Aspect	Slopes facing south and southeast are preferable for the Northern Hemisphere		Diagonal to the downslope direction	Mark J. Pavek: north to south, northwest to southeast and northeast to southwest.

4.1.2.1 Land Type

The texture indicates the relative content of different sized particles, such as sand, silt, and clay, in the soil. The texture has to do with the ease with which the soil can be worked, the amount of water and air it retains and the speed with which the water penetrates and passes through the soil. The soil texture can be classified from fine to coarse. The fine texture indicates a high proportion of finer particles such as silt and clay. The coarse texture indicates a high proportion of sand (8).

Potato can grow in most soils, although soils with low resistance to tuber growth are recommended. The best soils are loam, loamy sand, and loam-clay with a small percentage of silt and with good drainage and ventilation, which also facilitate harvesting. However, high yields can be achieved in soils with clayey texture by applying organic matter and regulating irrigation frequencies (16).

In Finland, cultivation is concentrated on sandy soils and organic soils. Potatoes are also grown on clayey soils in some areas. The ideal potato soil is a well-structured and well-permeable soil with no risk of compaction. The depth should be between 40 cm from the surface and no greater than 70 cm (13).

The optimum pH for potatoes is 5.2 to 6.4 (9). PH have a direct effect on the solubility of nutrients. Finnish soils are typically acidic. This influences the availability of phosphorus.

The textural soil triangle in figure 4 (9) makes possible to determine the soil structure by its physical composition. In this case, although the range is wide, the ideal suitability for potato is medium soil texture. Therefore, sandy clay loams, which has a structural combination range of 20% or less clay, and 52% or more sand and a minimum percentage of silt (9) are preferred. The selection of soils was based on the good performance of potato crops on sandy topsoil described by M. Roman, G. Hurtado in their potato technical guide (In Spanish: Guia tecnica de la papa – 2002). It is mentioned that structural combinations with a high percentage of sand loam have a good aeration and drainage capacity. They are also rich in organic matter.

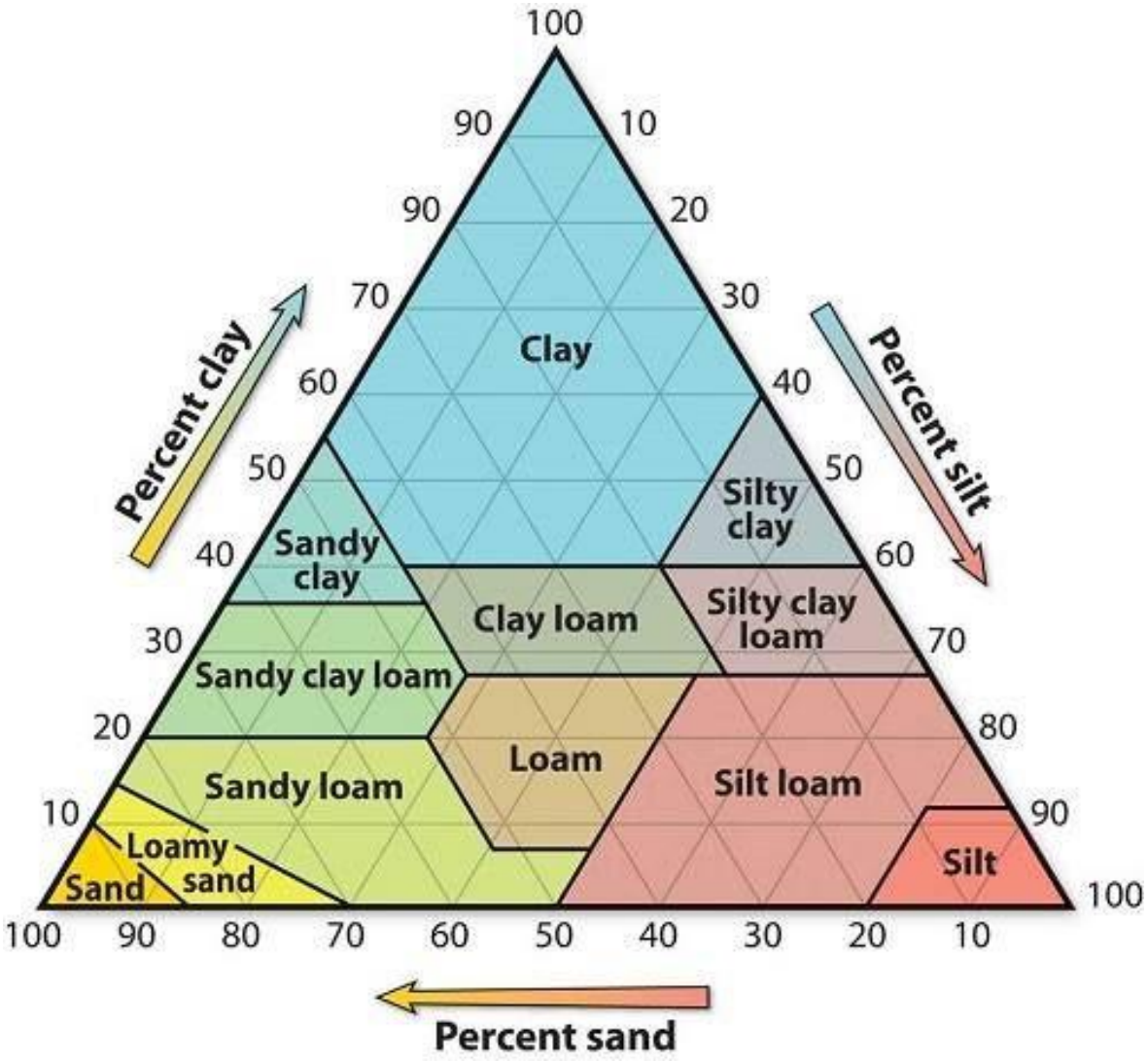


Figure 4 – Textural soil triangle – Source: Food and Agriculture Organisation. The particles that make up soil are categorized into three groups by size – sand, silt, and clay. (9)

4.1.2.2 Slope

The slope gradient has a very close relationship with the retention and collection of water, in addition to the soil depth and access of machinery. For a good crop productivity, a slope of 0.0% to 5.0% is recommended, slopes greater than 5.1% cause the tuber production to decrease. One way to deal with steep slopes is through furrowing on contour lines or through terraces. Although Slopes from 5.1% to 9% can support the crop cultivation but conservation measures must be taken in order to prevent erosion (13).

