Paludiculture in Estonia

Modelling of climate-smart management and utilization of peatlands required quantitaive spatial assessment of several GIS data layers, including map algebra, combining several data, distance analysis etc. We appled mostly raster-based modelling. To ensure sufficent spatial detail, while considering limited computer resources, the chosen pixel size was 1 are (10 x 10 m2).

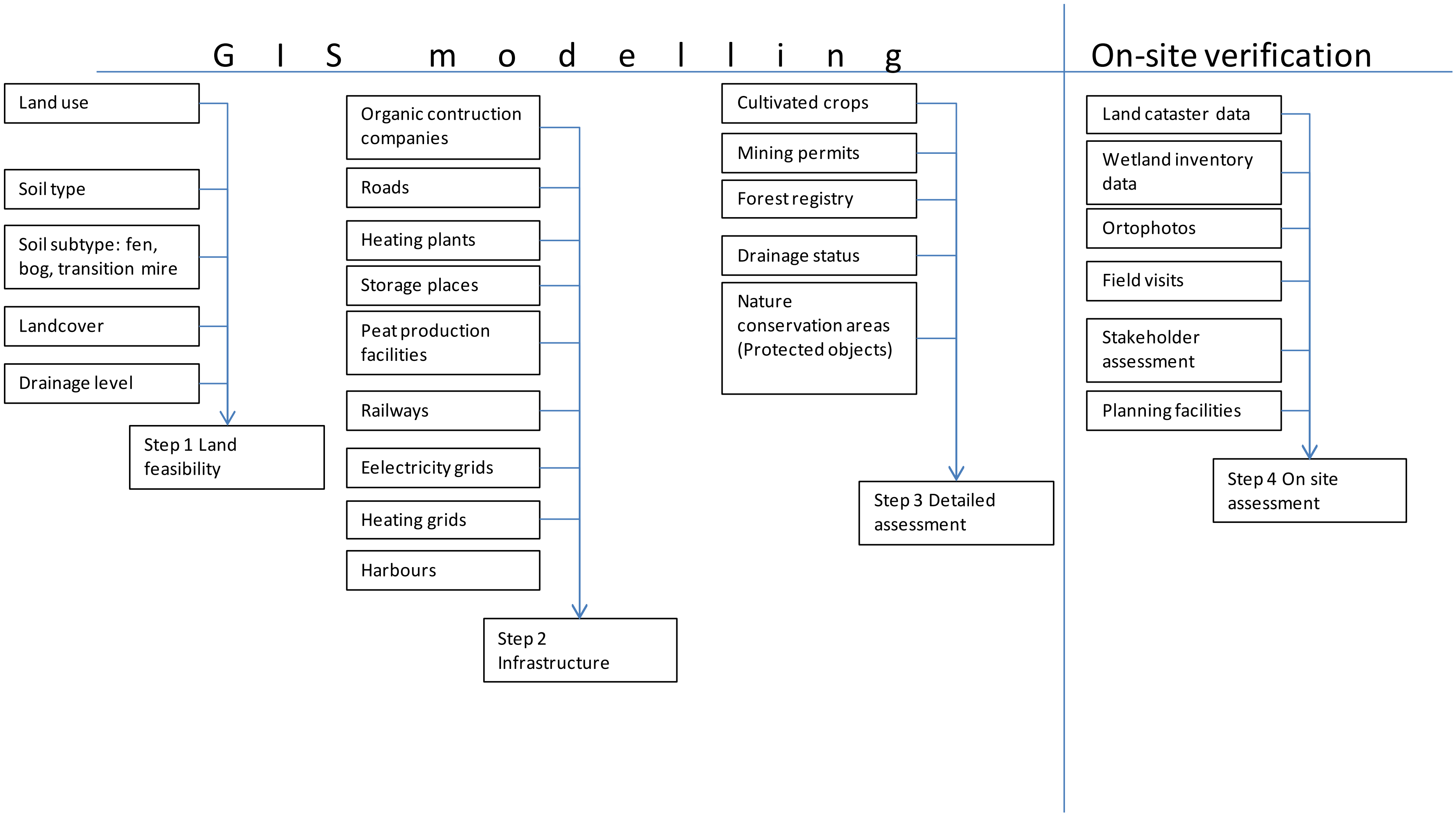
Processing of vector data. Meandering of streams was analysed, comparing the length of polylines (stream segments) with direct distance between endpoints of these segments. Such meandering was used to define ditches and related drainage effects.

Merge tool was used to integrate polygons from various Baltic countries. For instance, polygons indicating suitable areas for paludiculture („green" areas) in Lithuania was merged with corresponding Latvian and Lithuanian polygons. Similarly, other suitability classes were merged.

Spatial analyst tools. The model is a sequence of map operations, combining various data and parameters. The most usual operations are following.

- Conditional tools. These tools filter maps in relation to the quantitative values or quantitative terms. This is the most common approach to combine two datasets. For instance, it extracts agricultural peatlans from soil map and land use map.
- Distance tools. When analysing economic feasibility of paludiculture, distance from roads, heating houses and other infrastructure might be critical. Various distance tools, such as Euclidean and path distance, can indicate the ratio of economic feasibility.
- Cell statistics. From several map layers, minimum, maximum, mean, sum and other statistics were calculated. This enables, for instance, rating suitability of paludiculture against several criteria. We used cell statistics, for instance, to combine various types and subtypes of paludiculture suitability to one layer. The most common type of statistics was 'maximum'.
- Map algebra. Sometimes, an output map could be generated, resulting from an algebraic expression of one one more input maps. For instance, a predicted yield of Sphagnum biomass might be a complicated logarithmic equation, related to the thickness of peat layer and other environmental characteristics. Map algebra can solve these relationships.
- Focal statistics. It might be that an ecomomic feasibilty of Sphagnum farming depends on the volume of needed fuel in a given radius. For such cases, focal statistics can indicate the best sites. We used focal statistics to assess the vicinity of streams.
- Reclass. The GIS databases can have variable nomenclature and classification systems in different Baltic states. The model requires a uniform nomenclature over the entire area, describing landcover, land use, soils etc. For such uniformalisation, reclass tools can generate a required model input. We applied reclass to reclassify soils, land use classes, drainage rates and other variables for the model.
- Region group. Preselection areas were grouped to continuous regions where each region has a unique id and is spatially isolated from other regions. This enabled to assess zonal geometry and statistics.
- Zonal geometry. After the preliminary suitability assessment, each preselection site requires a sufficient surface area (for instance, just one are is not feasible). Determining that, zonal geometry was applied.

- Zonal statistics. To interprete model output, zonal statistics was used, for instance, to analyse the results through various administrative regions.


