YRKESHÖGSKOLAN
NOVIA

Bachelor's thesis

Risk map for the runoff of the total suspended solids and total phosphorus for Southwestern Finland.

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Abstract:

Coastal waters are those most affected by terrestrial runoff, and they can be considered hot spots of carbon and nutrient enrichment as well. However, despite nutrient loading is a popular topic for research, there are not enough studies that are dealing with the sources of nutrient loading and coastal filter function. The aim of my bachelor's thesis was to create a map based on the model for non-point source pollution analysis for Raseborg, Hanko and Inkoo areas. The map shows areas that are important for water quality and may be considered as requiring increased attention from environmental managers.

The model that was used in risk-map production is a simplified USLE (universal soil loss equation) model. It is possible to use it, because the hydrological processes for erosion and the transportation of water pollutants/sediments are basically the same. The model is designed to predict the total suspended solids (TSS) and total phosphorus (TP) loads and highlight the areas on land, runoff from which is critical for the water quality.

All the data for the risk-map production was taken from publicly open sources. ArcGIS Pro was used for processing data and model implementation. The final map shows us good results in identifying risk areas and proving that the model is valid. The resulting map can already be used by environmental management, however, with updated coefficients for land use, especially for forestry, the identification of risk areas could be even more precise.

Language: English
Key words: risk map, runoff, modeling, gis

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1. Introduction

Coastal waters are those most affected by terrestrial runoff. Such runoff from land is one of the most important factors that influence water quality and thus all aquatic life. Eutrophication is also one of the consequences of terrestrial runoff, which enriches coastal waters with carbon and nutrients. It results in hypoxic waters (low oxygen concentration), abnormal bloom of algae, disturbance of ecosystem balance and death of different animal species (National Ocean Service, 2023). According to the latest HELCOM integrated status assessment that was conducted from 2011 to 2016, at least 97% of the Baltic Sea was classified as eutrophicated (HELCOM, 2018).

However, coastal areas vary a lot in their properties and pollution vulnerability level. The limitations also come in the way that the terrestrial runoff is not a point-source pollution, but a non-point source. Non-point pollution sources are much harder to identify and assess their degree of influence. Runoff from land can go into the sea in any place along the shoreline, not only from rivers, ditches, and creeks – it is called diffuse loading. In its turn, rivers flowing into the sea can receive their terrestrial loading from anywhere along their banks. On the same basis, the transport, retention, transformation and removal of the pollutants are determined by complex patterns of mixing, flushing and currents (Asmala et al., 2017).

Another indicator of how important it is to identify the exact areas of runoff is the fact that despite different water protection measures took place, the trend analyses in 1995–2016 showed that nutrient export from Finnish rivers has not substantially decreased, and even increased in some areas due to the changes in temperature and precipitation, and ditching of peatlands (Räike et al., 2020). The other fact is that point sources are responsible only for less than 15% of the Finnish nutrient inputs to the Baltic Sea, meaning that the other 85% is non-point sources which are difficult to identify (Räike et al., 2020).

So, the question is how is it possible to identify non-point sources of pollution and to estimate what areas should be considered the riskiest in terms of possible loading of carbon and nutrients with runoff?

2. Objectives

The aim of my bachelor’s thesis was to create a map, that that highlight the areas on land from where most terrestrial loading is contributing to bad water quality in the coastal areas of Raseborg, Hanko and Inkoo municipalities. In order to conduct an analysis of non-point pollution sources it is possible to look at the different properties of coastal land areas and assess their influence on terrestrial runoff by modeling.

After the runoff hot spots are identified, their relation to the water quality will be briefly assessed by combining the runoff map with the interpolated maps of several parameters (such as fDOM and turbidity), acquired from high-resolution water monitoring campaigns of the “Havsmanualen” project, conducted by Pro Litore ry, the company where I had my internship.

3. Materials and methods

3.1 Runoff risk modelling

The model that was used to create a runoff risk map of critical for water quality areas was developed by Åke Sivertun and Lars Prange (2003). The hydrological process for erosion and the transportation of water pollutants is basically the same, therefore it is possible to use the simplified USLE (universal soil loss equation) model to estimate the load of the total suspended solids (TSS) and total phosphorus (TP) (Sivertun and Prange, 2003). These variables are the most important to estimate as the pollution from agricultural fields, which are treated with different types of fertilizers, was always considered to be the most contributing to nutrient loading and therefore eutrophication. Moreover, suspended solids in general play a significant role in carrying pollutants such as phosphorus in streams (Villa et al., 2019).

The original Universal Soil Loss Equation (USLE) was developed by W.H. Wischmeier and D.D. Smith, and first published in 1965, then followed by an updated version in 1978 (US Department of agriculture, 2016). It is a model that aims to describe the process of erosion. Basically, USLE is able to estimate average annual soil loss by sheet and rill erosion, and it is not used for the areas of the slopes where the deposition process is taking place (FAO UN, 2023). There are several other models that were derived from the original model of W.H.

Wischmeier and D.D. Smith version 1978. For example, models like Revised USLE - RUSLE (Renard et al., 1991) and Modified USLE - MUSLE (Hensel and Bork, 1988).

However, such erosion models are usually complicated and require special software and accurate data, while in applied research it is valuable that the method allows making computations quickly enough with accessible software and data, so the results could later be used in the solution to the actual problem. Therefore, it is possible to use a simplified version of a model which will still highlight the critical areas that are more likely to be in need of targeted environmental management actions, and that would be at some point more effective and reasonable than using a heavy and slow model.

A simplified USLE model that I used in my analysis was first developed by Sivertun et al. in 1988, and then updated in 2003. The resulting map is based on four factors, and despite it does not tell anything about the precise pollution load, it is still able to highlight the areas with high risk of erosion and significant impact on water quality (Sivertun and Prange, 2003).

The formula for the model looks like:

$$\mathbf{P = K * S * W * U} \tag{1}$$

where,

P – resulting runoff risk map

K – soil factor map

S – slope length and steepness factor map

W – watercourse factor map

U – land use factor map

This updated model was verified in the Svartå river basin in Östergötland in Sweden by 1-year measurement program, and the model produced reliable results, as "the correlation between estimated load of suspended soils and the amount of critical areas was between 91 and 95%, and the correlation between the estimated load of phosphorus and the critical area size was 98%" (Sivertun and Prange, 2003).

3.2 High-resolution water monitoring data

In order to get a visual representation of the relations between modelled risk areas and the actual parameters related to water quality, the resulting risk map was combined with data from the "Havsmanualen" project, conducted by Pro Litore ry. The project started in 2018 and made it possible to collect high-resolution water monitoring data in Southwestern Finland (Fig.1). The data is collected with a flow-through system of sensors installed on the boat. Numerous parameters are recorded every 5 seconds, while the boat is moving at approximately 20 knots speed. The transect of 1,200 km within the project Havsmanualen is surveyed once a month (during the whole non-ice period), which results in about 150,000 observations each year (Scheinin, Asmala, 2020).

Table 1. A list of recorded variables within the project Havsmanualen.