If the soil is saturated, or if the rainfall rate is greater than the rate at which water can permeate the soil, surface runoff occurs. If the runoff has sufficient flow energy, it will

transport loose soil particles (sediments) down the slope. This effect is known as Laminar Fluid Flow, which is another form of erosion (9).

4.1.2.3 Aspect

The direction in which the field is facing the sun can determine the crop development. After the tuber emerges, the cultivation requires a lot of light. In addition, the luminosity of plants directly affects photosynthetic processes, allowing a series of secondary reactions in which water and CO_2 intervene. Those processes benefit the formation of different types of sugars, which in turn are part of the potatoes. The amount of light needed varies according to the temperature. Hence, for optimal production, a potato crop requires periods of approximately 8 to 12 and even 16 hours of light (20,000 to 50,000 Lux) depending on the variety cultivated. The amount of light has a great influence on the tuberisation of the potato and the duration of the vegetative growth. Short days favour the start of tuberisation and shorten ones the vegetative cycle, while long days have the opposite effect (18).

According to a study published by the Potato Country Magazine, in order to maximise the plant light absorption, the optimal direction is the one that allows the maximum light saturation on both sides of the row as much as possible. The research showed that best result for northern latitudes are obtained in rows planted in a north-to-south, northwest-to-southeast and northeast-to-southwest orientation. They absorbed more sunlight on both sides of the rows due to the sun trajectory in the summer season (Northern Hemisphere), avoiding as much as possible shadows from other rows (10).

4.1.2.4 Other Factors

A suitable field for potato cultivation has other requirements apart from the ones already mentioned. For instance, the altitude can vary, since the crop develops well from minimums of 1500 to 3800 meters above the sea level (MASL) in regions near the equator with a tropical climate but the ideal altitude for a good development is from 1,500 to 2,500 MASL (11).

Finland is one of the northernmost regions where potato is widely cultivated. The altitude here is not a crucial factor and it goes closely associated to temperature and seasonality. In

the southern part of the country, the cultivation can start as soon as March arrives, depending on the weather conditions it can be delayed or advanced few weeks (1)

The rainfall requirements vary between 600 to 1000 millimetres per production cycle, which will depend on the temperature conditions, soil storage capacity and the variety. The highest demands of water take place in the stages of germination and growth of the tubers. Therefore, it is necessary to irrigate the field a second time in the most critical periods of the crop development, when the precipitation is lower than average (11).

Temperature is the main limitation. Whenever temperatures are below 10° C and above 30° C, they irreversibly affect the development of the crop, while the optimum temperature for better production ranges from 17 to 23° C. For this reason, the potato is planted in early spring in temperate zones and in late winter in the hottest regions. In places with a warm tropical climate it is planted during the coolest months of the year. The potato is considered a thermoperiodic plant, meaning that it needs a variation in temperatures between day and night. This variation must be between 10 to 25º C in the air. The suitable soil temperature for the development of tubers should be between 10 and 16º C during the night and between 16 and 22º C during the day (11).

Table 2. Required temperature for the crop development (11)

Stage		Temperature
Environment temperature	2 weeks after sowing	13 ºC
	Foliar development	12 to 14 ºC
	Stem elongation and flowering	18 ºC
	Tuber formation	16 to 20 ºC
Soil Temperature	Leaf growth and emergence	21 to 24 ºC
	Tuber formation	15 to 24 ºC

Low temperatures on soils during the vegetative growth of the crop, decrease the growth and development of roots, in addition to the assimilation of nutrients, especially

phosphorus. On the other hand, high temperatures accelerate the development of the plant and its ageing, especially in early maturing varieties (10).