G I S modelling
On-site verification
Land use
Soil type
Soil subtype: fen, bog, transition mire
Landcover
Drainage level
Step 1 Land feasibility
Organic contruction companies
Roads
Heating plants
Storage places
Peat production facilities
Railways
Eelectricity grids
Heating grids
Harbours
Step 2 Infrastructure
Cultivated crops
Mining permits
Forest registry
Drainage status
Nature conservation areas (Protected objects)
Step 3 Detailed assessment
Land cataster data
Wetland inventory data
Ortophotos
Field visits
Stakeholder assessment
Planning facilities
Step 4 On site assessment

The most important qualitative links between input data and expected output is indicated in the above figure. In general, the assessment was divided to four sequential stages: (1) land feasibility, (2) infrastructure, (3) detailed assessment, and (4) on-site assessment.

Input data are mostly in vector format. These were mostly converted to raster to enable spatial analysis. For visualisation purpose, some output data were converted back to vector format: points and lines. For instance, centroids of proposed paludiculture fields make these areas well visible in the pan-Baltic map.

Step 1. Land feasibility

Conceptual model

Green: suitable areas

The final areas were sorted from preselection areas: each preselection area, exceeding 1 ha, was qualified as suitable. Those preselection areas were those which were suitable fields on drained wetlands but not in protected areas. Drained wetlands were those which fulfill one of three conditions: drained according to hydrographical assessment, drained according to wetland inventory, or drained according to infrastructure assessment. Hydrographiical approach was based on mostly stream and soil data. We assumed that each stream with width below 4m is a ditch if it is not sinuous. Sinuous is a stream with sinuosity rate lower than 0,95.

$$Sinuosity = \frac{\text{Distance between polyline endpoints}}{Polyline\ length}$$

Sinuosity rate is between 0 and 1 where higher number means lower sinuosity. Each ditch drains bog soils in the radius of 50 m, fen soils and transitional soils 100m, flood plain soils 120m. Peat mines were assumed working as ditches. Infrastucture assessment assumed that all land covered by areal drainage systems are drained. Finally, wetland inventory assumed that if drainage impact has set ’0’ then wetland is not drained, even if hydrographic or infrastructure assessment suggested differently. It means that wetland inventory did not expand by only decreased drained areas.

Green subtype 1: Areas of Paying Agency. Of various types of fields, suitable ones were field cultures and permanent grasslands.

Green subtype 2: Areas out from Paying Agency. Suitable fields were extracted from landcover map where category ’cultivated land’ was indicated. In the same time, Paying Agency fields were sorted out.

Yellow: fully suitable areas after careful consideration of restrictions

Yellow subtype 3: Exhausted peat mines. Exhausted peat mines were extraxted from landcover map. The minimum feasible area of each isolated patch is 1 ha.

Yellow subtype 4: Areas from peat mining longlist. The assessment results from „Green“ section was used to determine the rate of drainage in peat mining longlist. In Estonia, a priority list and a map layer of wetlands to be mined has been previously generated, containing 145 481 ha in 266 peat deposits.

This is referred here as 'longlist' because it contains peat to mine for many decades. The final areas were sorted from preselection areas: each preselection area, exceeding 1 ha, was qualified as suitable.

In addition to paludiculture assessment, we shortened the longlist by ranking all areas according to how much each is drained. We added the data of green networks, proposing that peat could be mined in the areas of less green networks and more drained soils. Many peat deposits in the longlist consist of several isolated polygons. In the assessment, rather comparing deposits we compared all those patches. As a result, the model proposes priority patches to mine which we call here „Shortlist".

Yellow subtype 6: Fields on drained wetlands, protected areas. In „Green" section, a part of fields were sorted out due to being located in protected areas. These areas were sorted to this „Yellow" subtype. However, target conservation zones were sorted out from here.

Orange: conditionally suitable areas after consideration of major restrictions.

This class has just one subtype.

Orange subtype 5: Forests on drained wetland soils. The final areas were sorted from preselection areas: each preselection area, exceeding 1 ha, was qualified as suitable. The assessment results from „Green" section was used to determine the rate of drainage in wetland soils. Landcover map indicated forestes. Preselection areas were those, overlapping forests and drained wetlands.

Red: Areas not suitable for paludiculture

This class has just one subtype.

Red subtype 7: target conservation zones. From the layer of protected areas, natural target conservation zones overran all other colors and types. In the Estonian administrative system, protected areas have softer 'restriction zones' and stricter 'target conservation zones'. The latter is divided between 'managed target conservation zones' and 'natural target conservation zones'. Any paluciculture in 'natural target conservation zones' is forbidden.


Land cover
Streams
Width < 4m; sinuosity: low
Ditches
Peat mines: active, abandoned
Ditch potential impact radius: 50m
Focal statistics
Open quarries
Bog soils
Soil existence
Soil type (repaired)
Fen soils, transitional soils
Ditch potential impact radius: 100m
Drained wetlands according to hydrography
Soil type
Floodplain soils
Ditch potential impact radius: 120m
Cultivated land
Inventory of wetlands: drainage impact
Drainage impact: more than 0
Drained wetlands according to inventory
One of three conditions
Paying Agency fields
No Paying Agency field
Drainage systems (areas)
Drainage systems: yes
Drained wetlands according to infrastructure
Cultivated land, no Paying Agency
Drained wetlands
Forest
Both conditions
Longlisted wetlands to be mined
Both conditions
Both conditions
Both conditions
Forest on drained wetlands
Paying Agency fields on drained wetlands
Fields on drained wetlands, no Paying Agency
Size: > 1ha
Paludiculture areas from longlist
5 Orange - forest on drained wetland soils
Reclass (filter): field cultures, permanent grasslands
Size: > 1ha
Include protected areas
6 Yellow - fields on drained wetlands, protected areas
Exhausted peat mines
Longlisted wetlands, exhausted peat mines cut out
Size: > 1ha
4 Yellow - areas from peat mining longlist
Suitable Paying Agency fields on drained wetlands
3 Yellow - exhausted peat mines
Green networks
Subtypes: [all]
Green networks
All conditions fulfilled
Exclude protected areas
Protected areas
Exclude protected areas
No green network
Shortlisted wetlands for peat mining
Drafted Paying Agency green areas
Category: target conservation zone
Drafted green areas, no Paying Agency
Zonal statistics
7 Red - target conservation zones
Zonal geometry
Area of suitable land within each Paying Agency field
Area of isolated zones
Size: > 1ha
Size: > 1ha
1 Green - areas of Paying Agency
2 Green - areas out from Paying Agency