Water sensors (0.5m depth)	**Surface sensors (installed on the boat)**
Chlorophyll a	Air pressure
Phycocyanin	Air humidity
Turbidity	Air temperature
fDOM (Fluorescent Dissolved Organic Matter)	PAR (Photosynthetically Active Radiation)
Oxygen	
pH	
Conductivity	
Temperature	
Carbon Dioxide	
Methane	

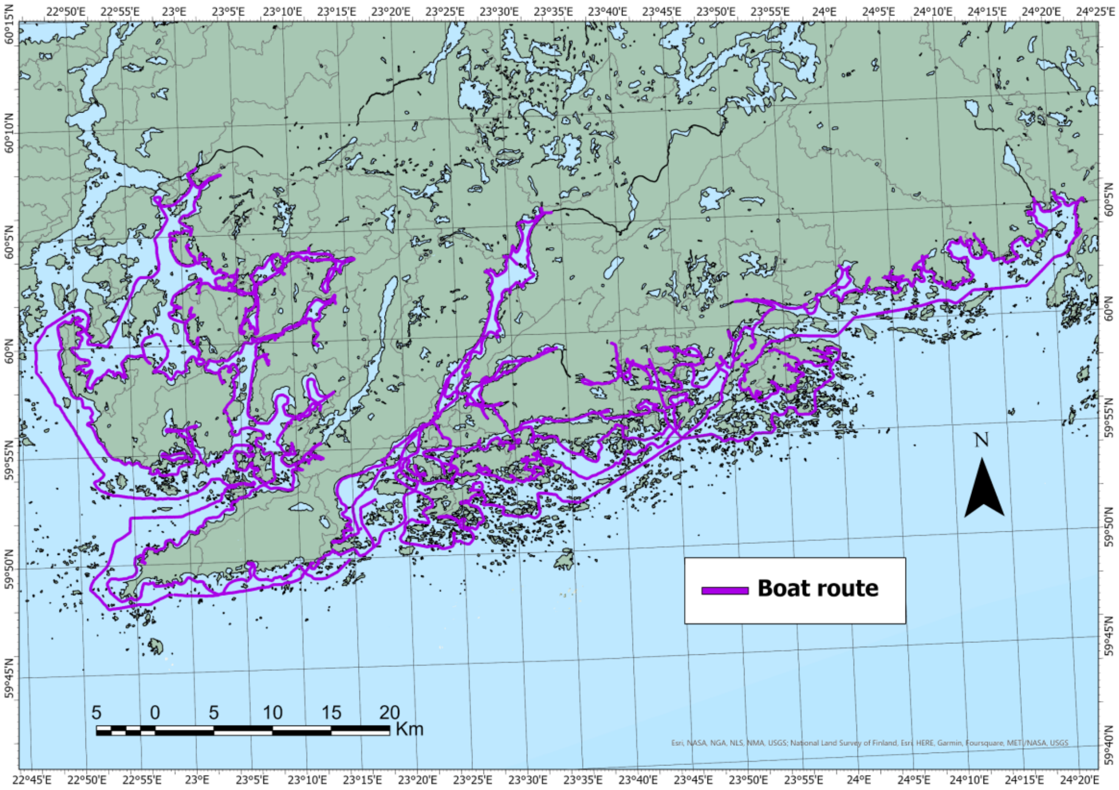


Fig.1. The route of Havsmanualen project, Pro Litore.

The resulting runoff risk map was combined with fDOM QSU measurements done at the beginning of June 2021, and Turbidity FNU measurements from the same sampling occasion. The interpolations for the variables were done using Diffusion Interpolation with Barriers (Geostatistical Analyst) tool in ArcGIS Pro.

Dissolved organic matter (DOM) is a complex composition obtained mainly from the products of the decomposition of plants and bacteria (United States Geological Survey, 2023). It acts as a reliable indicator of the changes in ecological processes (Bolan et al., 2011). fDOM is a **Fluorescent Dissolved Organic Matter**, and it refers to the fraction of Coloured Dissolved Organic Matter (CDOM) that fluoresces (YSI, 2023). Moreover, there is a connection between flow and discharge, and fDOM concentrations in water bodies (Xylem Analytics Australia, 2023). All in all, fDOM measurements are one of the ways of fast means of analysing DOM concentrations in water bodies.

Turbidity is a measure of the relative clarity of the water (United States Geological Survey, 2018). Different particles inside water make it turbid. The particles could be small parts of algae and plants, dissolved organic matter (DOM), parts of soil, phytoplankton, and zooplankton, etc.

Both fDOM and turbidity have a direct connection with general water quality and could be combined with the risk map that shows estimates of the total suspended solids (TSS) and total phosphorus (TP) loads for visual comparison.

4. Procedure for creating a runoff risk map

4.1 Soil factor map

The first step is to download the publicly available data with the soil type information. For Finland, the open data is “Superficial deposits of Finland 1:200 000 (sediment polygon)” produced by the Geological Survey of Finland (GTK). It comes in vector format and contains the data for the whole Finland for the years 2002-2009.

The link for the dataset: https://hakku.gtk.fi/en/locations/search?location_id=3

The mapping scale has been 1:50 000 – 1:200 000, and the minimum size of the sediment polygons is about six hectares (Geological Survey of Finland, 2018). The dataset comes in Finnish, therefore the translation to English is needed to be done.

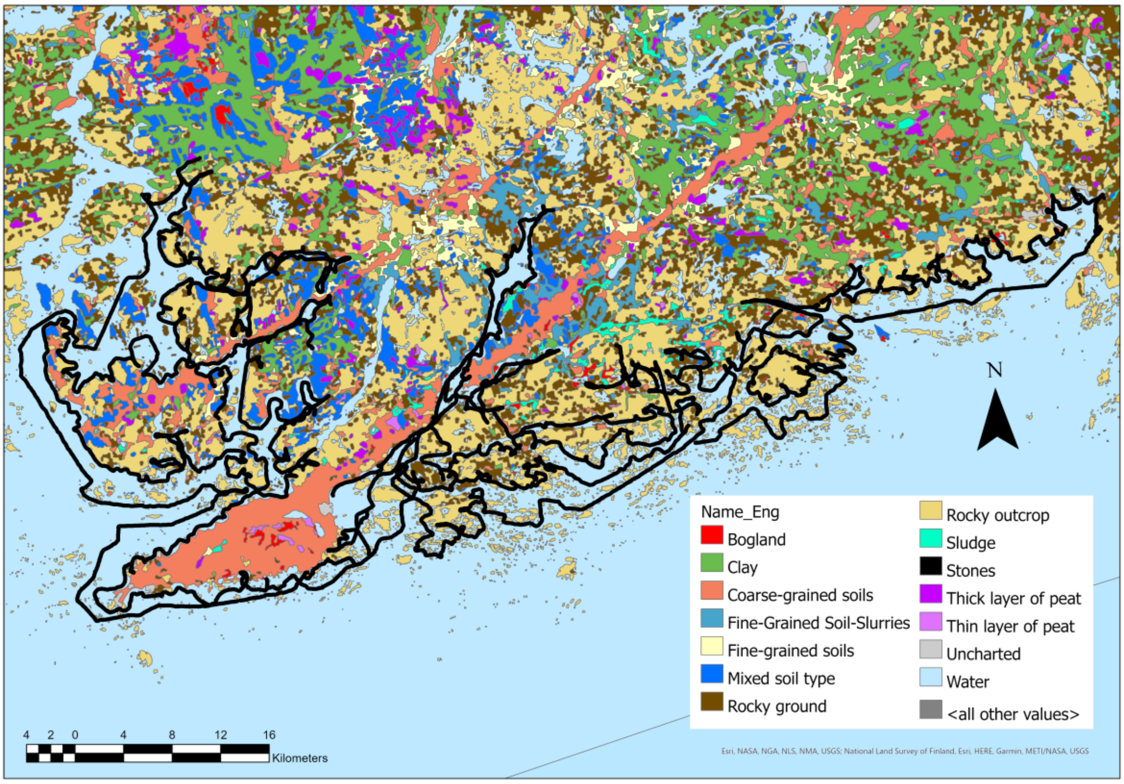
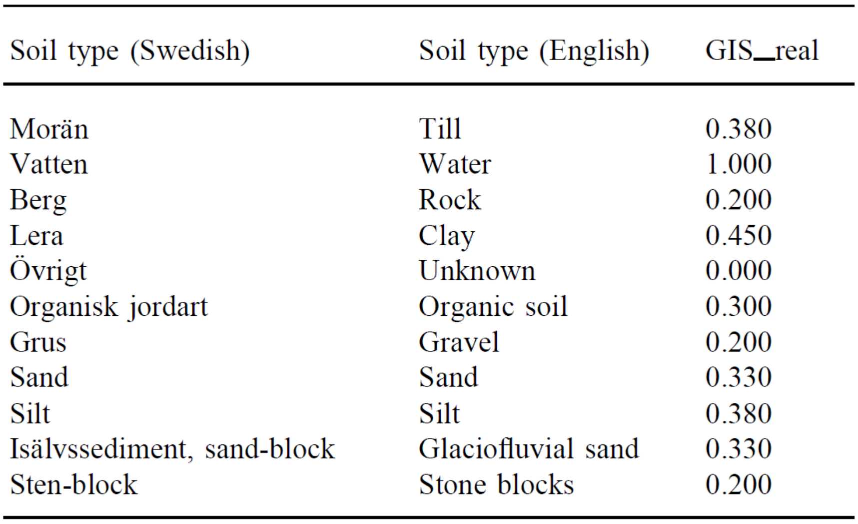