4.2 Conceptual Model

The following flowchart outlines the course of action or research methodology

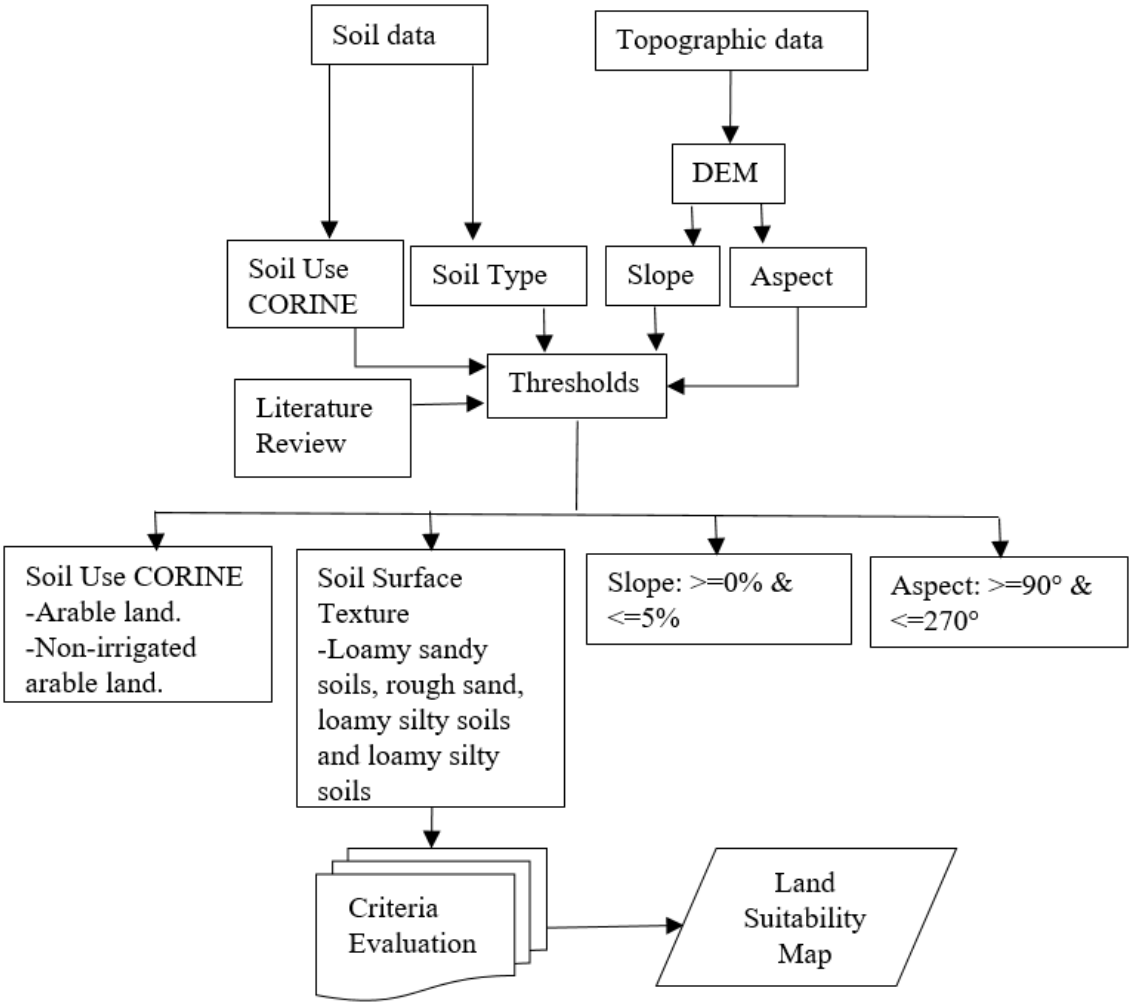


Figure 5 – Conceptual framework of the research methodology, the process describes different phases for the outcome (Land Suitability Map).

4.3 GIS Data Collection

The Software ArcGIS 10.6.1 was used for processing all data. The digital elevation model (DEM) dataset was obtained from the National Land Survey of Finland in the free download services section, the grid resolution is 10x10m. The land cover (CORINE 2018)

dataset, has been produced in the Finnish Environment Institute (SYKE), based on automated interpretation of satellite images and data integration with existing digital map data; the raster format has a resolution of 20x20 m. The land type or land texture is a polygon file, the data show the soil type at a depth of one meter as subsoil and a 0.2 – 0.9m layer as topsoil. The general mapping scale has been 1:20 000. The described datasets can be downloaded from the following links:

– Digital Elevation Model: https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta?lang=en

– Land Use CORINE 2018: https://www.syke.fi/en-US/Open_information/Spatial_datasets/Downloadable_spatial_dataset

–Soil Type: http://tupa.gtk.fi/paikkatieto/meta/maapera_20_50k.html

4.4 GIS Data Processing

Once all the data was stored, the digital elevation model was added into ArcGIS and then combined multiple input datasets into a single with the merge function. The purpose of having a digital elevation model is to obtain the slope and aspect. The slope is obtained by running the function slope from the spatial analyst, the input raster will be the raster from where the slope is derived, meaning the digital elevation model. The figure 4 shows the fields mentioned above. The output measurement can be either in degrees or percentage.

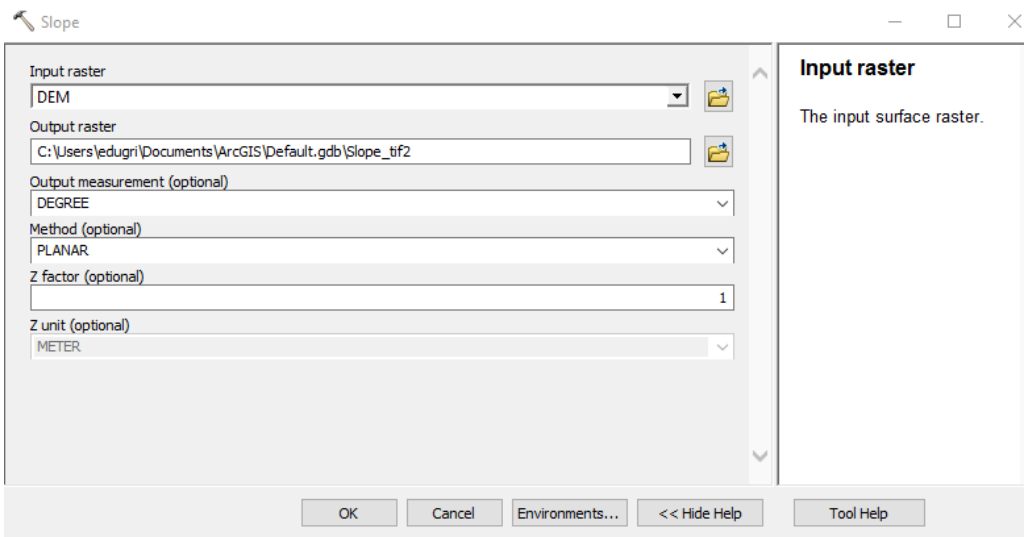


Figure 6 – Slope function, can be found by typing slope in the search window (Ctrl+F)

In the same way, the aspect function is based on the digital elevation model layer and can be found by typing aspect on the search window. The result, a map layer where terrains facing north correspond to 0° and 360°. Therefore, as it goes clockwise, 90° is east, 180° is south and 270° is west.