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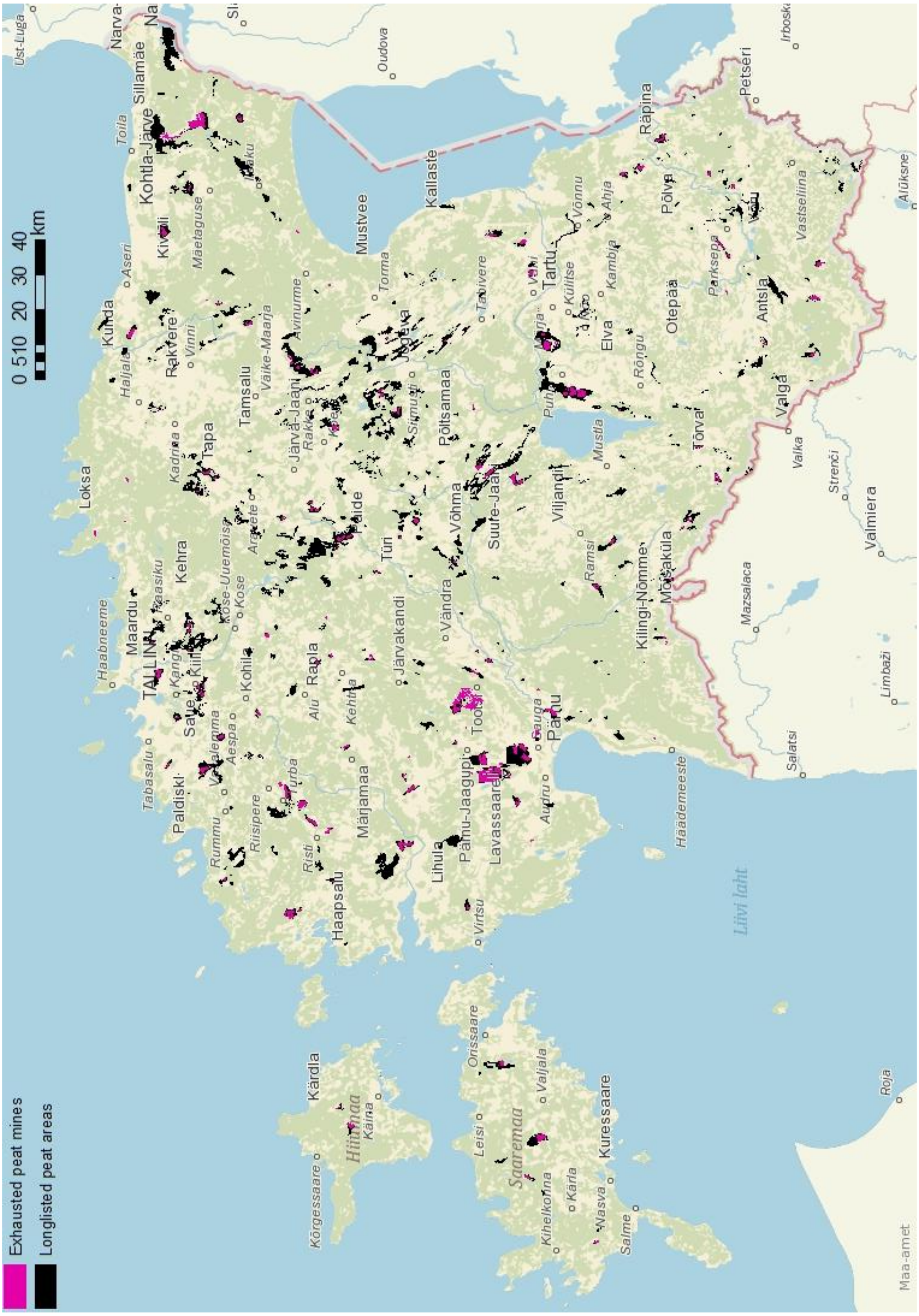
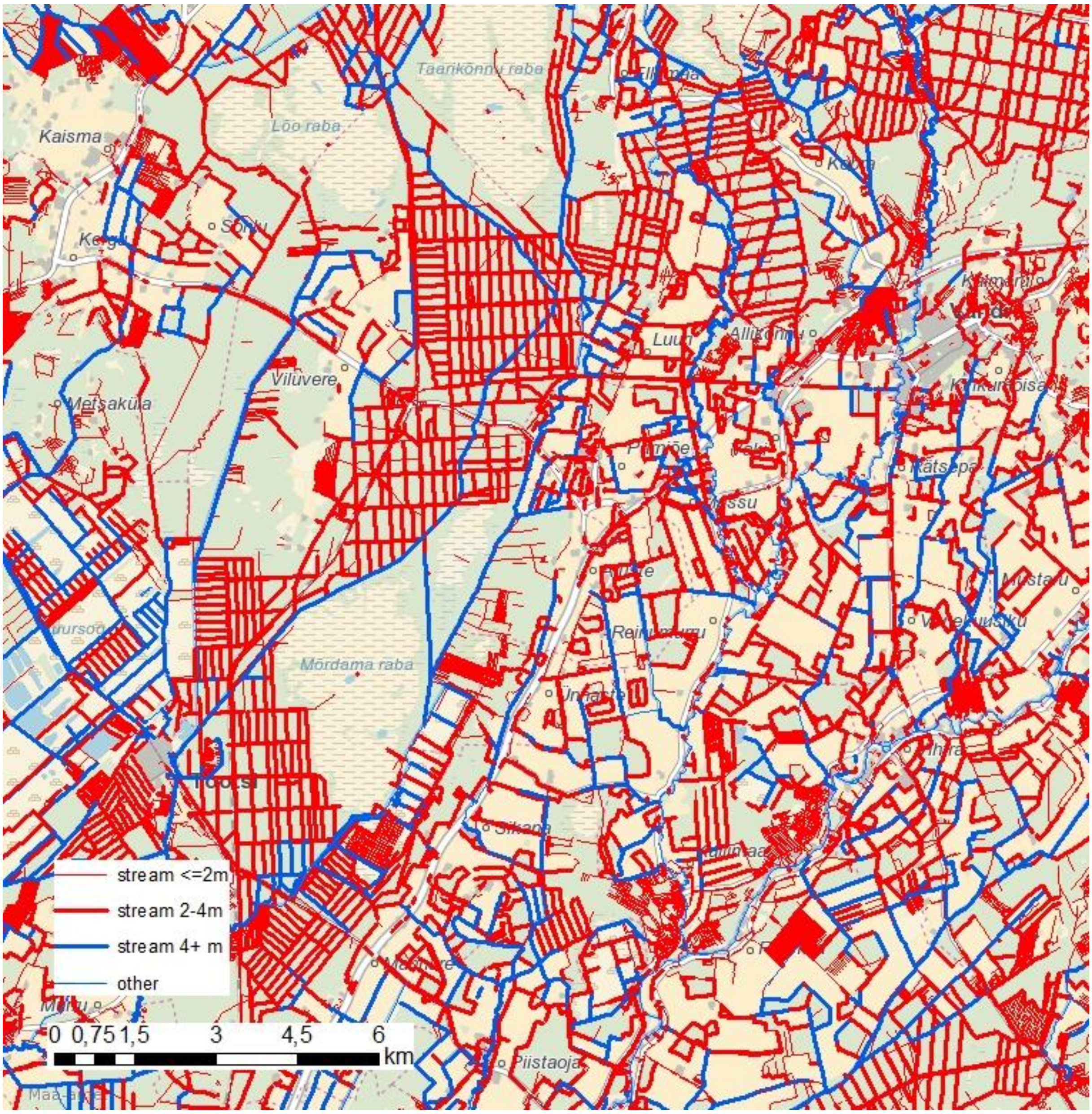
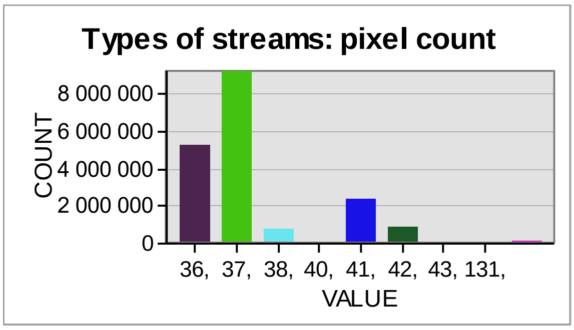