Fig.2. The map of the superficial deposits with Havsmanualen project monitoring route.

In the article with the original model created by Sivertun and Prange (2003) the data from the Swedish Geological Survey (SGU) was used, and, of course, the names of the soil types were different (Table 2). However, it is possible to link Swedish classification and naming to the Finnish one and assign the USLE coefficients.

Table 2. Classification of the soil map used by Sivertun and Prange (2003)



Soil type (Swedish)	Soil type (English)	GIS_real
Morän	Till	0.380
Vatten	Water	1.000
Berg	Rock	0.200
Lera	Clay	0.450
Övrigt	Unknown	0.000
Organisk jordart	Organic soil	0.300
Grus	Gravel	0.200
Sand	Sand	0.330
Silt	Silt	0.380
Isälvssediment, sand-block	Glaciofluvial sand	0.330
Sten-block	Stone blocks	0.200

The names of the sediments were translated to English and a new field in the attribute table with the values of USLE classes was created. Table 3 and Fig.3 provide explanations of the values chosen.

Table 3. The results of reclassification and assigning USLE values

Name Sediments map	Explanation	Classification used by Sivertun and Prange (2003)	USLE
Bogland Soistuma (Tvs) RT		Organic matter + water	0.65
Clay Savi (Sa) RT		Clays	0.45

Coarse-grained soils Karkearakeinen maalaji, päälajitetta ei selvitetty (KY) RT	It is difficult to distinguish between sand and gravel. Coarse grained soils have good drainage qualities. There is no volume change with change in moisture condition.	The mean value of sand and gravel is used.	0.265
Fine-Grained Soil-Slurries Liejuinen hienorakeinen maalaji RT	Silty fine-grained soil type	Silt	0.38
Fine-grained soils Hienojakoinen maalaji, päälajitetta ei selvitetty (HY) RT	It is difficult to distinguish between silt and clay. Fine grained soils have a poor load bearing capacity. Fine grained soils are nearly impenetrable in nature because of its small size of particles.	The mean value of silt and clay is used.	0.415
Mixed soil type Sekalajitteinen maalaji, päälajitetta ei selvitetty (SY) RT		Mean value of silt, clay, sand and gravel is used.	0.34
Rocky ground Kalliomaa (Ka) RT		Gravels/hard rock	0.20
Rocky outcrop Kalliopaljastuma (KaPa) RT		Gravels/hard rock	0.20
Sludge Lieju (Lj) RT	Organic substance p-% >20	Clay + organic matter	0.375
Stones Kiviä (Ki) RT		Gravels/hard rock	0.20

Thick layer of peat Paksu turvekerros		Organic matter	0.30
Thin layer of peat Ohut turvekerros		Organic matter	0.30
Uncharted Kartoittamaton(0)		Unknown	0.00
Water Vesi (Ve)		Water	1.00

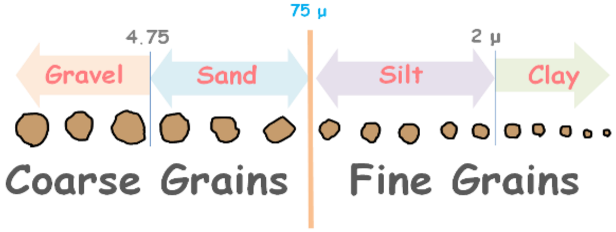


Fig.3. The visualization of sizes of particles in different types of soils. (Source: elementaryengineeringlibrary.com, 2023)

The USLE classes were assigned using Arcade programming language, a lightweight expression language that was created specifically for use in the ArcGIS platform (ArcGIS Developers, 2023).

```
if ($feature.Name_Eng == "Bogland") {return "0,65"}
if ($feature.Name_Eng == "Clay") {return "0,45"}
if ($feature.Name_Eng == "Coarse-grained soils") {return "0,265"}
if ($feature.Name_Eng == "Fine-Grained Soil-Slurries") {return "0,38"}
if ($feature.Name_Eng == "Fine-grained soils") {return "0,415"}
if ($feature.Name_Eng == "Mixed soil type") {return "0,34"}
if ($feature.Name_Eng == "Rocky ground") {return "0,2"}
if ($feature.Name_Eng == "Rocky outcrop") {return "0,2"}
if ($feature.Name_Eng == "Sludge") {return "0,375"}
if ($feature.Name_Eng == "Stones") {return "0,2"}
if ($feature.Name_Eng == "Thick layer of peat") {return "0,3"}
if ($feature.Name_Eng == "Thin layer of peat") {return "0,3"}
if ($feature.Name_Eng == "Uncharted") {return "0"}
if ($feature.Name_Eng == "Water") {return "1"}
else {return "0"}
```

The last step is to convert vector layer to raster with the cell size 10*10 m., using USLE field.

4.2 Land use factor map

One of the most known and publicly available datasets for land cover which covers all EEA39 countries is Corine Land Cover dataset, produced within the frame of Copernicus Land Monitoring (Copernicus, 2020). The last version was released in 2019 and revised in 2020.

The link for the dataset:

https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=download

In the article with the original model created by Sivertun and Prange (2003) different datasets were combined together - the Landsat TM5 image made in 1998 and classified by Metria Satellus, plus two datasets produced by the Swedish Board of Agriculture Jordbruksverket (Sivertun and Prange, 2003). Therefore, the naming differs from Corine Land Cover dataset (Fig.4) and the reclassification is needed.

