Paludiculture in the Baltics

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GIS Assessment report.

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Disclaimer

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Background

This study was conducted within a project of the European Climate initiative (EUKI) of the Federal Ministry for Environment of Germany (BMU) with partners from Germany, Estonia, Latvia and Lithuania and aimed at GIS based assessment of Peatland area suitable for the implementation for Paludiculture in the Baltic countries. The database compilation, GIS analyses, and ranking of readiness categories should support the selection of a potential paludiculture site in each Baltic country for compilation of preplanning documents in another activity of the Project. A generalised Pan-Baltic overview of readiness categories was envisaged as a base in policy consultation and decision making in Climate change mitigation and adaptation strategies and the reform process of the Common Agricultural Policy (CAP). Project partner Estonian Nature Fund (ELF) had the lead in coordination of the GIS teams in Latvia at Lake and Peatland Research Centre and Lithuania at Lithuanian Fund for Nature. The German Project lead, Michael Succow Foundation partner in the Greifswald Mire Centre, gave input from experiences with paludiculture potential assessment studies in Germany to set up the study design.

Common methodology

Before starting with analysis work a GIS database with relevant information for future implementation of paludiculture in the Baltic states was compiled in each country (see methodologies in Country sections). Analyses and integration of the available data, were processed to national overview maps for suitability for paludiculture. Teams in Estonia and Latvia had a more detailed approach discriminating 11 categories (see Estonian section and Latvian section sections). While in Lithuania a four category approach was used for national overview (see Lithuanian section). For a better general overview for all three Baltic countries, country approaches were harmonised and generalised to the Lithuanian four category approach resulting in a generalised Pan-Baltic map, indicating suitability of wetland areas for future paludiculture implementation in four colour classes (see Figure 32. Suitability of land for paludiculture in Estonia, Latvia and Lithuania):

- Green: suitable areas;
- Yellow: fully suitable areas after careful consideration of restrictions;
- Orange: conditionally suitable areas after consideration of major restrictions;
- Red: areas not suitable for paludiculture.

GIS analysis delivered polygons in ArcGIS. Technically, tables were therefore generated in the following way:

1. Polygons were generated in four colours: green, yellow, orange, red representing the suitability categories.
2. Dissolve tool was used to generalise polygons. Adjacent polygons, sharing a common border, were merged.

3. Deletion of small polygons. In case of green, yellow and orange areas, the size threshold was 1 ha. The Red category includes all polygon sizes.

A 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.

The assessment of wetland soils was carried out in four consequential steps (see Figure 1. Steps in spatial assessment of land suitability for paludiculture): (1) land assessment, (2) infrastructure assessment, (3) detailed assessment and (4) on-site verification. The above described colour codes resulted from national analyses following steps 1 and 2. Detailed description of assignment of sites to the different categories is described in the Country sections. Steps 3 and 4 were applied for selection of concrete paludiculture pilot sites for preplanning.

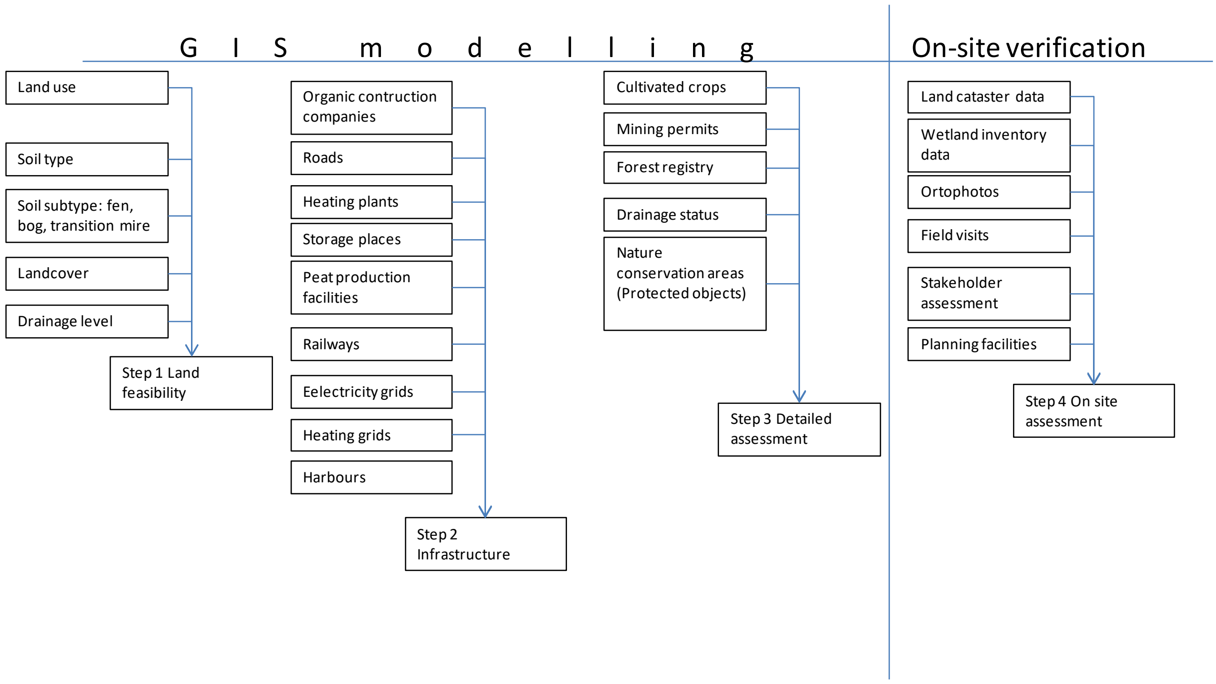


Figure 1. Steps in spatial assessment of land suitability for paludiculture

Estonian section

Methodology

Modelling of climate-smart management and utilization of peatlands requires quantitative spatial assessment of several GIS data layers, including map algebra, combining different data, distance analysis etc. We applied mostly raster-based modelling. To ensure sufficient spatial detail, while considering limited computer resources, the chosen pixel size was 1 pixel representing 10 x 10 m. Due to limited computational capacity, cost distance was analysed in 1 ha pixels.