Exhausted peat mines
Longlisted peat areas
0 5 10 20 30 40 km
Maa-amet

Results

As there is no data distinguishing between ditches and natural streams, we had to apply a very rough assumption that all streams with width below 4 m are ditches. Obviously, this contains serious misclassifications. All small natural streams are misclassified as ditches while most channelised rivers are misclassified as natural streams.

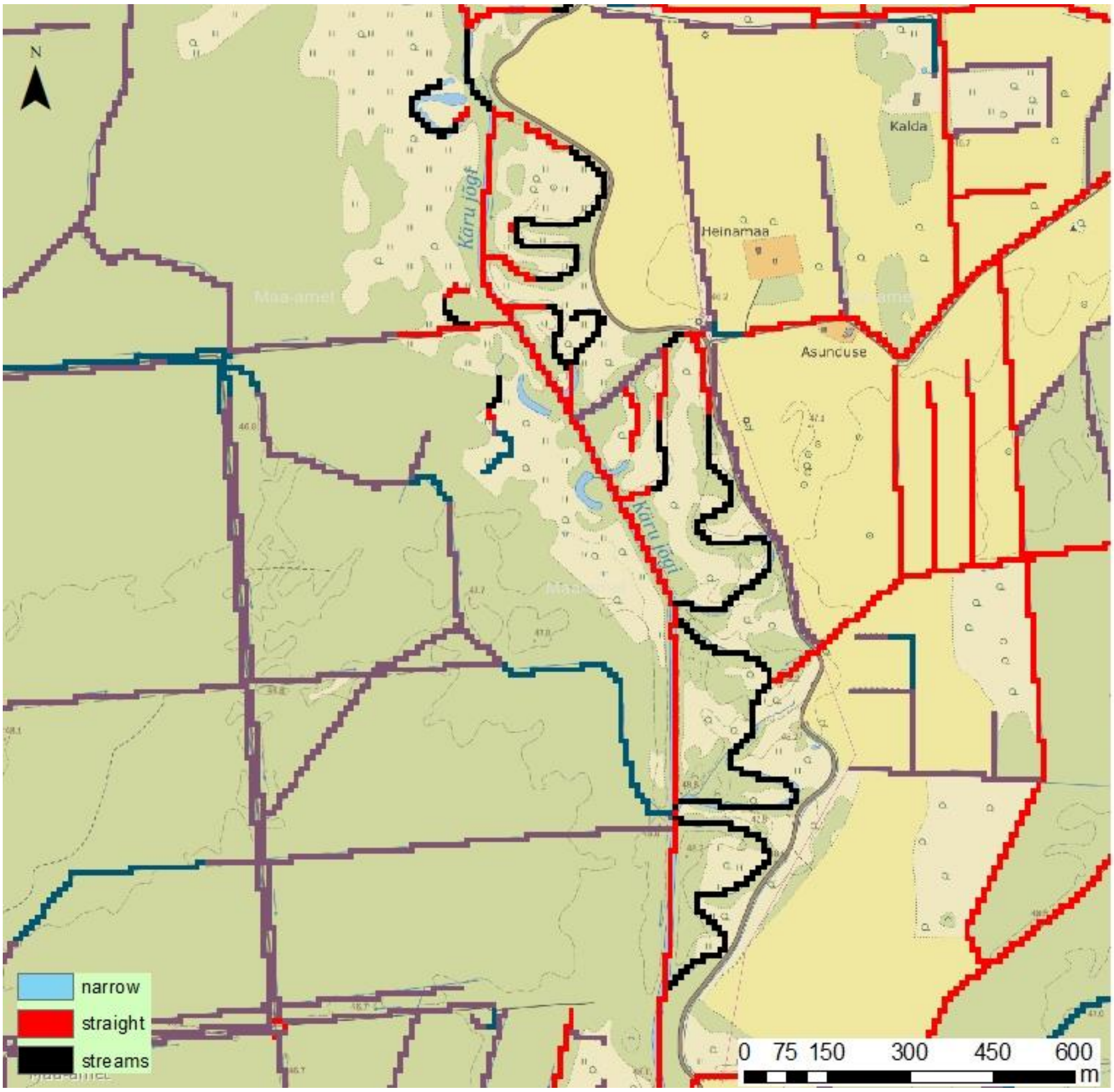


The most widespread stream type was in width 2-4 m.