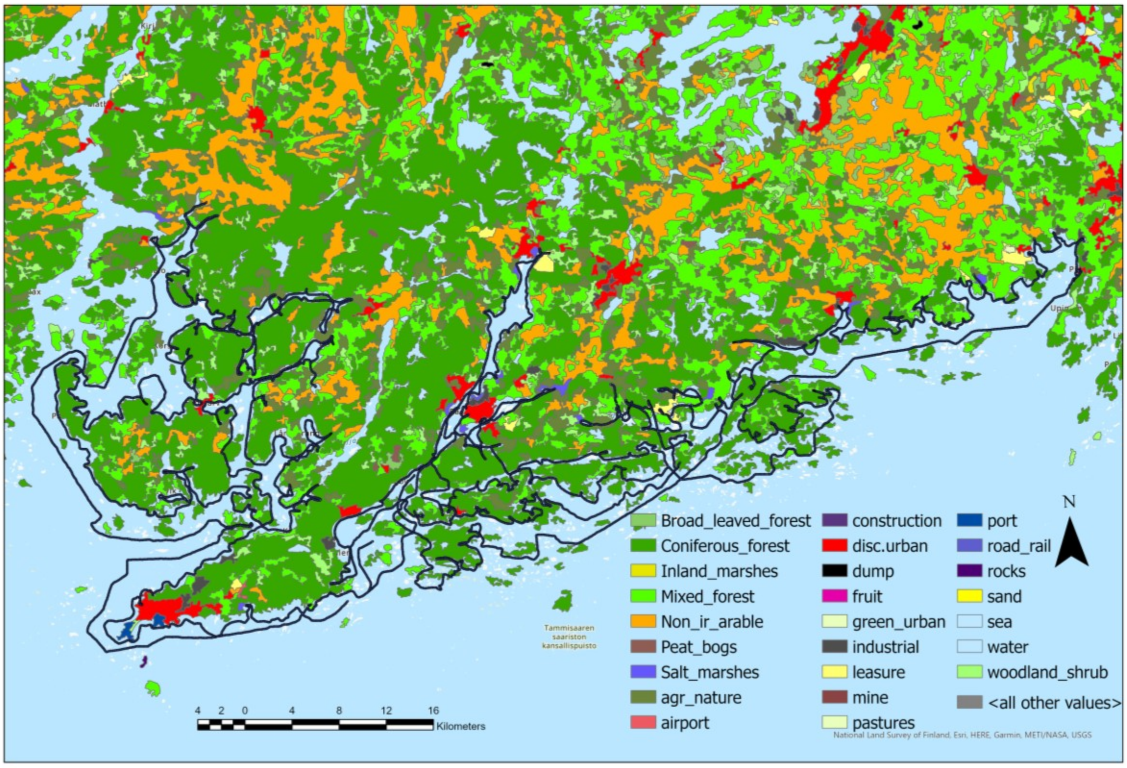
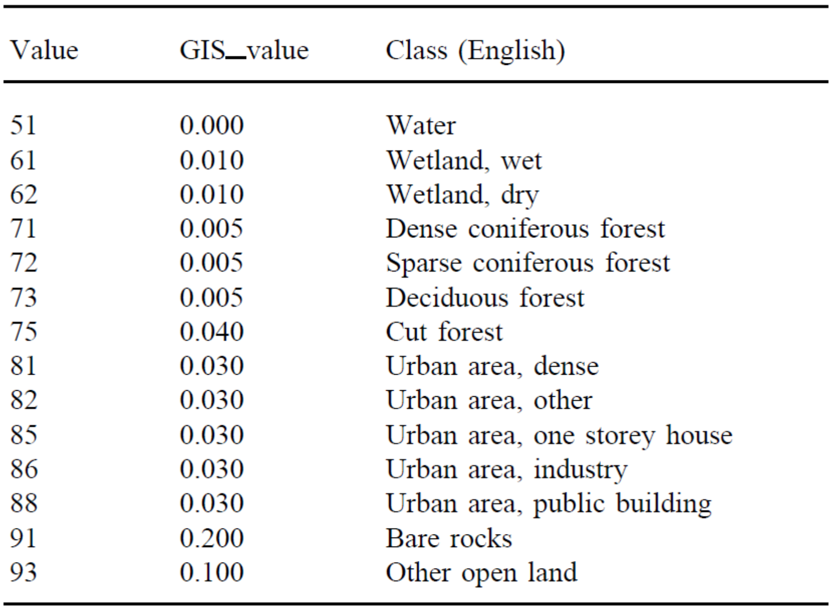


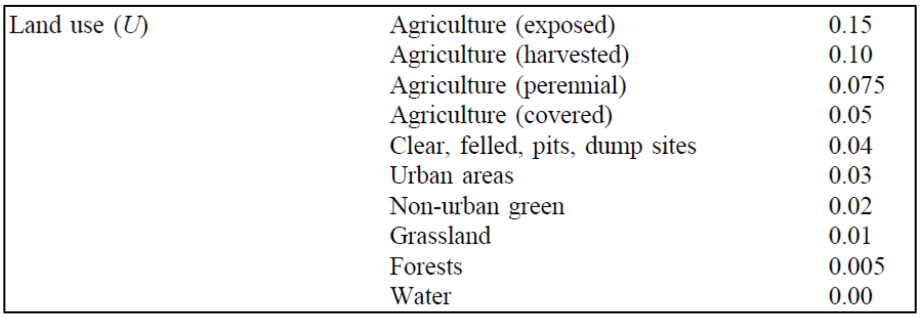
Fig. 4. Corine Land Cover (CLC) 2018, Version 2020_20u1 with Havsmanualen project monitoring route.

Table 4. Classification of the land use image used by Sivertun and Prange (2003)



Value	GIS_value	Class (English)
51	0.000	Water
61	0.010	Wetland, wet
62	0.010	Wetland, dry
71	0.005	Dense coniferous forest
72	0.005	Sparse coniferous forest
73	0.005	Deciduous forest
75	0.040	Cut forest
81	0.030	Urban area, dense
82	0.030	Urban area, other
85	0.030	Urban area, one storey house
86	0.030	Urban area, industry
88	0.030	Urban area, public building
91	0.200	Bare rocks
93	0.100	Other open land

Table 5. The values for the land use factor map of the previous version of the model by Schein (2001)



Land use (U)	Agriculture (exposed)	0.15
	Agriculture (harvested)	0.10
	Agriculture (perennial)	0.075
	Agriculture (covered)	0.05
	Clear, felled, pits, dump sites	0.04
	Urban areas	0.03
	Non-urban green	0.02
	Grassland	0.01
	Forests	0.005
	Water	0.00

Both Tables 4 and 5 were used in order to assign the right classes to the Corine Land Cover dataset. The resulting classes are shown in Table 6.

Table 6. USLE coefficients assigned to Corine Land Cover dataset.

Corine Land Cover	New name	USLE
Broad_leaved_forest	forest	0.005
Coniferous_forest	forest	0.005
Inland_marshes	wetland	0.01
Mixed_forest	forest	0.005

Non_ir_arable	agriculture	0.1
Peat_bogs	wetland	0.01
Salt_marshes	wetland	0.01
agr_nature	agriculture	0.1
airport	urban	0.03
construction	urban	0.03
disc.urban	urban	0.03
dump	dump	0.04
fruit	non-urban green	0.02
green_urban	urban	0.03
industrial	urban	0.03
leasure	non-urban green	0.02
mine	urban	0.03
pastures	grassland	0.01
port	urban	0.03
road_rail	urban	0.03
rocks	Bare rocks	0.2
sand	other open land	0.1
sea	water	0
water	water	0
woodland_shrub	non-urban green	0.02

The USLE classes were assigned using Arcade programming language:

```
if ($feature.Name == "Broad_leaved_forest") {return "0,005"}
if ($feature.Name == "Coniferous_forest") {return "0,005"}
if ($feature.Name == "Inland_marshes") {return "0,01"}
if ($feature.Name == "Mixed_forest") {return "0,005"}
if ($feature.Name == "Non_ir_arable") {return "0,1"}
if ($feature.Name == "Peat_bogs") {return "0,01"}
if ($feature.Name == "Salt_marshes") {return "0,01"}
if ($feature.Name == "agr_nature") {return "0,1"}
if ($feature.Name == "airport") {return "0,03"}
if ($feature.Name == "construction") {return "0,03"}
```

```
if ($feature.Name == "disc.urban") {return "0,03"}
if ($feature.Name == "dump") {return "0,04"}
if ($feature.Name == "fruit") {return "0,02"}
if ($feature.Name == "green_urban") {return "0,03"}
if ($feature.Name == "industrial") {return "0,03"}
if ($feature.Name == "leasure") {return "0,02"}
if ($feature.Name == "mine") {return "0,03"}
if ($feature.Name == "pastures") {return "0,01"}
if ($feature.Name == "port") {return "0,03"}
if ($feature.Name == "road_rail") {return "0,03"}
if ($feature.Name == "rocks") {return "0,2"}
if ($feature.Name == "sand") {return "0,1"}
if ($feature.Name == "sea") {return "0"}
if ($feature.Name == "water") {return "0"}
if ($feature.Name == "woodland_shrub") {return "0,02"}
else {return "0"}
```

The last step is, as always, to convert vector layer to raster with the cell size 10*10 m., using USLE field.