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 if ditches are natural or artificial and inherently related drainage effects.

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

- Conditional tools. These tools filter maps in relation to the quantitative values or qualitative terms. This is the most common approach to combine two datasets. For instance, it extracts agricultural peatlands 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 logistic 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 more input maps. For instance, map algebra was used substituting missing data with zeros.
- Focal statistics. We used focal statistics to assess the vicinity of streams.
- Reclass. We applied reclass to reclassify soils, land use classes, drainage rates and other variables for our model.
- Region group. Preselection areas were grouped to continuous regions where each region has a unique ID-code and is spatially isolated from other regions. In that way zonal geometry and statistics were assessed.
- Zonal geometry. After the preliminary suitability assessment, each preselection site requires a sufficient surface area (for instance, just one are (10 X 10 m) is not feasible). Determining that, zonal geometry was applied.
- Zonal statistics. To interpret model output, zonal statistics was used, for instance, to analyse the results through various administrative regions.

In general, the assessment was divided to four sequential steps: (1) land feasibility, (2) infrastructure, (3) detailed assessment, and (4) on-site assessment (Figure 2. Modelling of paludiculture areas in Estonia, step 1 and Figure 3. Modelling of paludiculture areas in Estonia, steps 2, 3 and 4). We propose paludiculture primarily to drained wetland soils.

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

Figure 2. Modelling of paludiculture areas in Estonia, step 1

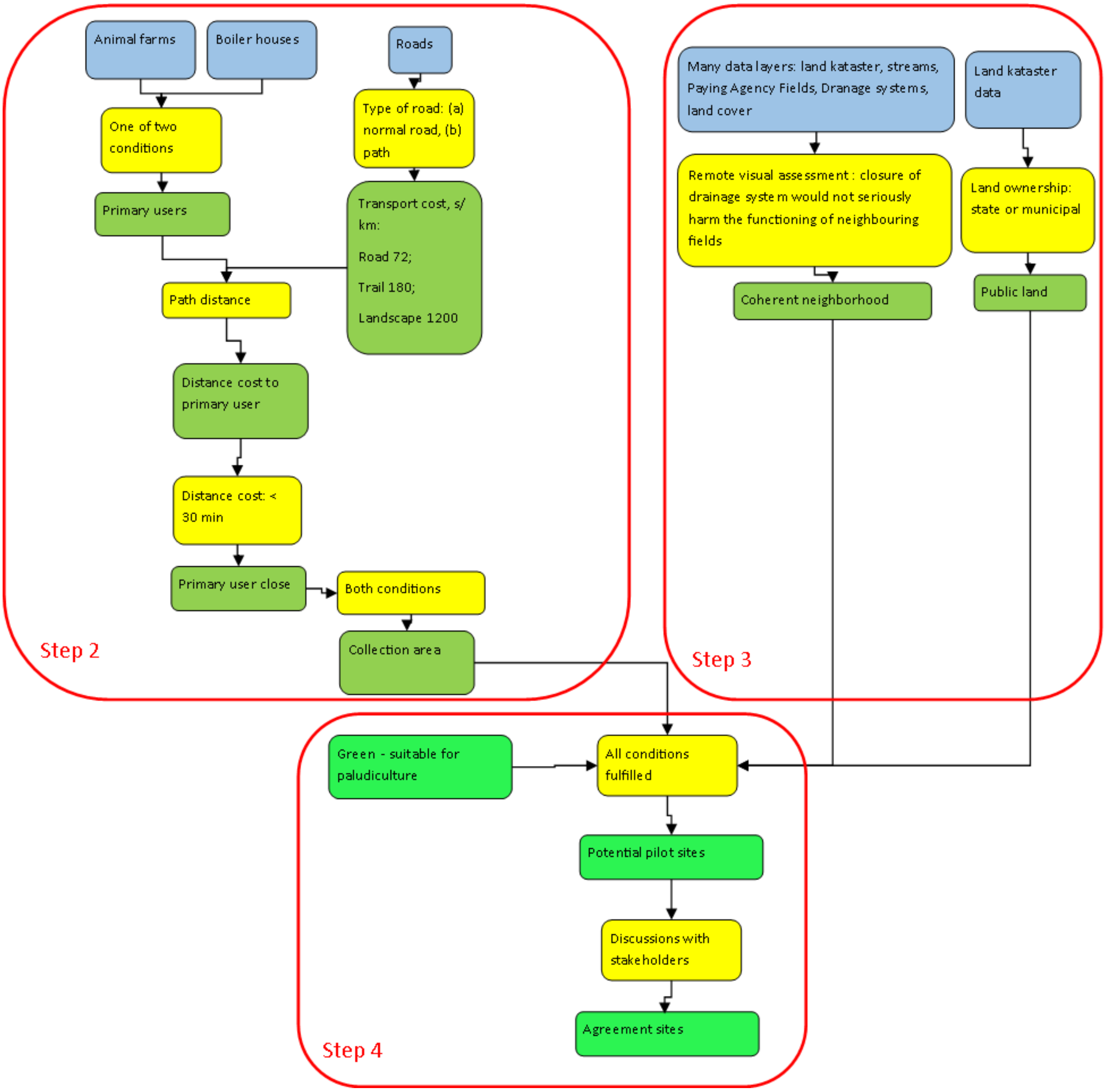


Figure 3. Modelling of paludiculture areas in Estonia, steps 2, 3 and 4

In order to maintain country specific information that seems to be relevant for a finer differentiation for future planning of paludiculture implementation in Estonia, each of the main four colour classes sets were divided into further which will be explained in detail in the next section.

General assessment was based on information provided in Table 1. Overview on specification of the discriminated 11 Sybtypes in Estonia and based on following assumptions.