Once the slope and aspect layers are displayed, they were customised according to the requirements by clicking in the properties of each layer (in the table of contents) as shown in the figure 5. The slope was divided in 5 classes, displaying the first class from 0% to 5%, this is the ideal slope for potato production fields. The second class from 5% to 9%; some fields can be used for potato cultivation, but they need special preparation to reduce the risk of erosion. The third class from 10% to 25%. The fourth class from 25% to 45% and the fifth class >45°. The last 3 classifications are not recommended for potato cultivation (13).

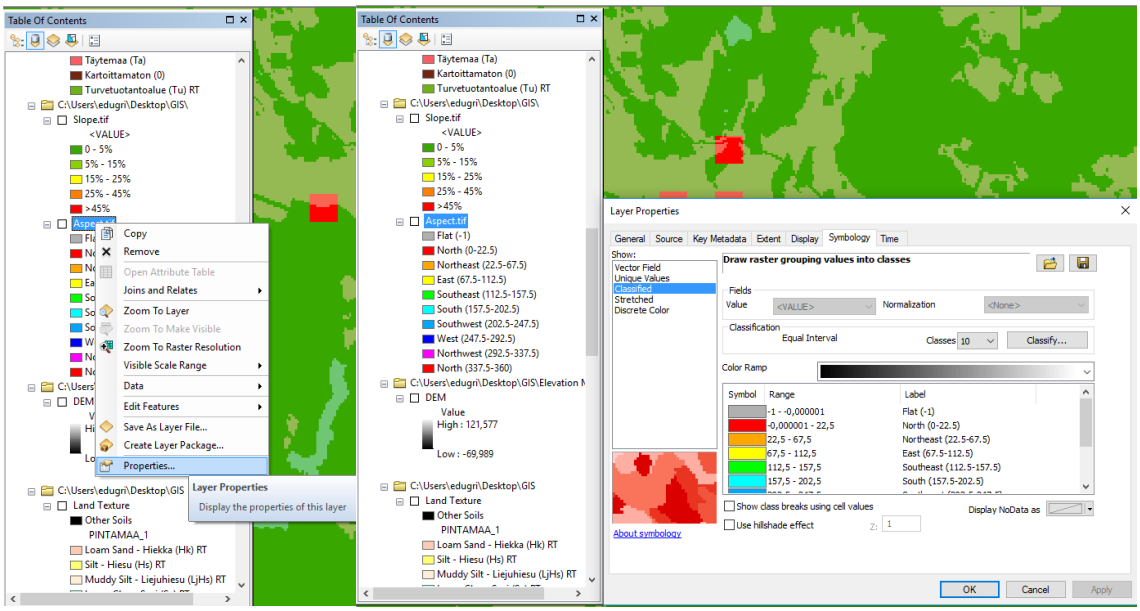


Figure 7. Screenshot showing the access to the aspect layer properties.

The land cover CORINE 2018 and soil type datasets were added by dragging the file into the open ArcGIS software. The soil type polygon file was converted to raster format.

The raster calculator was used to obtain the final raster map, it included all the layers thresholds for potato cultivation. The raster calculator builds and executes a single map algebra expression using Python syntax in calculator-like interface. The expression is described as:

((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))

5 Results and Discussion

The selected criteria to analyse and produce maps with suitable fields for potato cultivation was dependant on data availability. Therefore, the criteria analysis considers soil physical and morphological conditions. Threshold values were established in a general approach, but they are more related to the Nordic region conditions. The aim of this work is to set the ideal threshold values for soil selection when cultivating potatoes in the Västra Nyland Region.

5.1 CORINE - Suitable Land Use

The land use or land cover describes a standardised inventory of land utilisation. The main objective was to support environmental policy in Europe (14). The data is relevant to this model in order to determine and filter which land is appropriate for agricultural purposes. For instance, a field can meet the criteria related to slope, soil type and aspect but if the Finnish CORINE is classifying it as forest, the current methodology would not be applicable.

According to the Finnish CORINE land cover classes developed by SYKE, the CORINE classification contains 3 hierarchy levels. The agricultural areas in general as a level 1 category, which in turn, is divided into 4 Sub-levels: arable land, permanent crops, pastures and heterogeneous agricultural land. The arable land sub-level contains 2 sub-classes: non-irrigated arable land and arable land outside farming subsidies. The procedure for obtaining the desired features from this layer is done by using a map algebra expression, a raster analysis was performed to obtain the suitable soil sub-classes (raster calculator function) as described in the data processing section. The selection was based on land use policy adopted by the Ympäristöministeriö and the Maa- ja metsätalousministeriö together with the Council of the European Union. Finnish and European legislations approved the two sub-classes from arable land to have crop cultivation purposes according to the Directive (2007/2 / EC) and the CLC illustrated nomenclature guidelines (14).

The selected areas presented as suitable in the map from figure 8, show the land where agricultural activities can occur. Some of those fields are already in use for farming purposes.