4.3 Slope length factor map

In the last version of the model created by Sivertun and Prange (2003), the improved version of LS factor is used, which was developed by Mitasova and Mitas (1999). “It takes into account not only the steepness but also the slope length and the upstream water contribution area and is suited to modelling the increased erosion in areas of concentrated water flow” (Sivertun and Prange, 2003).

Firstly, the Digital Elevation Model (DEM) 10m was downloaded from the National Land Survey of Finland (NLS) open data service.

The link to the dataset:

https://asiointi.maanmittauslaitos.fi/karttapaikka/tiedostopalvelu

Then it is needed to fill sinks in DEM by using the tool called “Sinks”, which is available with Spatial Analyst license in ArcGIS Pro. Sinks or sometimes peaks are basically mistakes in the data, because of the rounding of elevations or data resolution (Fig.5). “Sinks should be filled to ensure proper delineation of basins and streams. If the sinks are not filled, a derived drainage network may be discontinuous” (ESRI, 2023).

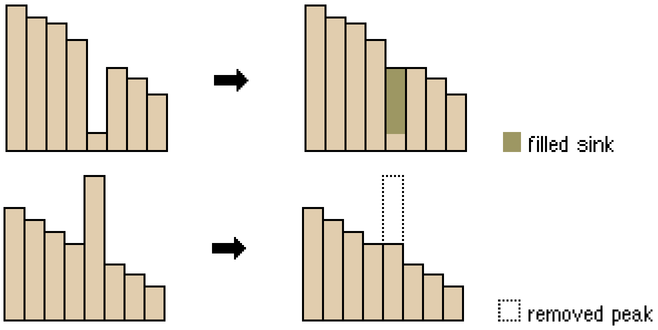


Fig. 5. Illustration of how the tool “Fill” in ArcGIS Pro works. (Source: pro.arcgis.com)

All water bodies (sea, rivers, lakes, etc.) should be clipped out from the raster. “They are treated as water outflow and their removal avoids unrealistically high flow accumulation values” (Sivertun and Prange, 2003).

Then it is needed to compute Flow direction raster and Flow accumulation raster. That could be done by using Esri's ArcHydro extension for ArcGIS Pro or a normal Hydrology toolset (Spatial Analyst). The next important step is a computation of Slope raster by using the tool “Slope”, Spatial Analyst (Fig. 6).

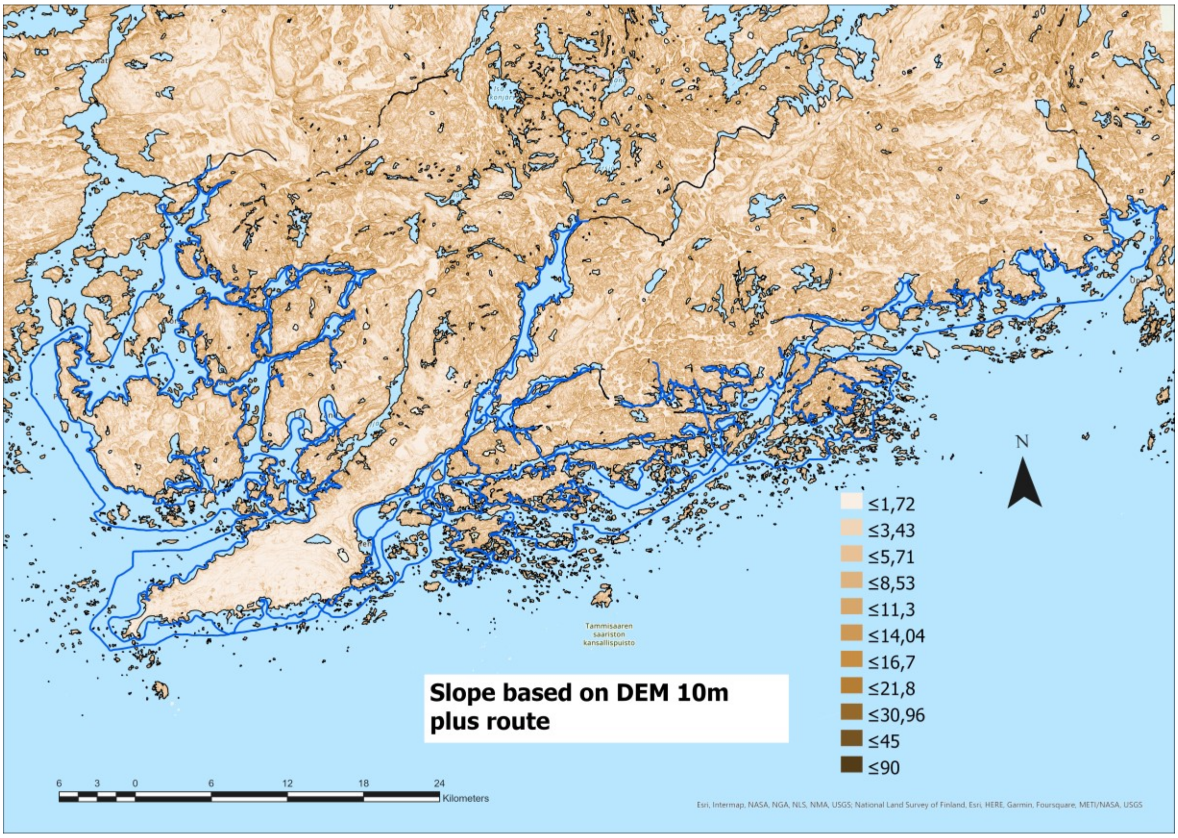


Fig.6. A slope raster (in degrees) with Havsmanualen project monitoring route.

The final formula applied through Raster Calculator looks like that:

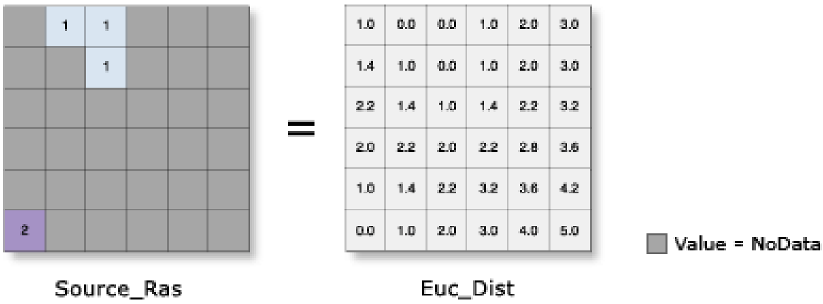
`Power("FlowAcc_fdr21"*10/22.1,0.6)*Power(Sin("Slope_Fill_d1"*0.01745)/0.09,1.3)*1.6`

4.4 Watercourse factor map

The data for the watercourse factor map was taken from the National Land Survey of Finland (NLS) open data service. The dataset can be accessed from the same link as the Digital Elevation Model and has the name “Topographic map (vector), 1:100 000”.

The dataset comes as a vector file, so it is needed to choose 2 layers from it – *“VesiViiva”* for the rivers and ditches, and *“VesiAlue”* for the coastal waters and lakes. Both layers should be converted to raster with cell size 10m and combined.

The next step is to compute the distance of each cell to the water bodies. The “Euclidean Distance” (Spatial Analyst) tool in ArcGIS Pro could be used for this purpose (Fig.7).