- Each artificial ditch drains bog soils in the radius of 50 m, fen soils and transitional soils 100 m, flood plain soils 120 m (relevant soils are classified as peat soils which with at least 30 cm depth, soil map was provided by Estonian Land Board).
- Peat mines function as ditches.
- Land covered by areal drainage systems, identified in the infrastructure assessment, is assumed to be drained.

- Wetlands are not drained if the Estonian Mire Inventory[1] addressed drainage impact as ’0, even if hydrographic or infrastructure assessment suggested differently. It means that wetland inventory did not expand but only decreased drained areas.

In order to assess if a ditch is artificial or natural, a hydrographical approach was used – we assumed that each stream with width below 4 m is an artificial 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.

[1] Paal, Jaanus; Leibak, Eerik 2013. Eesti soode seisund ja kaitstus. Tartu: AS Regio. (*In Estonian:* State and protection of Estonian mires).

Table 1. Overview on specification of the discriminated 11 Sybtypes in Estonia

Subtype	No of Subtype	Drainage systems	Land cover	Paying Agency	Longlisted wetlands to be mined	Protection status
Paying Agency fields	1	Yes	-	Croplands, permanent grasslands	-	No
Arable land, no Paying Agency	2	Yes	Cultivated	No	-	No
Exhausted peat mines	3	Yes	Exhausted peat mine	-	-	No
Areas from peat mining longlist	4	Yes	-	-	Yes	No
Forests on drained wetlands	5	Yes	Forest: trees, bush, young trees	-	-	No
Protected areas	6	-	-	-	-	Restriction zones
Target conservation zones, natural	7	-	-	-	-	Target conservation zones, natural develop-ment
Target conservation zones, managed	8	-	-	-	-	Target conservation zones, managed
Forests on wetlands, not drained	9	No	Forest: trees, bush, young trees	-	-	No
Existing paludifarms	10	No	-	Yes	-	-
Other wetland soils	11	-	-	-	-	-

Land feasibility for paludiculture development under different classes

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 peat soils but not in protected areas. Drained peat soils were those which fulfilled one of three conditions: drained according to hydrographical assessment, drained according to wetland inventory, or drained according to infrastructure assessment (Table 1. Overview on specification of the discriminated 11 Sybtypes in Estonia).

Green subtype 1: Paying Agency fields. Of various types of fields, suitable ones were croplands and permanent grasslands where land management is supported via different agricultural subsidies based on data from Estonian Agricultural Registers and Information Board (Paying Agency). Total area under this land use class 72 712 ha (Table 3. Suitability for paludicultures Subtype classes and their total area in Estonia).

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. Total area under this land use class 3 877 ha.

Yellow: fully suitable areas after careful consideration of potential restrictions:

Yellow subtype 3: Exhausted peat mines. Exhausted peat mines were extracted from landcover map. The minimum feasible area of each isolated patch is 1 ha. Exhausted peat mines cover 5 492 ha of land and their location is provided at Figure 4.

Yellow subtype 4: Areas from peat mining longlist. The assessment results from the rate of drainage in peat mining longlist[2]. In Estonia, a list of potential areas and a map layer of peatlands for peat mining has been previously generated, containing 145 481 ha in 266 peat deposits (Figure 4.). This is referred here as 'longlist' because it contains peat for mining 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[3], proposing that peat could be mined in the areas of less green networks and more on 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, our model proposes priority patches for mining which we call here „Shortlist". This covers 24 457 ha.

Yellow subtype 6: Fields on drained peatlands in protected areas. In „Green" section, 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 (presented under red subtype).

[2] list of peatland for potential mining based on legal act by Ministry of Environment (2017)
[3] Green Network and Estonian Soil Map (Estonian Landboard)

Orange: conditionally suitable areas after consideration of major restrictions.

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 forests. Preselection areas were those, overlapping forests and drained wetland soils.

Red: Areas not suitable for paludiculture

Red subtype 7: Natural target conservation zones. From the layer of protected areas, natural target conservation zones overrule all other colours 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 paludiculture in ’natural target conservation zones’ is forbidden.

Red subtype 8: Managed target conservation zones. Any economic activity in such zone is forbidden except those defined in the management plan. Usually, these are related to the restoration and maintenance of semi-natural habitats. Normally, paludiculture should not be allowed there. However, traditional forms of paludiculture (e.g. making hay in flood plain etc.) might be supported there.

Blue: Possibly already existing paludiculture areas. The idea is that if a wetland soil is not drained while it is managed, it might indicate an existing paludiculture. This class has two subtypes.

Blue subtype 9: forests on wetlands, not drained. Landcover map indicated forests. Preselection areas were those, overlapping forests and wetland soils while not affected by drainage. Unfortunately, there is no GIS data on the management of forests. Normally, forests on wetland soils are hard to manage if the land is not drained. However, if this is the case, then there might exist „paludiforestry“.

Blue subtype 10: existing paludifarms. If wetland soil is not affected by drainage and it receives support from paying agency, then our model predicts it as an existing paludiculture farm. However, a detailed assessment has indicated that most of such paludiculture farms are actually modelling errors due to improper classification of streams.

Grey (subtype 0): other wetland soils. When not qualifying to any above mentioned class, wetland soil was coloured grey. Normally, such areas are not suitable for paludiculture while these are not protected either.