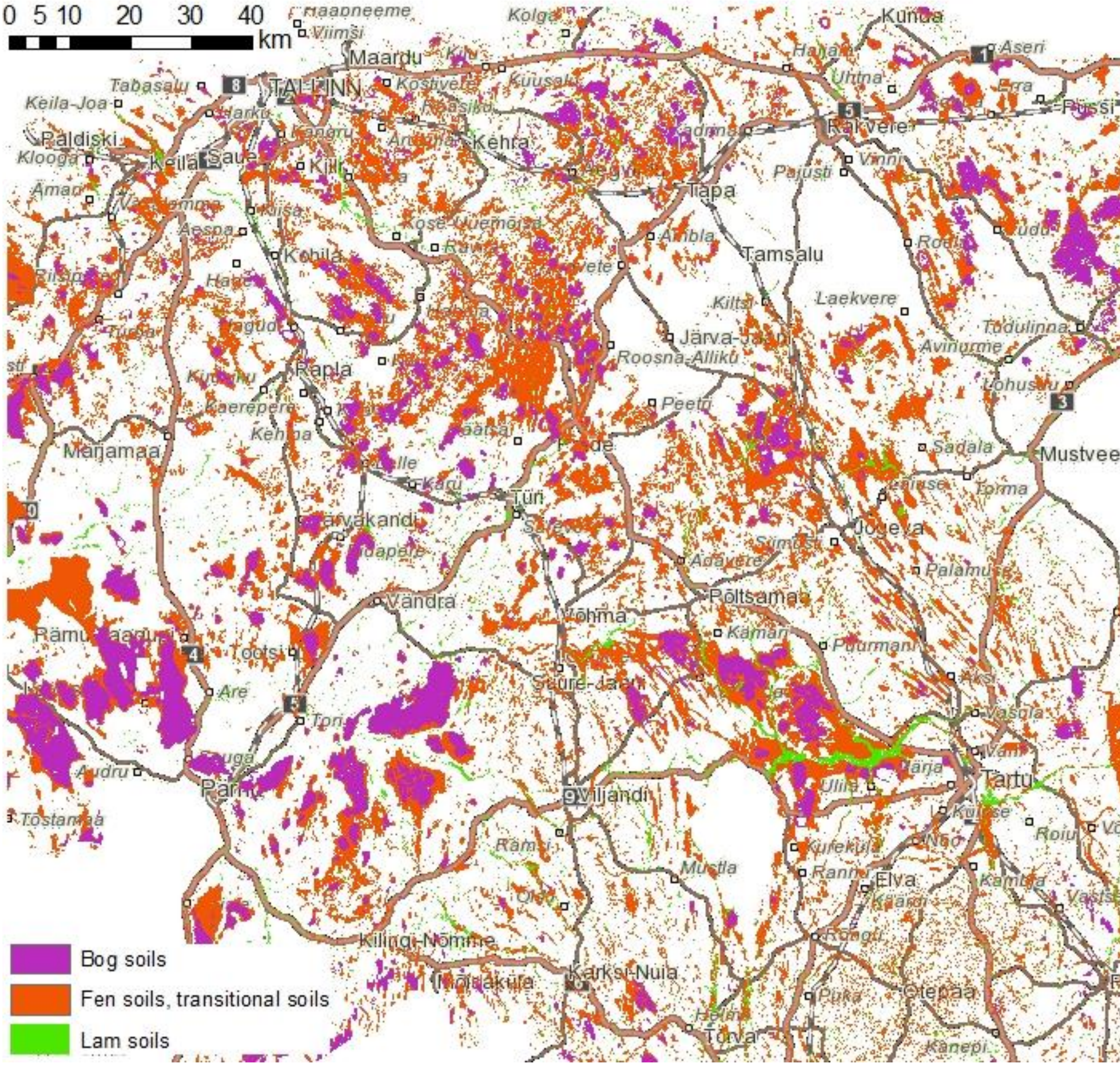


36 <=2m

37 2 – 4 m

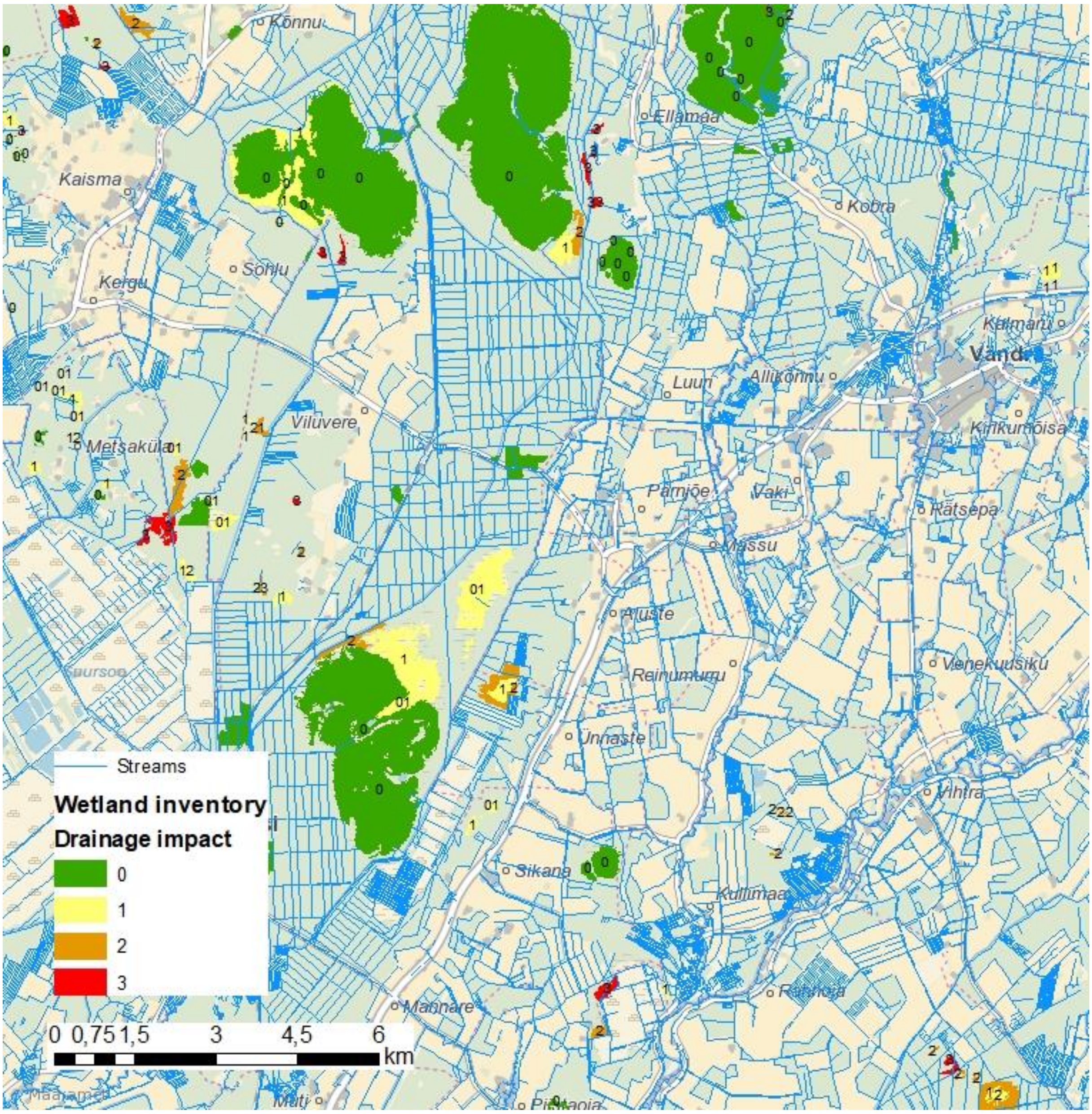


Most of the Estonian streams, according to the model, are both narrow and straight. Total number of 'streams' pixels was 19M. The number of 'narrow' pixels was 17M. The number of 'wide' pixels was 2M. The number of 'straight' pixels was 13M. The number of 'sinuous' pixels was 6M. The number of 'ditch' (both 'straight' and 'narrow') pixels was 10M.