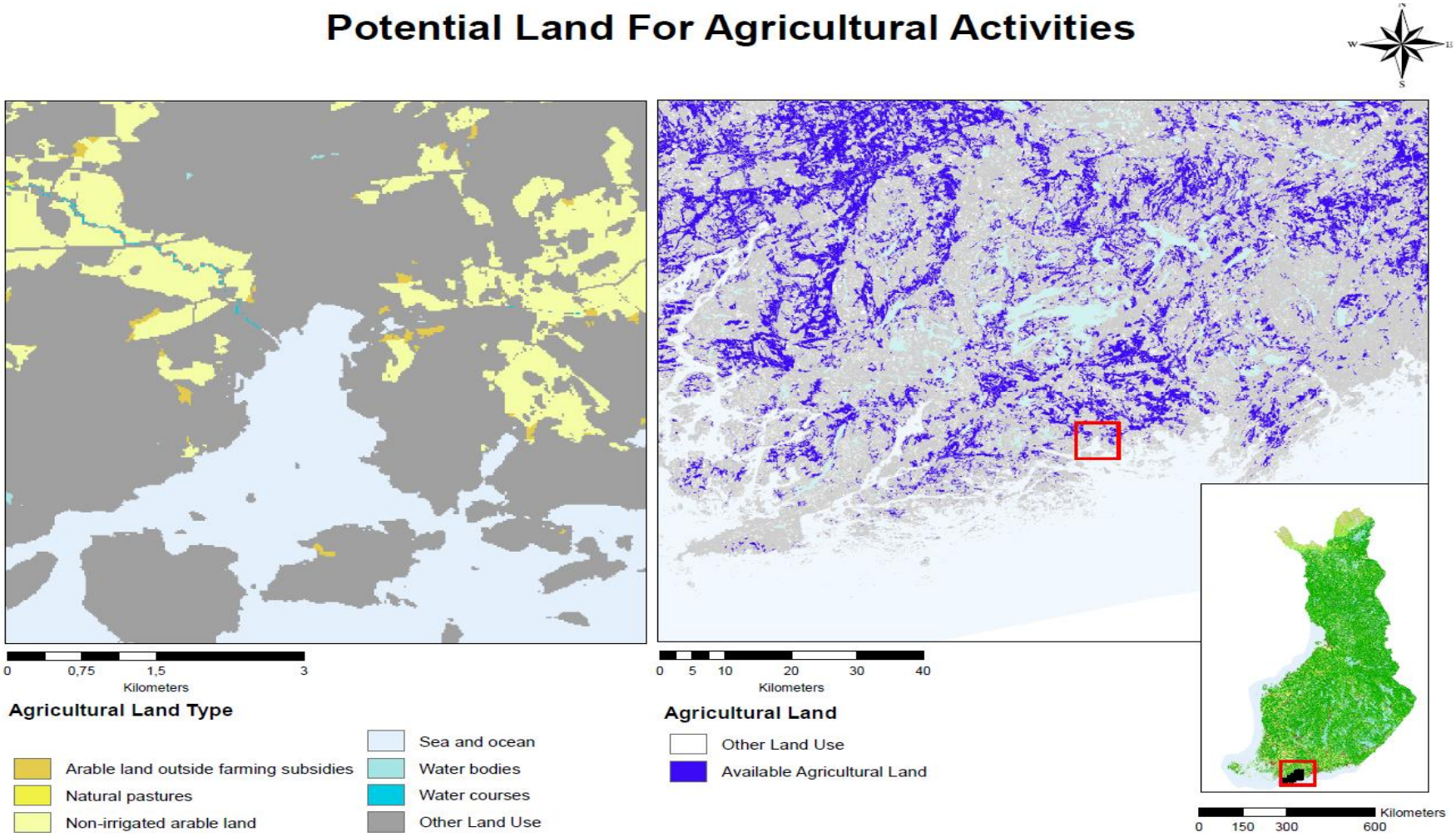


Figure 8 – The zoomed-in map on the left represents the area in the red square in the map from the right and it shows the Inkoo area and its surroundings. The area is traditionally known by its farms with extensive parcels growing potatoes, cereals amongst other crops.

5.2 Suitable Soil Types

As mentioned before, the soil type spectrum is wide for growing potatoes. This criterion was analysed according to the ideal soil type mixture given by the literature and the already existing soils in the region. In the figure 9 is possible to see sandy soils are predominant in some areas. The composition of sandy soils with larger particles than the rest of the soils have challenges retaining the water; those particles are widely separated from each other.

Plants in soils made up of high percentages of sand have to make use of nutrients efficiently due to the fast drainage of water. Therefore, the importance of the mixture of soil particles, which can be made up of about 40% to 60 % sand, 10% to 20% clay and 20% to 40% silt. It can work keeping a balance in the water and nutrient retention but avoiding floods in soils with minimum slopes (8).

The soil type data comprises 2 layers, the topsoil and the subsoil. In some areas the topsoil can reach about 150 meters of depth, but other areas have a very shallow topsoil. According to the metadata, about 83% of the topsoil is 80 cm deep (21). Potato can successfully develop roots in this topsoil. This study did not consider the depths of the layers. The suitable soils were obtained by selecting the silt and sand as the first layer (topsoil) and the clay as the subsoil. The map on the left in the figure 9 displays the areas where the topsoil is made of silt or sand (with no specific order) and the subsoil is made of clay. Consistently with the soil classification, it is presented as loam. Other areas represented with turquoise colour have clay as topsoil, it makes them slightly suitable.