	1	1			
		1			
2					

Source_Ras

=

1.0	0.0	0.0	1.0	2.0	3.0
1.4	1.0	0.0	1.0	2.0	3.0
2.2	1.4	1.0	1.4	2.2	3.2
2.0	2.2	2.0	2.2	2.8	3.6
1.0	1.4	2.2	3.2	3.6	4.2
0.0	1.0	2.0	3.0	4.0	5.0

Euc_Dist

▨ Value = NoData

Fig. 7. The illustration of how “Euclidean Distance” tool works. (Source: pro.arcgis.com)

The final formula applied through Raster Calculator looks like that:

`(Power((Exp("EucDist"*0.002))-0.4,-1))*0.6`

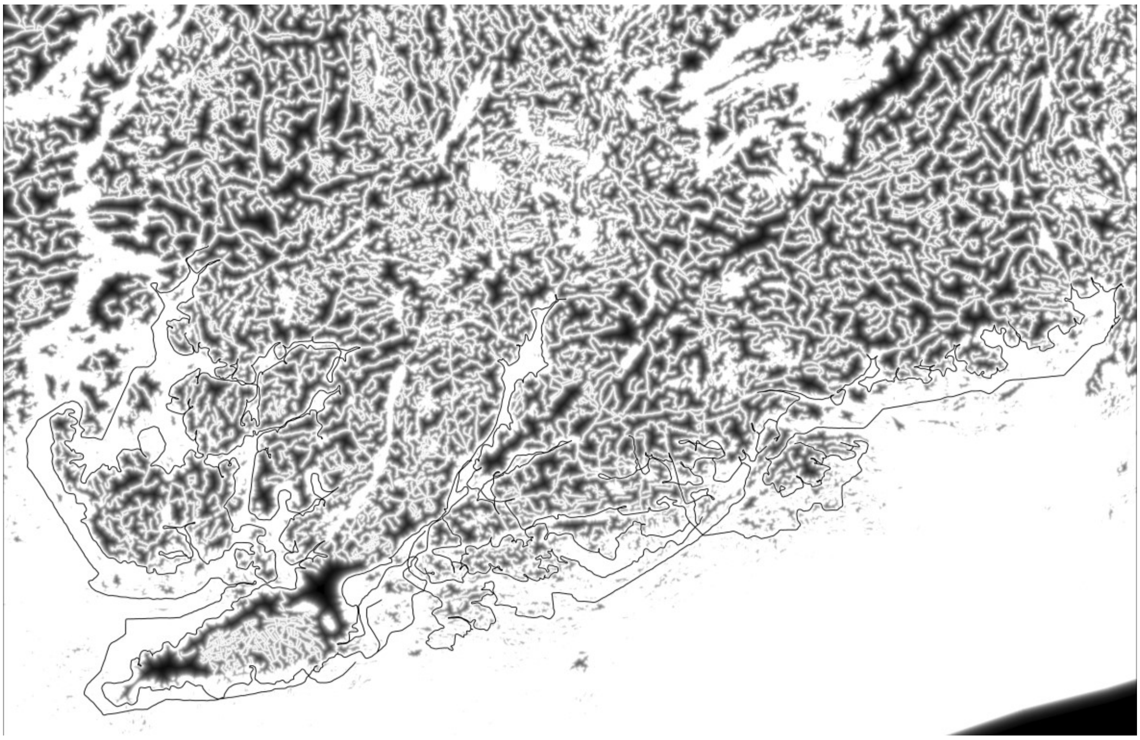


Fig.8. The example of how the resulting watercourse factor map could look like.

5. Risk map results

Four factor maps are combined by simple raster multiplication through Raster Calculator, according to the formula (1).

The classification of the risk areas (4 classes) was made according to Sivertun and Prange (2003), who stated that “Only areas with USLE values that are more than two standard deviations above the mean value are classified as risk areas and areas with values between one and two standard deviations above the mean value are called sub-risk areas”.

Table 7. The classification of the resulting raster.

Risk class	Value
Low influence on water quality	≤ 0,01
Low-risk areas	≤ 0,1
Sub-risk areas	≤ 0,19
Risk areas	> 0,19

Because the risk areas are quite small, and it is difficult to see them on a small-scale map, buffers of 50m were created around each risk area (Fig.9). However, on large-scale maps the original symbology without buffers were used (Fig.10 and Fig.11).

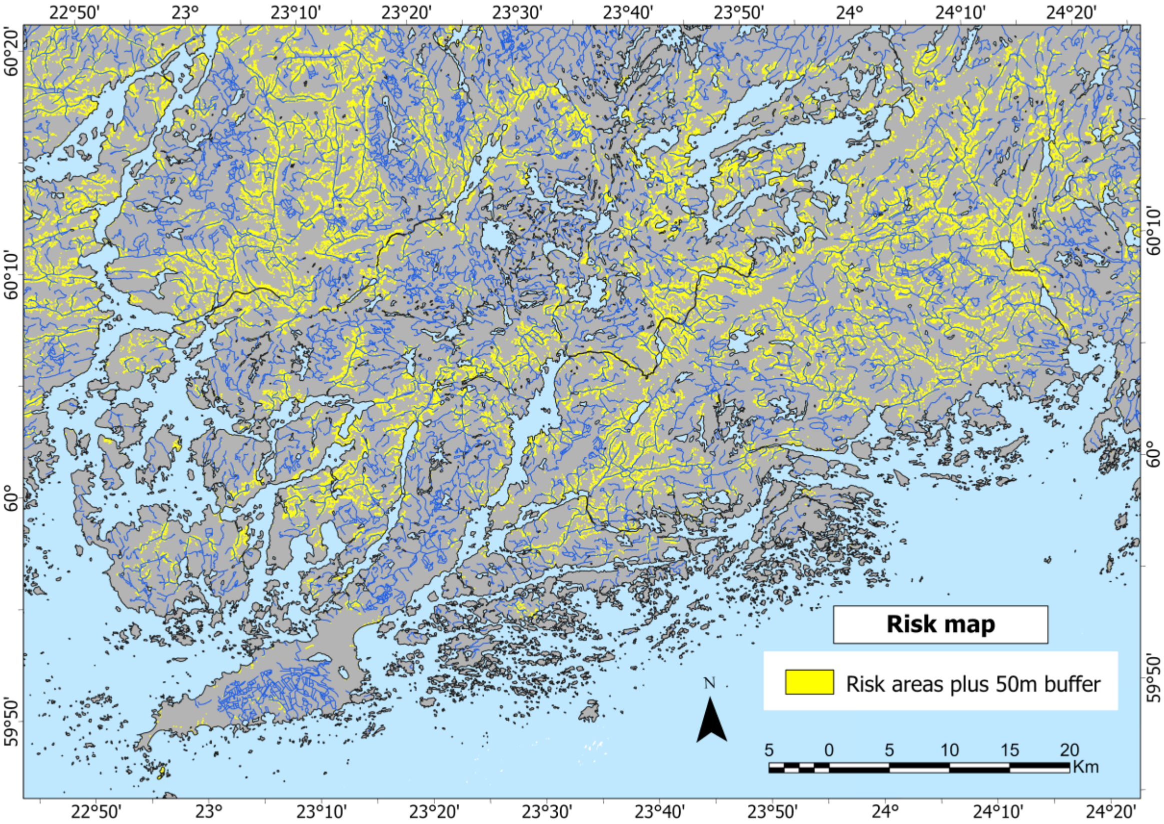


Fig.9. TSS and TP risk map with 50m buffer around risk areas for better visualization.