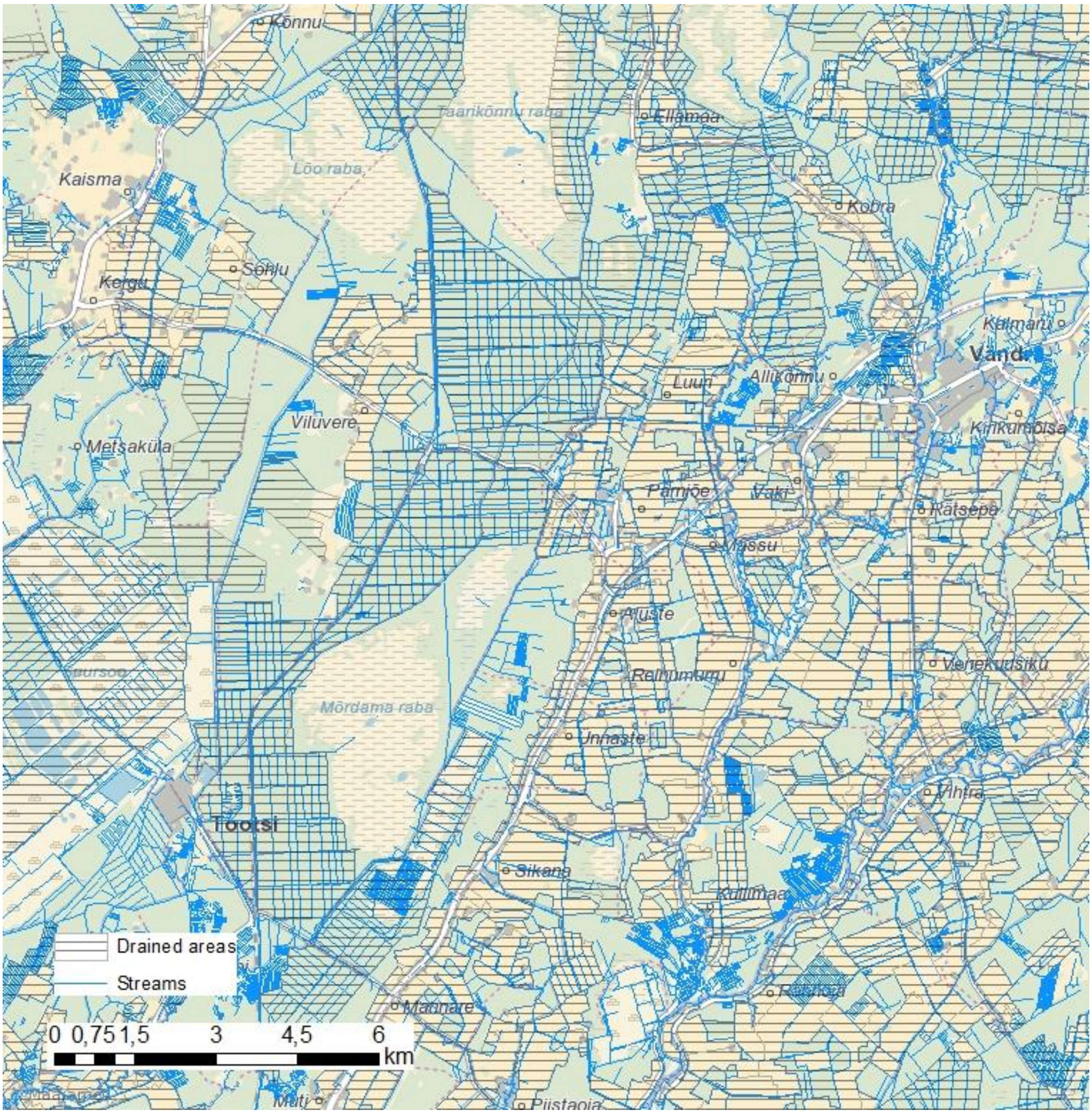


In total, landcover assessment elicitated 217 897 ha of peat soils, 734 007ha of fen and transitional soils as well as 60 440 ha of lam soils .

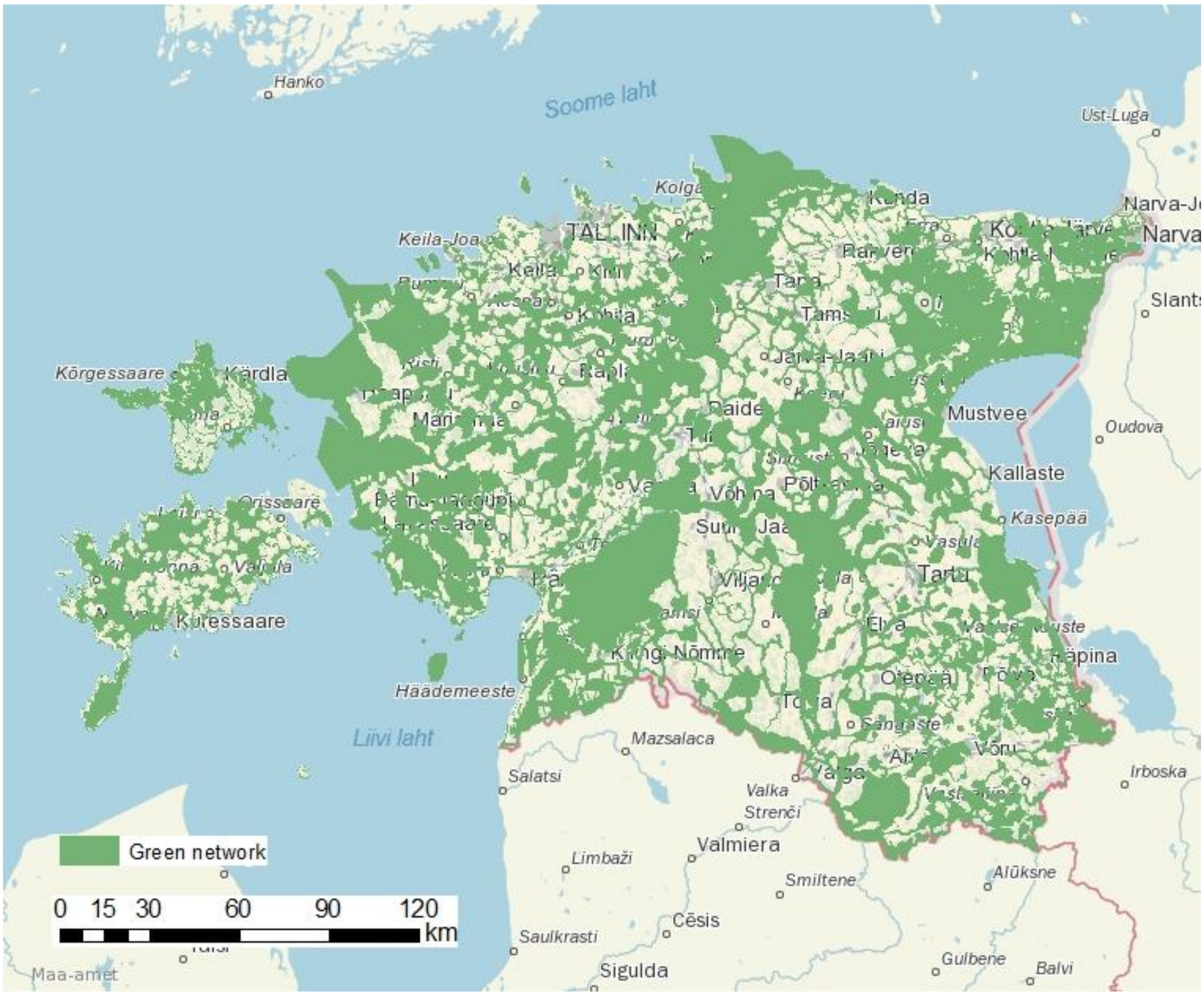
Total 473 362 ha of wetland soils have been drained by ditches. Areal drainage systems cover 644 120 ha of agricultural areas and 699 821 ha of forests.