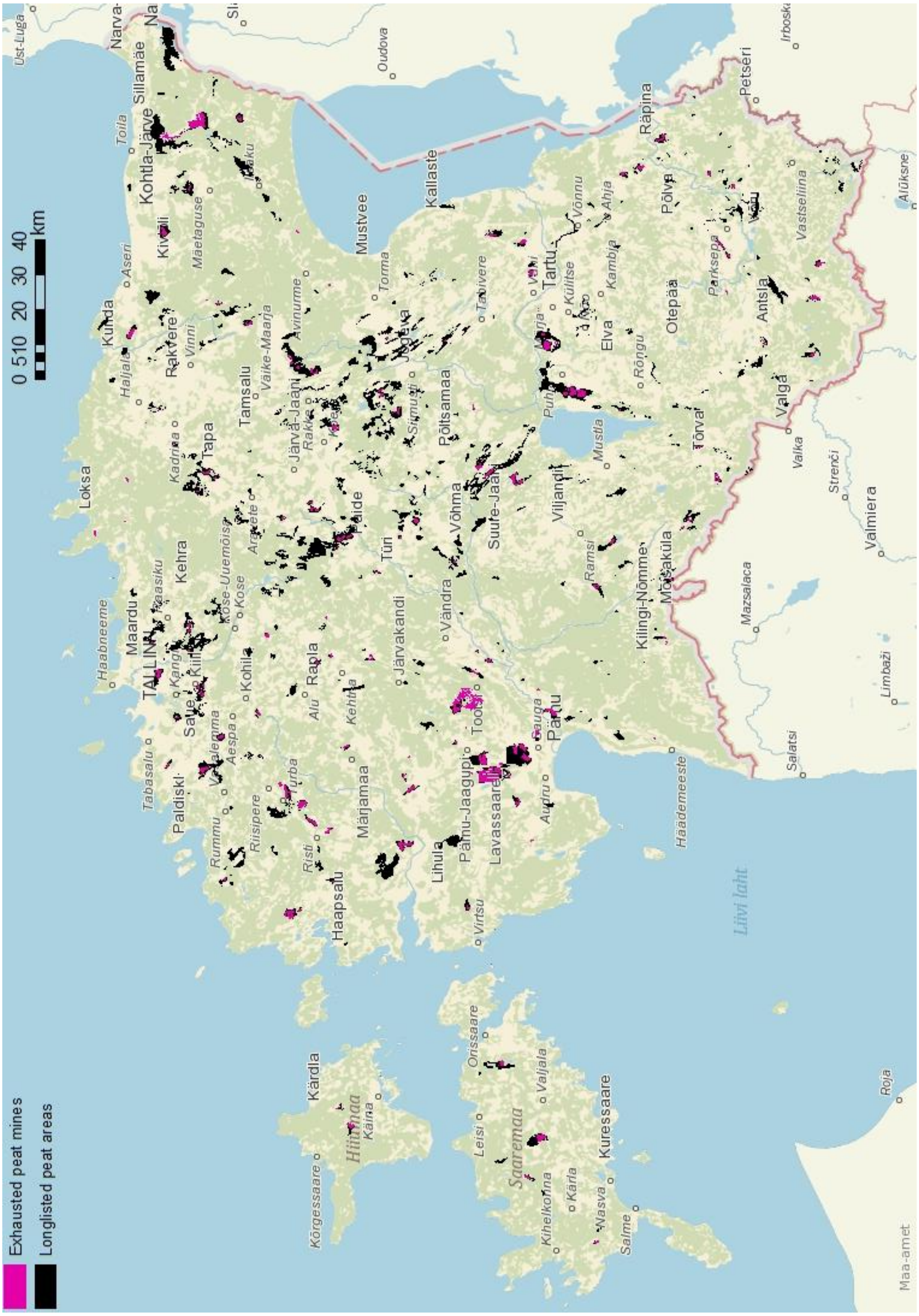


Figure 4. Past and future peat mining in Estonia

Methods to determine extent of drainage

A central question in spatial assessment is if peat a soils are affected by drainage or not. In order to do so hydrographical approach was used which allowed to assess the qualities and extent of the impact of artificial drainage system.

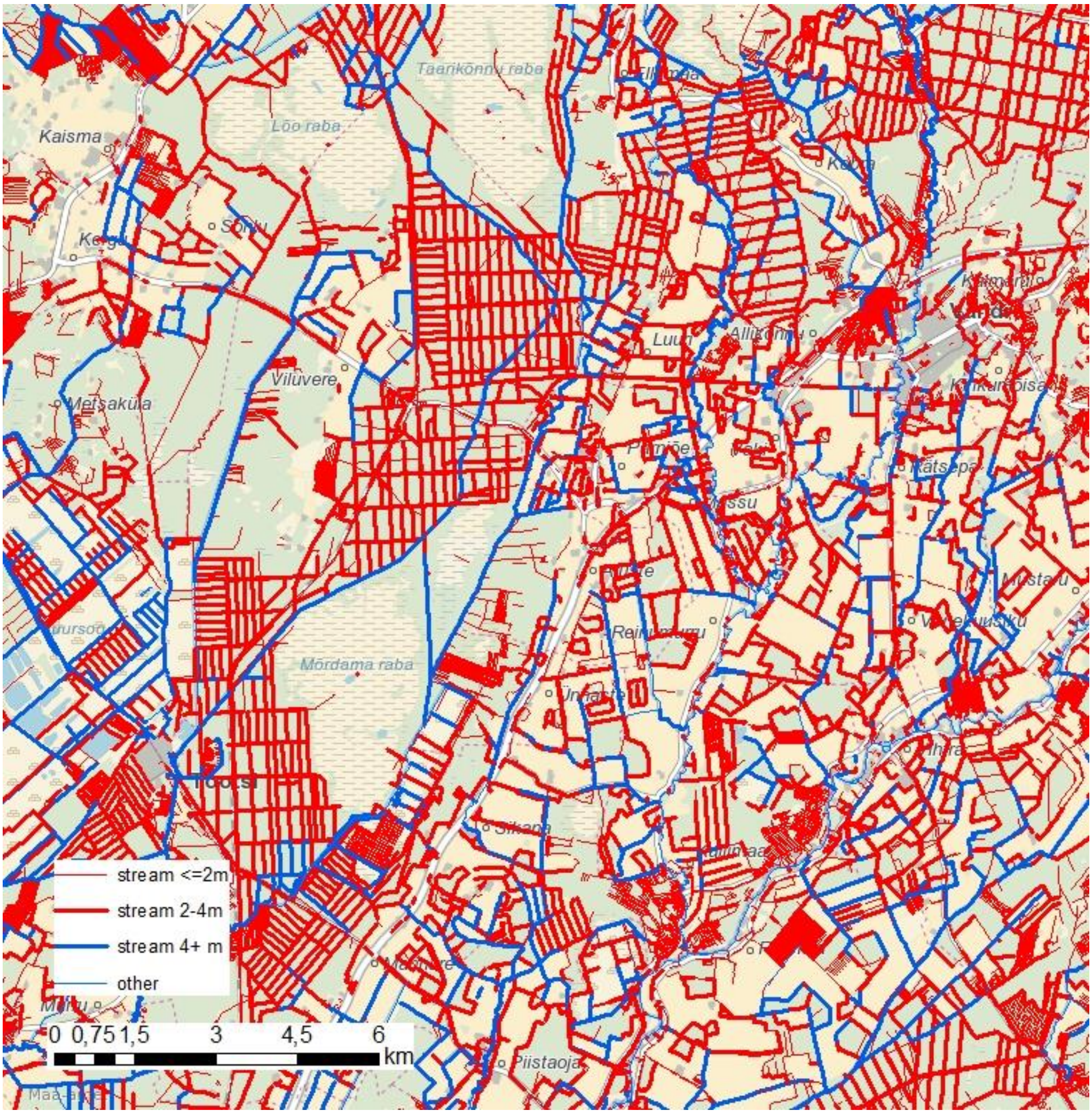
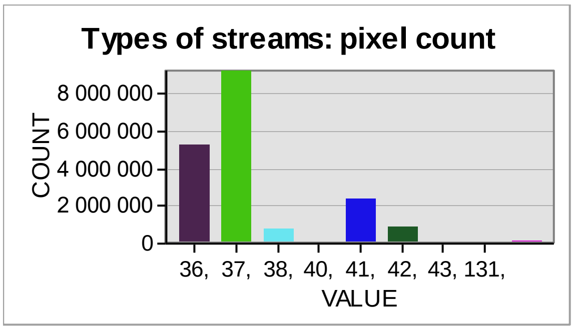