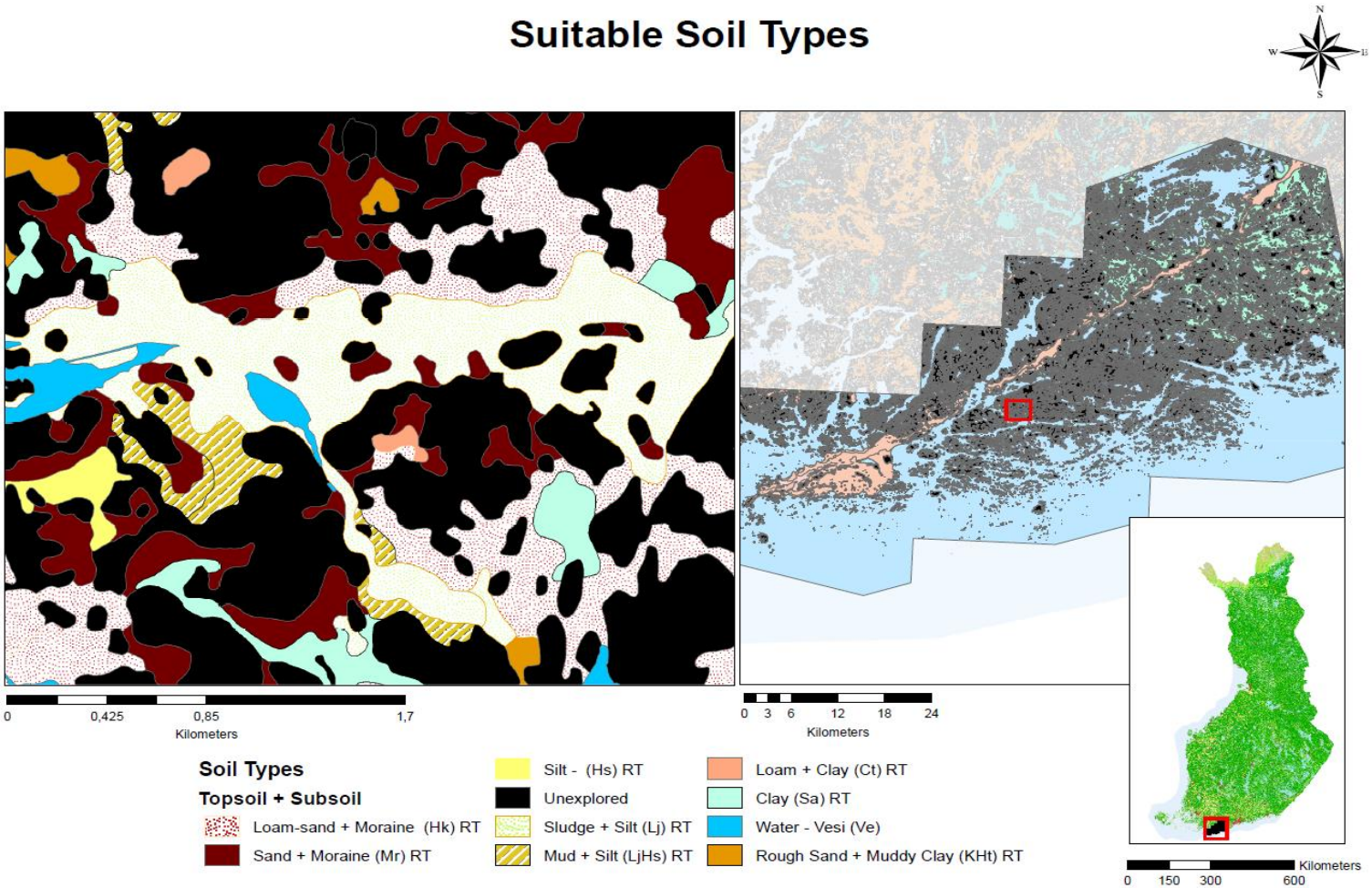


Figure 9 – Soil types. The map on the left is a polygon format. The data contains a sediment as a basal deposit at a depth of 0.80 to 1.40 metre. The minimum size of the basal deposit polygon is two hectares, with islands, mire and field enclosures.

5.3 Suitable Aspect and Slope

Obtaining the aspect or downslope and the slope gradient of the fields that compose the study area was possible with a Digital Elevation Model obtained from National Land Survey of Finland. Once the aspect and slope layers were produced as presented in the data processing section, the raster calculator ran the input expression with the conditions. In order to set thresholds values, these factors (aspect and slope) have to consider the geographic position of the study area. They cannot be set as general as the previous criteria.

The Västra Nyland Region latitude is in a range of 60.13°N and 60.35°N; therefore, fields in the growing season facing east to west from 90° to 270° are favourable in the northern hemisphere and will help the crop to obtain a great amount of sunlight (10).

The input expression for the slope gradient ranged between 0° (flat terrain) and 5° (gentle to moderate slope). The produced map in figure 10 displays only suitable areas where both conditions are met (suitable aspect and slope).