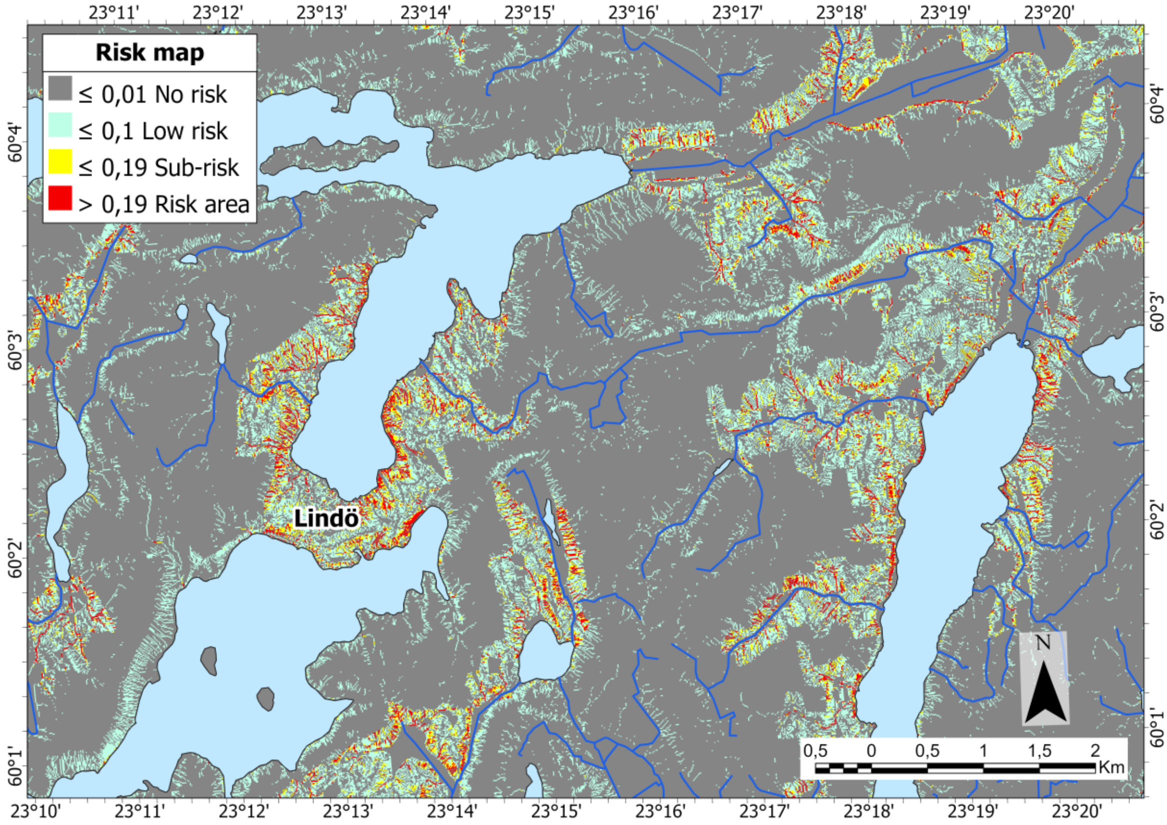


Fig.10. A risk map, showing a close-up of Lindö area with original symbology.

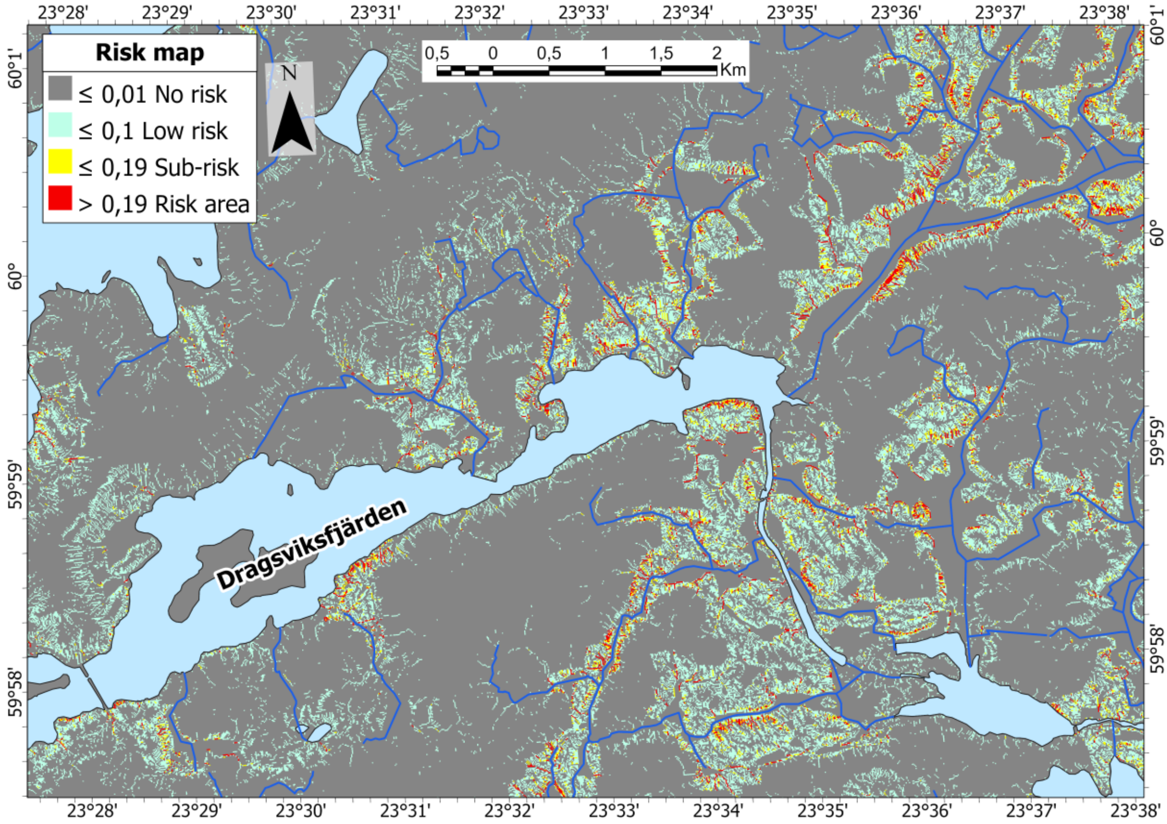
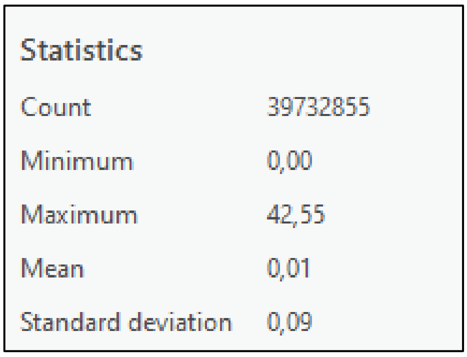


Fig.11. *A risk map, showing a close-up of Dragsviksfjärden area with original symbology.*



Statistics

Count	39732855
Minimum	0,00
Maximum	42,55
Mean	0,01
Standard deviation	0,09

Fig.12. Risk map raster statistics, acquired through ArcGIS Pro.

6. Discussion and suggestions for further research

The resulting runoff risk map for the total suspended solids (TSS) and total phosphorus (TP) loads was combined with the interpolated results for fDOM QSU and Turbidity FNU concentrations for June 2021 for the visual comparison.

In general, it is possible to conclude that the simplified USLE model shows good results for agriculture-dominated areas (Fig.13). This is an anticipated result as the coefficients in the model created by Sivertun and Prange (2003) were calculated for the area in Sweden (whose climatic conditions and ecosystem composition is not too different from Finland) with quite a lot of agricultural activities.

However, in Figure 14 it is possible to observe that there are basically no risk areas produced by the simplified USLE model with the used coefficients (very low weights assigned for forestry, for example), although, we can definitely see that the bay on the southern side of the Hanko peninsula (Täktbukten bay) receives a lot of runoff.