Figure 5. Width of streams in Estonia

The most widespread stream type shows width class 2-4 m (Figure 5. & Figure 6.).



36 <=2m
37 2 – 4 m

Figure 6. Spatial prevalence of various streams in Estonia according to width

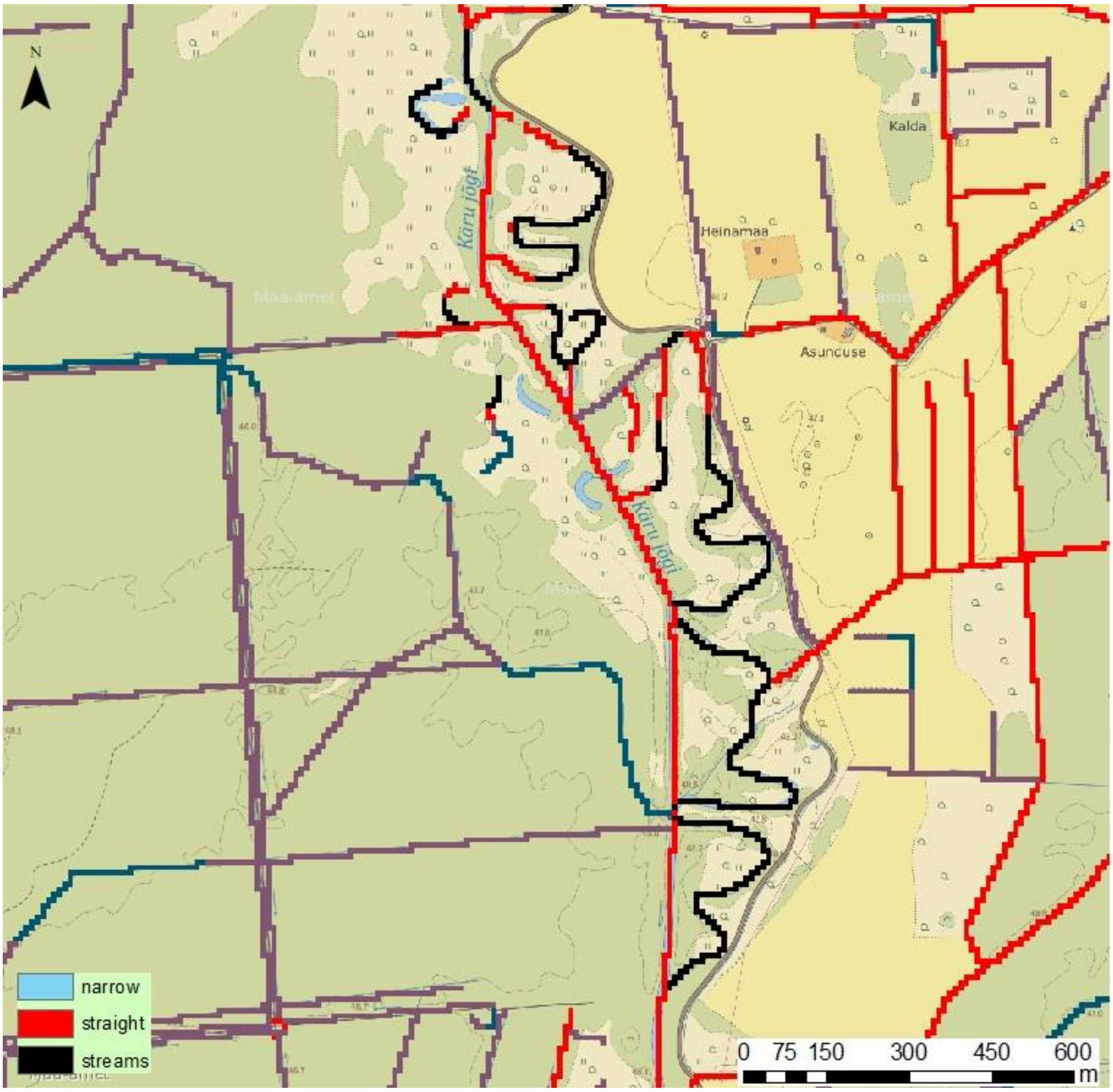


Figure 7. Sinuosity of Estonian streams

Most of the Estonian streams, according to our model, are both narrow and straight (Figure 7.). Total number of ’streams’ pixels was 19 mln, including 17 mln pixels of ’narrow’ and 2 mln of ’wide’ pixels.