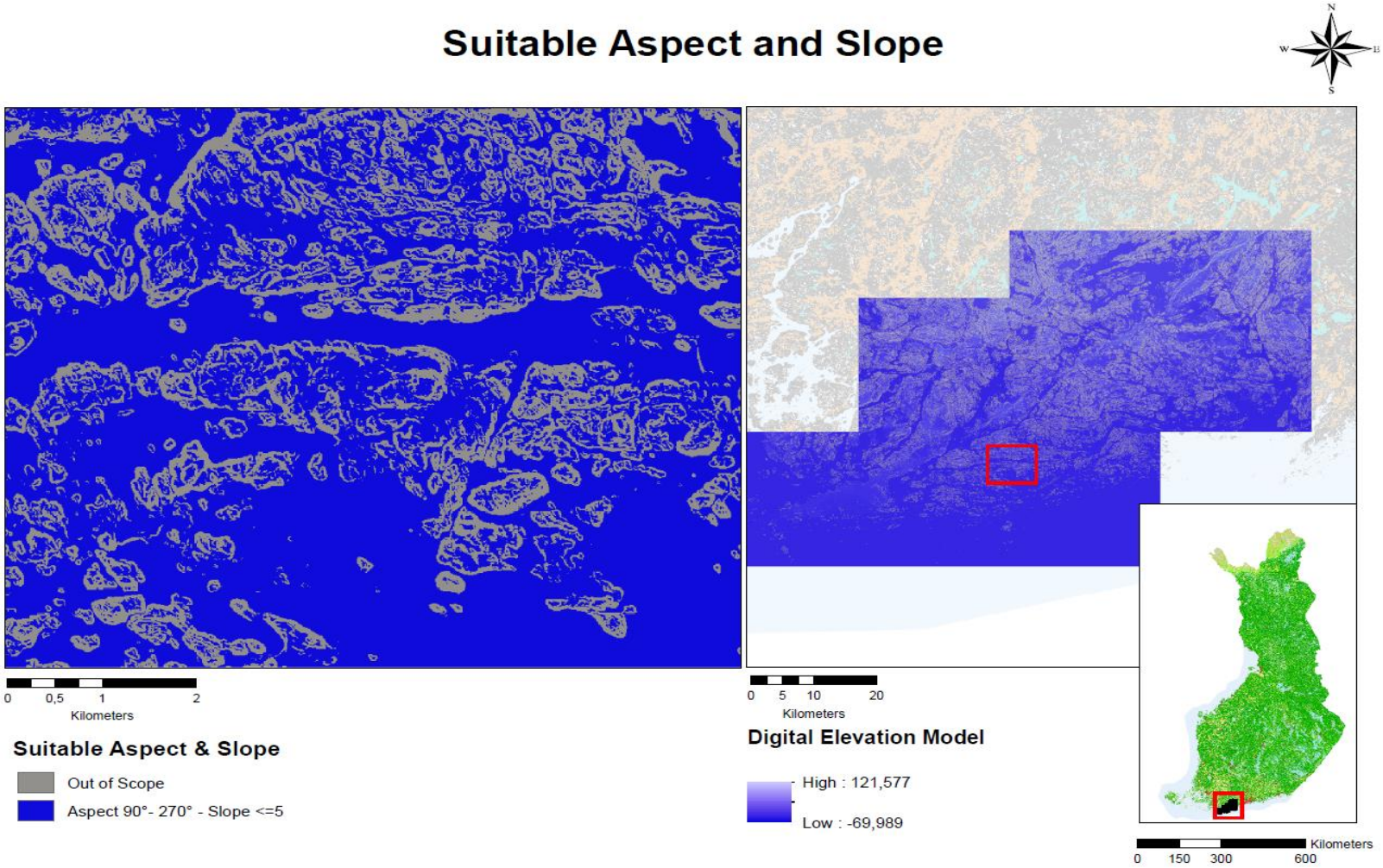


Figure 10 – Aspect and slope. The area in the red square in the map from the right is Inkoo, it is a DEM (measurement is in metres). The map from the left is the suitable area. The area mentioned in the legend as “out of scope” is an area where potato production could be still possible but out of the threshold values mentioned in this thesis.

5.4 Highly Suitable Area for Potato Cultivation

The importance of the earlier criteria is not probably to be equal but in a general approach, those factors are essential and previously evaluated when selecting a field for further assessment, for instance, a soil test. The operations performed with raster maps produced a final map of the land suitability, the highly suitable land has an area of 64 square kilometres or 6500 hectares. The total arable land in the Region is 68 795 hectares. The red square marks in the figure 11 represent the highly suitable area, which is about 10,5% of the arable land. This number was obtained by running the Zonal Geometry Function.

The zoomed-in map on the left in figure 11 displays some of the highly suitable areas that are in use by agricultural activities around Inkoo area. It was possible to identify and contact a farm owner which fields are overlapping the easternmost red mark in the map from the right (figure 11), Teira Gård is currently growing potato on those fields. This partially validates the calculations of the current methodology.

Existing agricultural areas not selected as highly suitable for potato cultivation by this model can have characteristics which were not described in the literature as potentially significant for the crop development. Nevertheless, those areas are not unsuitable, a crop could positively develop on those fields.

The data used for producing suitable soil types, tags as unexplored the unknown soils in the study area and they are represented in black colour; the pattern is frequent. Those soils could have different characteristics within the scope of this study that would possibly make them fit in the land suitability. It is highly important to note that concepts and analysis are based on literature review and research on land suitability and allocation.

The slope gradient in the calculation was based on a fully sufficient terrain that do not require adaption engineering. As with the soil texture, the slope can also have broader threshold. For instance, on different locations along Los Andes mountain range, the potato can grow on slopes from 5% to 20%. It requires a previous preparation of the field and a special way of sowing.