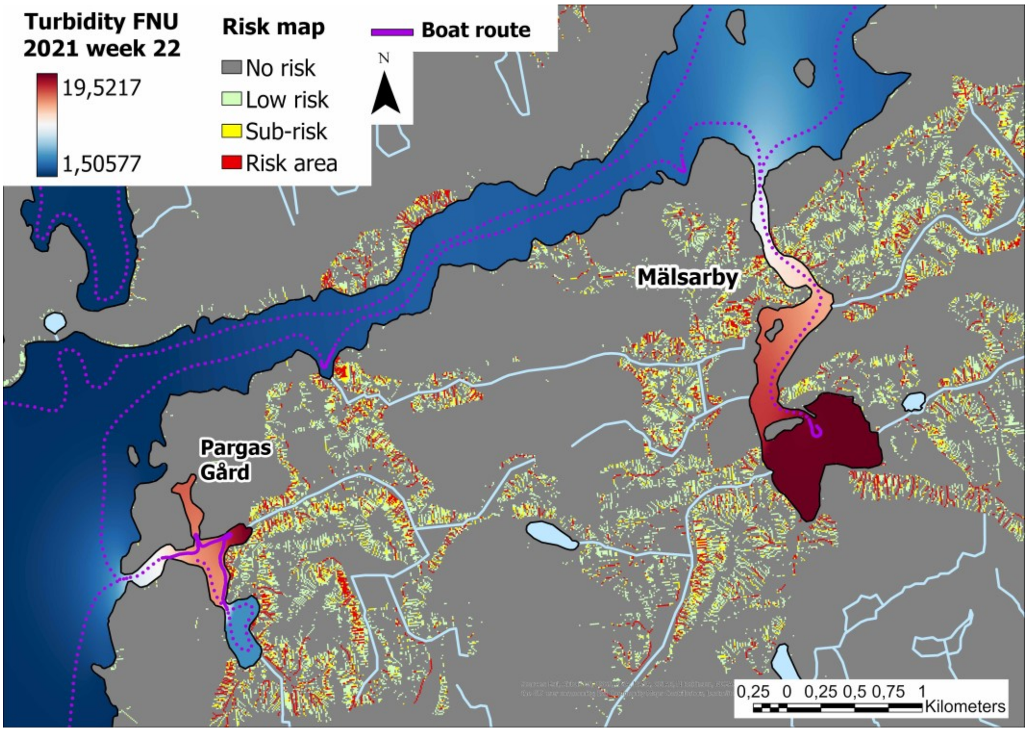


Fig. 13. USLE model with non-updated coefficients showing good results for agriculture-dominated areas.

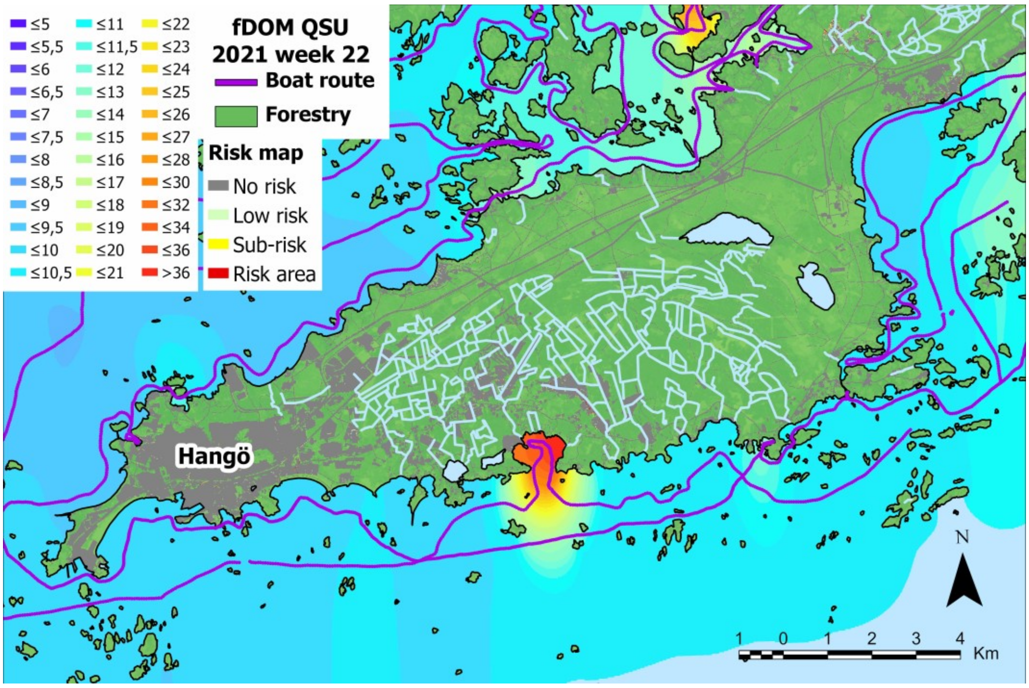


Fig.14. Täktbukten bay showing high and outstanding fDOM (QSU) values, presumably because of forestry activities.

However, as it was already said previously, the model does not calculate the exact amount of nutrient loading or sediment loss, it only assesses the risk of a specific area on land to influence water quality, considering its specific parameters (Sivertun and Prange, 2003). So, the actual pollution of specific water bodies will depend on the intensity of agricultural activities in the area, remediation practices that take place in this area, etc. Though, using the resulting risk map it is possible, for example, to redistribute the use of fertilizers or introduce more stringent thresholds for the use of fertilizers use for the identified risk areas.

Moreover, the quality of the resulting map fully depends on the resolution and accuracy of the data that is loaded to the model. The higher the resolution of Digital Elevation Map is – the more reliable Slope length factor map will be. The same goes for the rest of factor maps. In our case the weakest point is, probably, land use factor map, because it is based on CORINE Land Cover 2018 dataset, for which the thematic accuracy (mapped class compared to what was in reality on land) is ≥ 85% (Copernicus, 2020).

There are also some other restrictions for the model that are important to keep in mind. Firstly, the coefficients for the factor maps production are only valid for territories that have similar properties with the territories where these coefficients were obtained. In our case the coefficients were developed for the area in Sweden, which is morphologically very close to one in Finland. Otherwise, the coefficients need to be recalculated.

Secondly, the model is only true for the erosive part and not for the accumulative part of the slope (Sivertun and Prange, 2003). It is not possible to accurately calculate the material balance (erosion versus accumulation) with the standard algorithms (Schäuble, 1999), and complicated GIS implementations and special software are used for that purpose. However, such methods could be expensive, therefore for applied research and environmental management it is usually enough to have the results of simplified models that are cheaper and easier to execute.

7. Conclusion

Coastal areas vary a lot in their properties and pollution vulnerability level. A sheltered and shallow bay could be significantly different from a neighboring more exposed and deeper zone, however, they both would be considered coastal areas. Coastal areas are like a patchwork, not a uniform surface (Scheinin and Asmala, 2020). Therefore, it is quite difficult to identify the source of pollution from land, especially if it is diffuse terrestrial loading, which is a non-point source pollution.

Such models, like the described previously simplified USLE model, can contribute a lot to the identification of such non-point source pollution risk areas. A far-reaching benefit of creating a successful runoff risk model is that it could be easily applied in environmental management, highlighting potential problem areas, and allowing the distribution of resources and funding in cost-efficient manner. The actions on land should always be the first step, so the subsequent water bodies restoration and conservation projects will be successful. It is important to investigate the environmental drivers for the current state of marine ecosystems, however, this cannot be done if the sea is considered as an isolated domain without connections to land.

However, all models work better if the coefficients are created specifically for the area where the model is going to be applied for. These coefficients could be updated through water monitoring, and the accuracy of the coefficients will depend on the resolution of the monitoring. Therefore, high-resolution water monitoring with a flow-through system of sensors installed on a boat that can be driven through all small bays and flads – is a good solution for getting very precise datasets that could be used for different purposes, including the updating of runoff risk models.

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