The number of ’straight’ pixels was 13 mln and ’sinuous’ 6 mln. The number of ’ditch’ (both ’straight’ and ’narrow’) pixels was 10 mln.

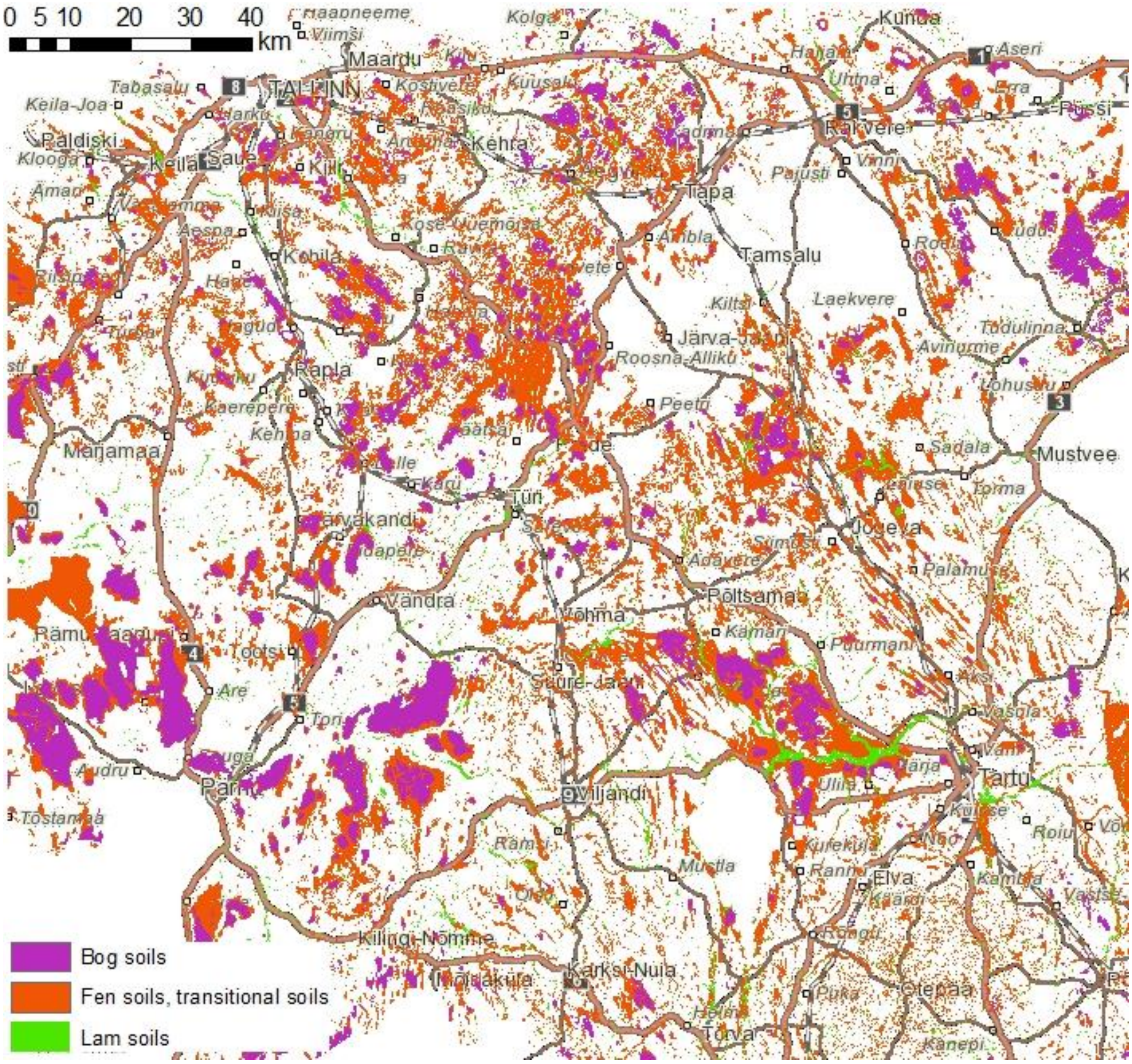


Figure 8. Peat and lam soils in Estonia

In total, landcover assessment differentiates 217 897 ha of bog soils, 734 007 ha of fen and transitional soils as well as 60 440 ha of lam or flood plain soils (Figure 8).

Figure 9. Impact of ditches to wetland soils in Estonia

Areal drainage systems cover 644 120 ha of agricultural areas and 699 821 ha of forests on all soil types in Estonia. Based on the results of GIS analyses, in total 473 362 ha of peat soils have been drained by ditches (Figure 9.).