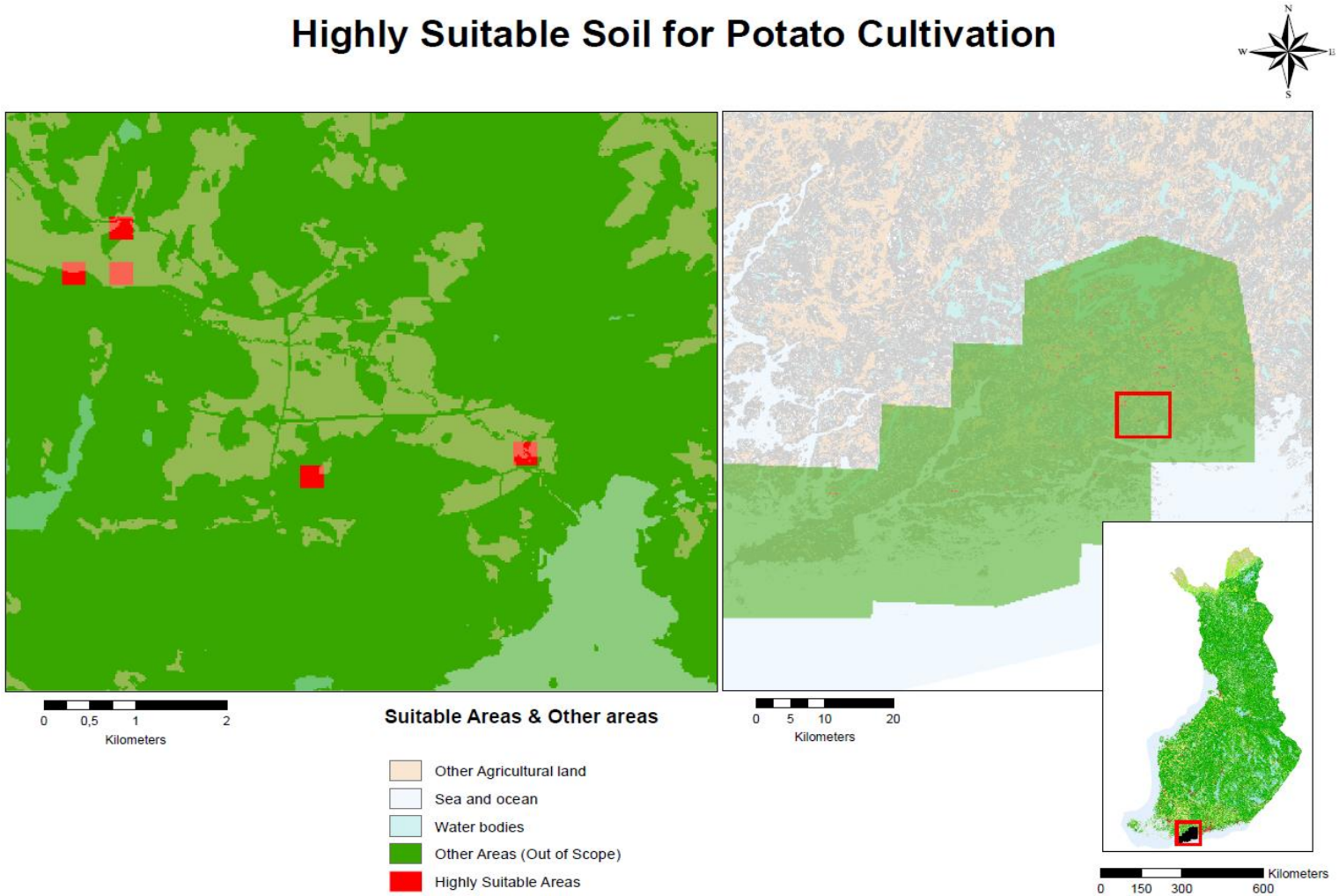


Figure 11 – Suitable soil for potato cultivation. This final map contains all the thresholds, thus, the red squares displayed in the map from the left are highly suitable areas. The map on the left is showing the municipality of Inkoo, where only one of the red marked fields where confirmed as potato field.

The climatic factors are of great importance. The temperature can significantly influence the quality of a field in the growing season. However, temperature varies as a function of distance and other environmental conditions. Those variations might not be significant in air temperature if measured in degrees Celsius but other variables such as humidity and moisture are affected in a local scale.

At the field level, like an individual crop or a plantation, there is one aspect of climate that can be managed - the microclimate. The microclimate is the localised condition of temperature, humidity and air conditions in the immediate environment of a crop (13). Although the microclimate includes other factors besides temperature, farmers are probably more interested in it when they modify the microclimate or take advantage of microclimatic variations.

Within a crop system, the conditions of temperature, humidity, light, wind and air quality vary with the specific location. The conditions on the canopy of the crop system can be very different from those registered in the interior, on the soil surface, in the root zone. The specific microclimatic conditions of a crop system shape the microclimatic profile of the system. Both the structure of the system and the activities of the components have an impact on the microclimatic profile. Microclimates can be naturally and artificially generated, being the last option very common in farming systems, for instance, floating groove covers made of nylon fibre (13).

In the development of this thesis, it was perceptible that temperature as a variable is significantly dependant on other climatic factors such as precipitation, wind and luminosity/solar radiation. Different models include the temperature conditions but large-scale weather aspects changing from one season to another such as cold fronts, windstorms, and rain patterns, are best dealt with by understanding the microclimatic conditions created from not constant circumstances. Temperature as a criterion was not included due to unavailability of soil temperature data on a fine scale. Data on temperature was accessible from the Copernicus open data programme but the data was about air temperature; there can be a significant difference in degrees from air temperature to soil temperature. That difference could influence the crop development. Data related to the weather aspects can considerably help to understand how small temperature variations influence some areas. The soil temperature data can be used in a way that it relates to the period of potato first growing phases. For instance, data of March and April for two years

and then use measures of dispersion to know how wide the data is and how spread out it is around the mean, indicating high temperatures with low variation.

After completed the soil type maps, it is possible to assume that the suitability of an area depends on how well soil conditions compensate themselves. For instance, a soil with a slope gradient over 6% can be compensated by a clayey soil or soil with small particles that retain nutrients and the necessary water and at the same time erosion does not affect it as much as it could affect soils with larger particles. This method template can be complemented by a survey directed to the potato farmers. They hold knowledge about local fields that could be valuable for further development of this GIS model and for the Food Strategy Plan of the region.

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