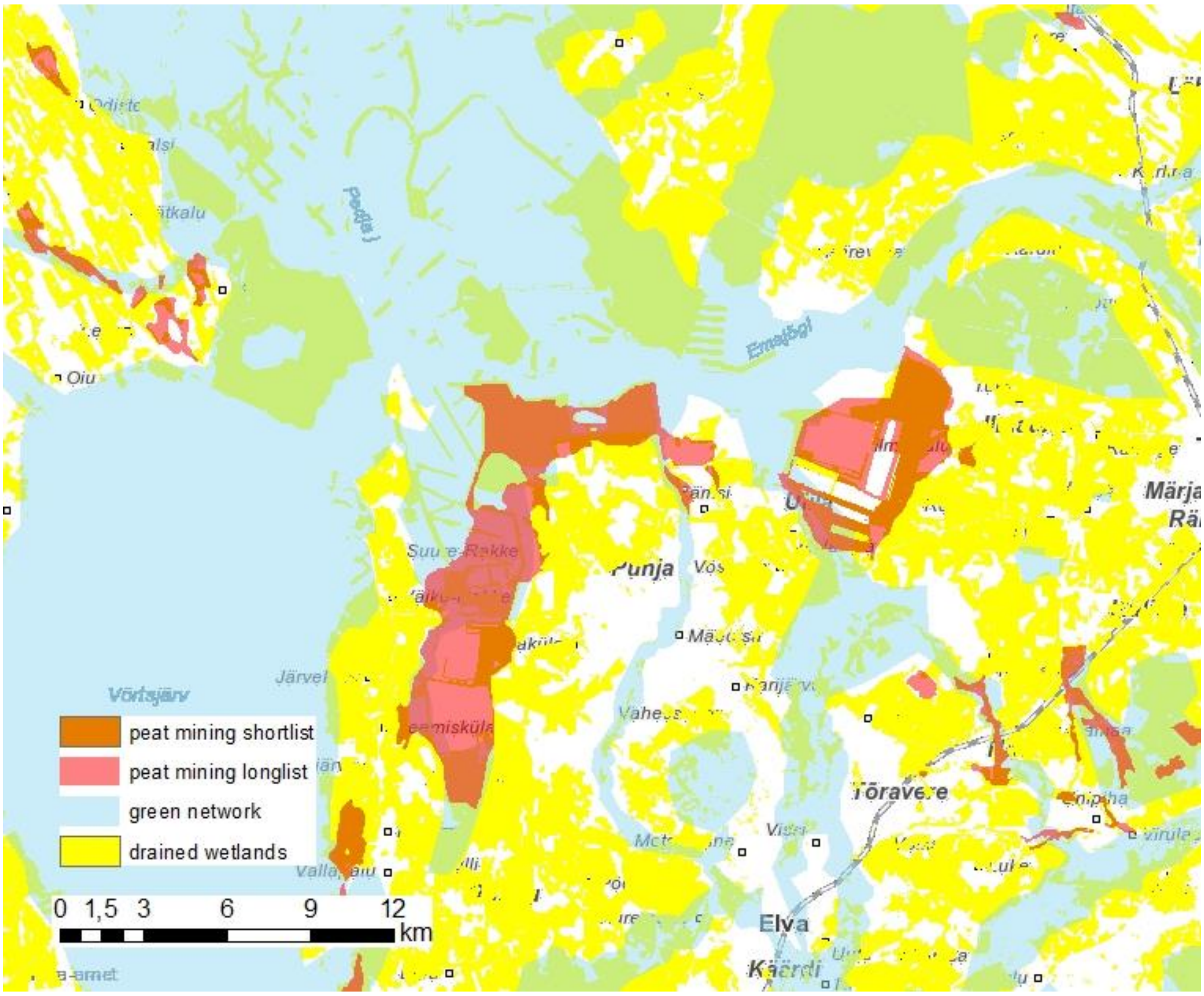
In total, ELF inventory has found 169 759 ha of wetlands as not affected by drainage while the remaining 98 414 ha as either affected or not assessed in that parameter.