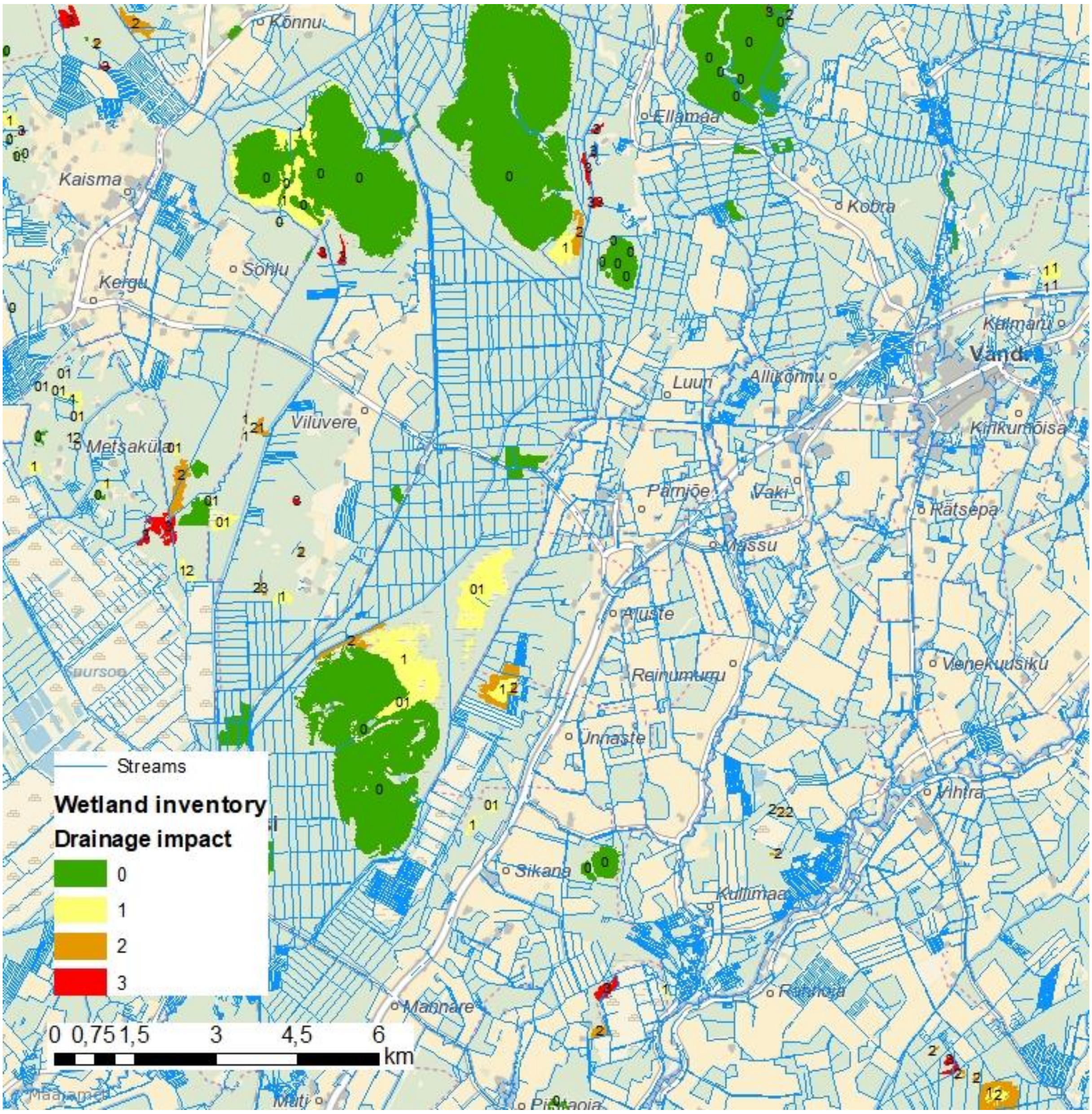


Figure 10. Status of Estonian wetlands according to drainage

Based on the results from Estonian Mire Inventory, we identified that 169 759 ha of wetlands are not affected by drainage while the remaining 98 414 ha is either affected or not assessed in that parameter (Figure 10.).