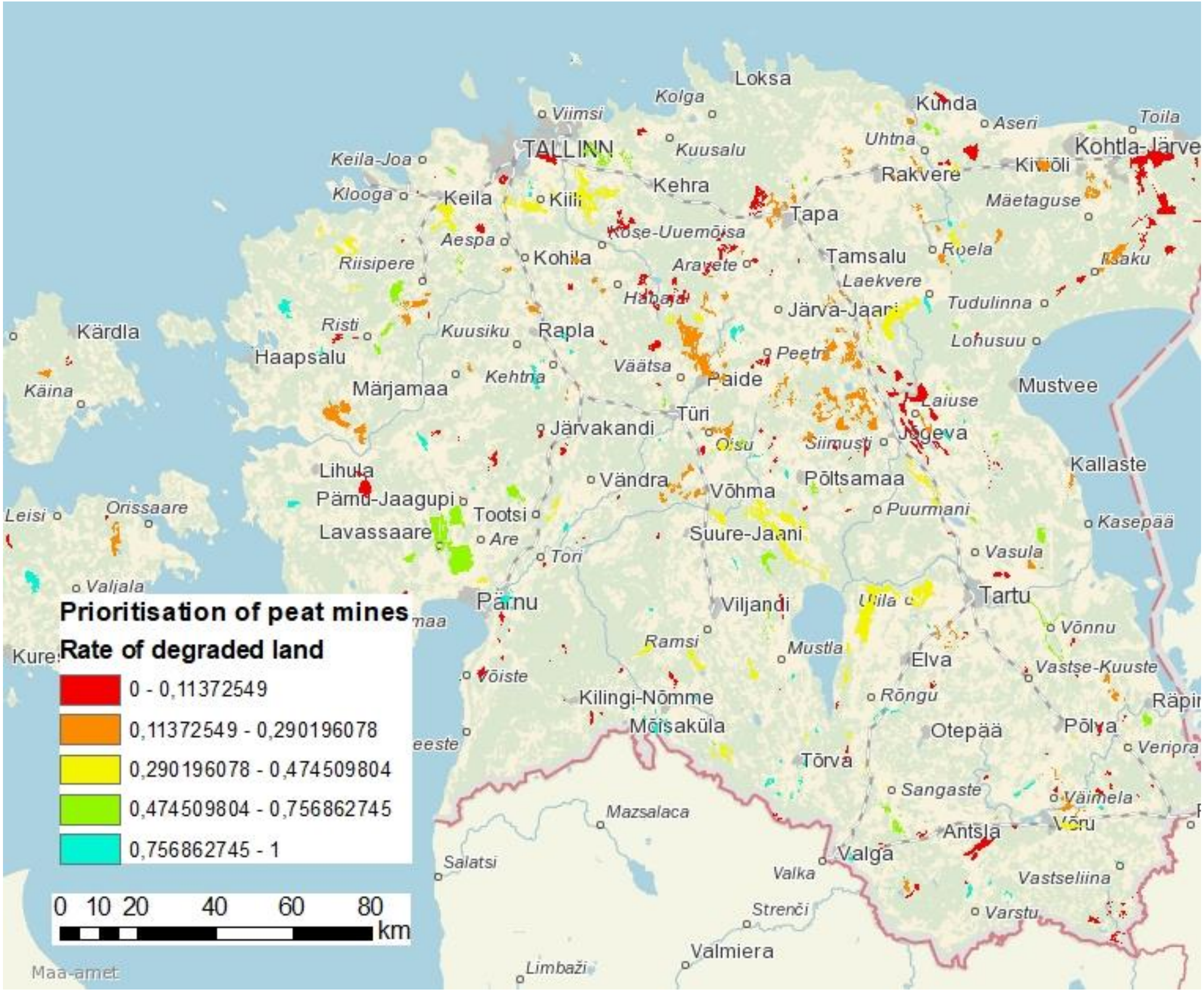
In total, 499 129 ha of wetlands were defined as affected by drainage.



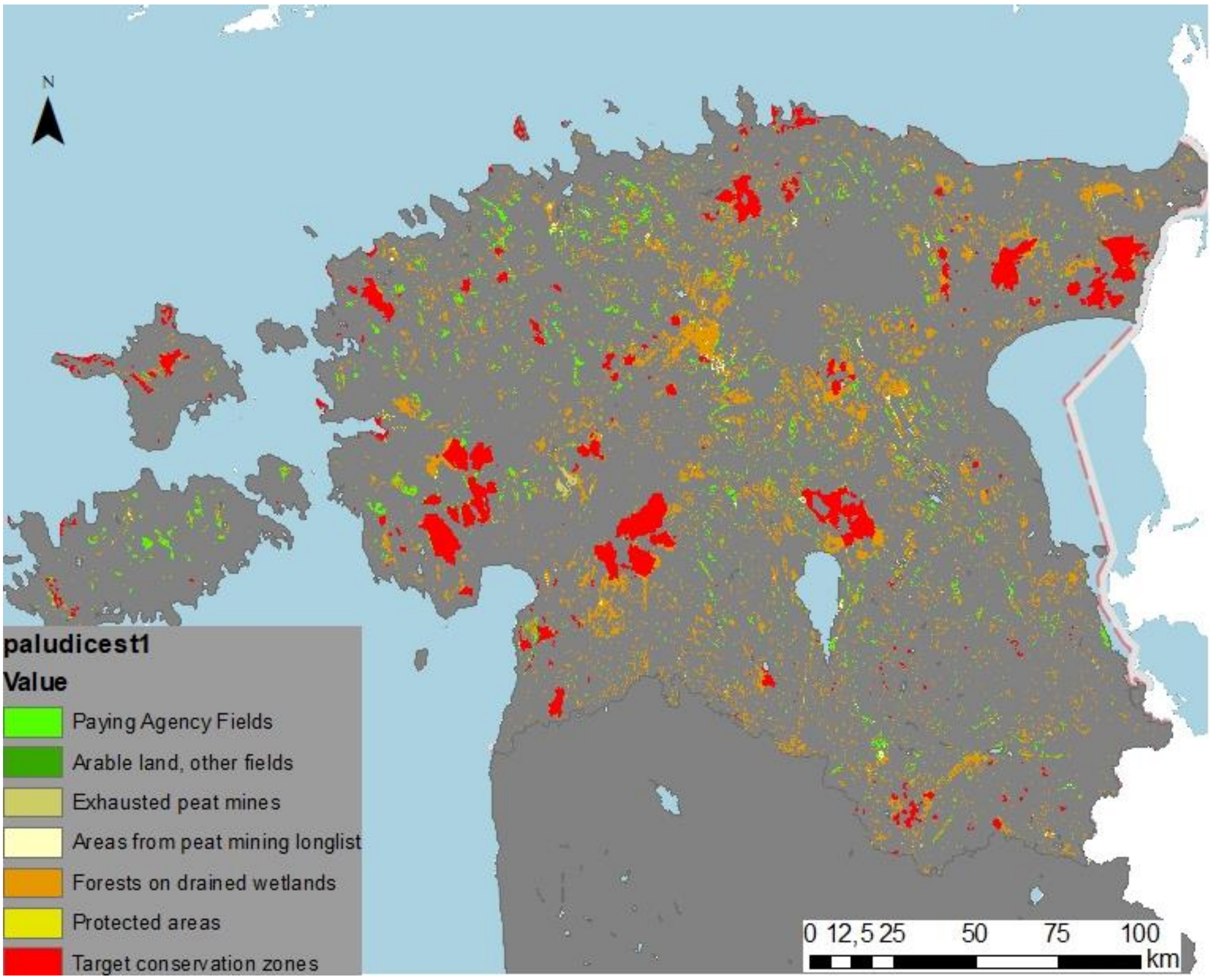
Green networks cover 2 495 358 ha.



Exhausted peat mines cover 5655 ha of land. Paludiculture areas from the longlist cover: 33 000 ha. Total area for the preselection for paludiculture is 38 650 ha.



From the peat mining ’longlist’ of 145 481 ha, just 27 634 ha was shortlisted for mining.



Color	Subcolor	Subtype code	Subtype name	Pixel count	Area, ha
Green	a: light green	1	Paying Agency fields	7405877	74 059
Green	b: dark green	2	Arable land, no Paying Agency	396973	3 970
yellow	a: lime yellow	3	Exhausted peat mines	556085	5 561
yellow	c: light yellow	4	Areas from peat mining longlist	563025	5 630
Orange	orange	5	Forests on drained wetlands	30383937	303 839
yellow	b: dark yellow	6	Protected areas	219015	2 190
Red	red	7	Target conservation zones	16701425	167 014