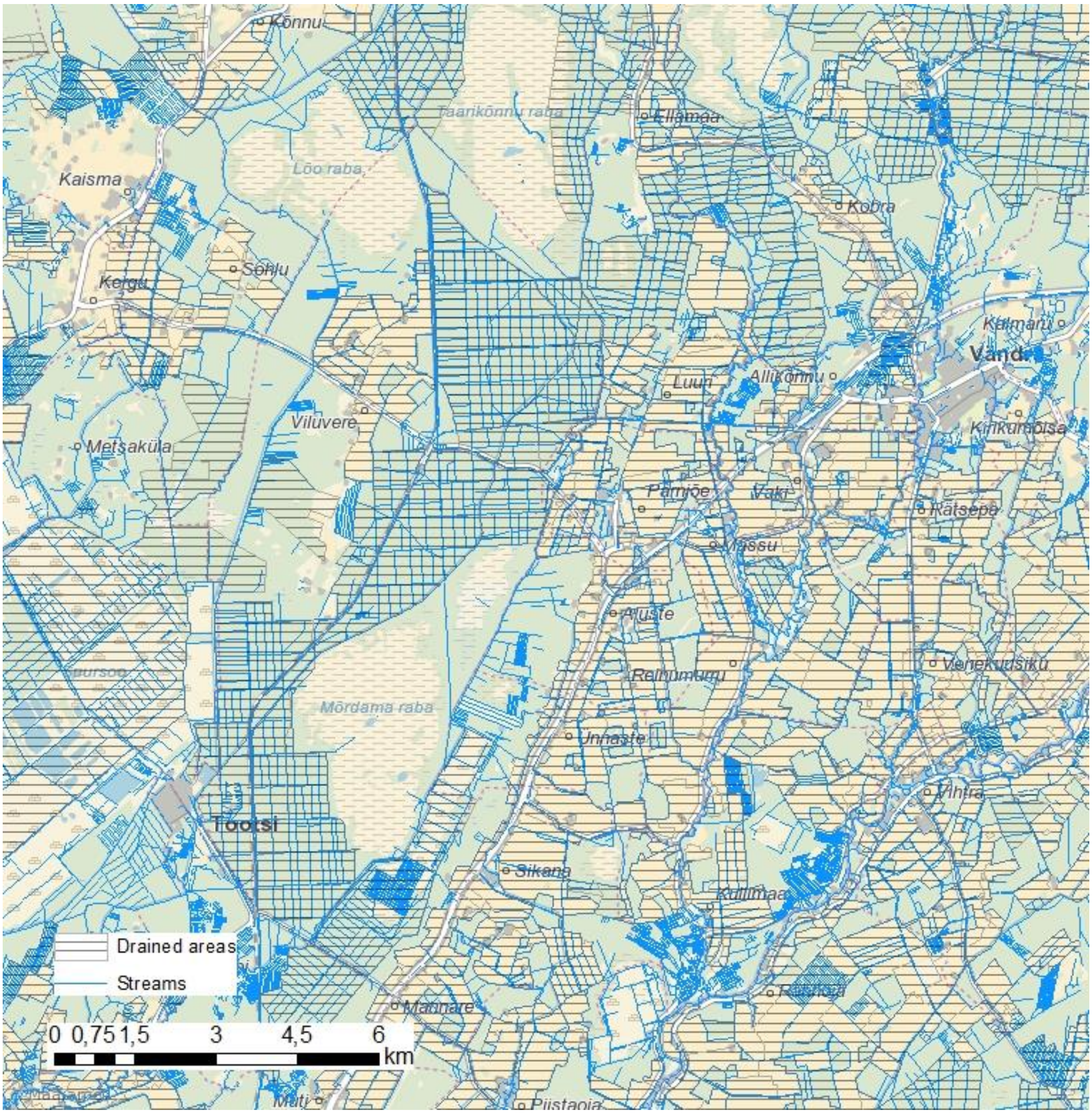


Figure 11. Drained areas in Estonia

In combination of Estonian Mire Inventory data and GS assessment, 499 129 ha of wetlands were defined as affected by drainage (Figure 11.).

Green network contradicting potential peat mining development

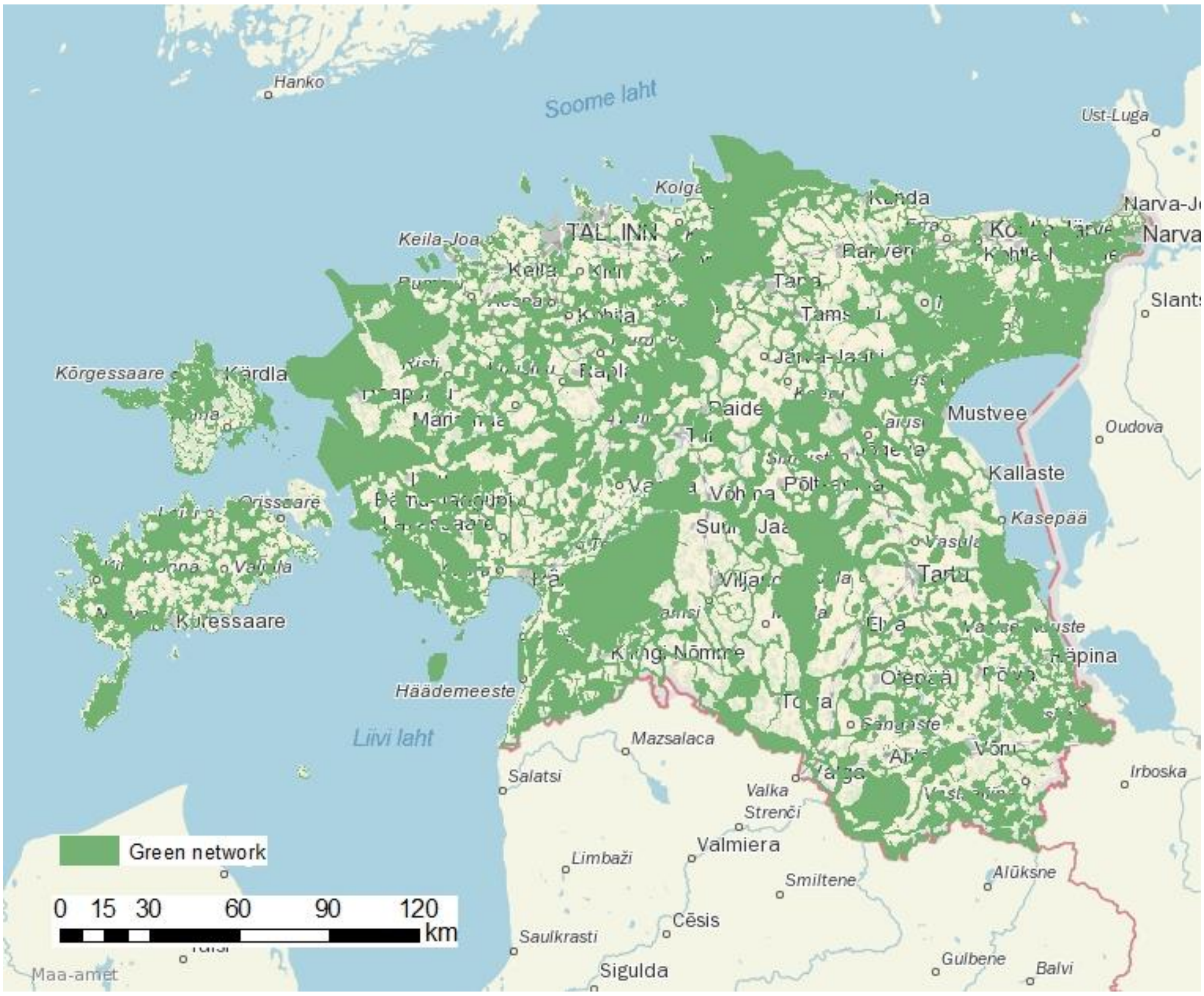


Figure 12. Green networks in Estonia

Green network is a spatially broad concept in Estonia, containing green corridors and other areas. In general, these are defined in spatial master plans. Their function is mostly provision of natural habitats. An area of green network can be protected but not necessarily - normally it is legally not binding. Instead, it usually serves as a recommendation hint for further planning. Green networks cover 2 495 358 ha of the land territory (Figure 12). Our model proposes not to plan peat mines to green network while allowing paludiculture there.

Estonia has spatially mapped possible future peat mines where restriction from nature conservation have not been established. It is assumed that mostly these are extensions of existing mines and already drained peat areas. As far as these areas contain peat for mining for a very long time, we call it here 'longlist' (Figure 13.). Excluding green networks and wetlands with relatively naturally maintained water regime our model proposed a 'peat mining shortlist' which contains less conflicts with environmental protection targets (Figure 14.).

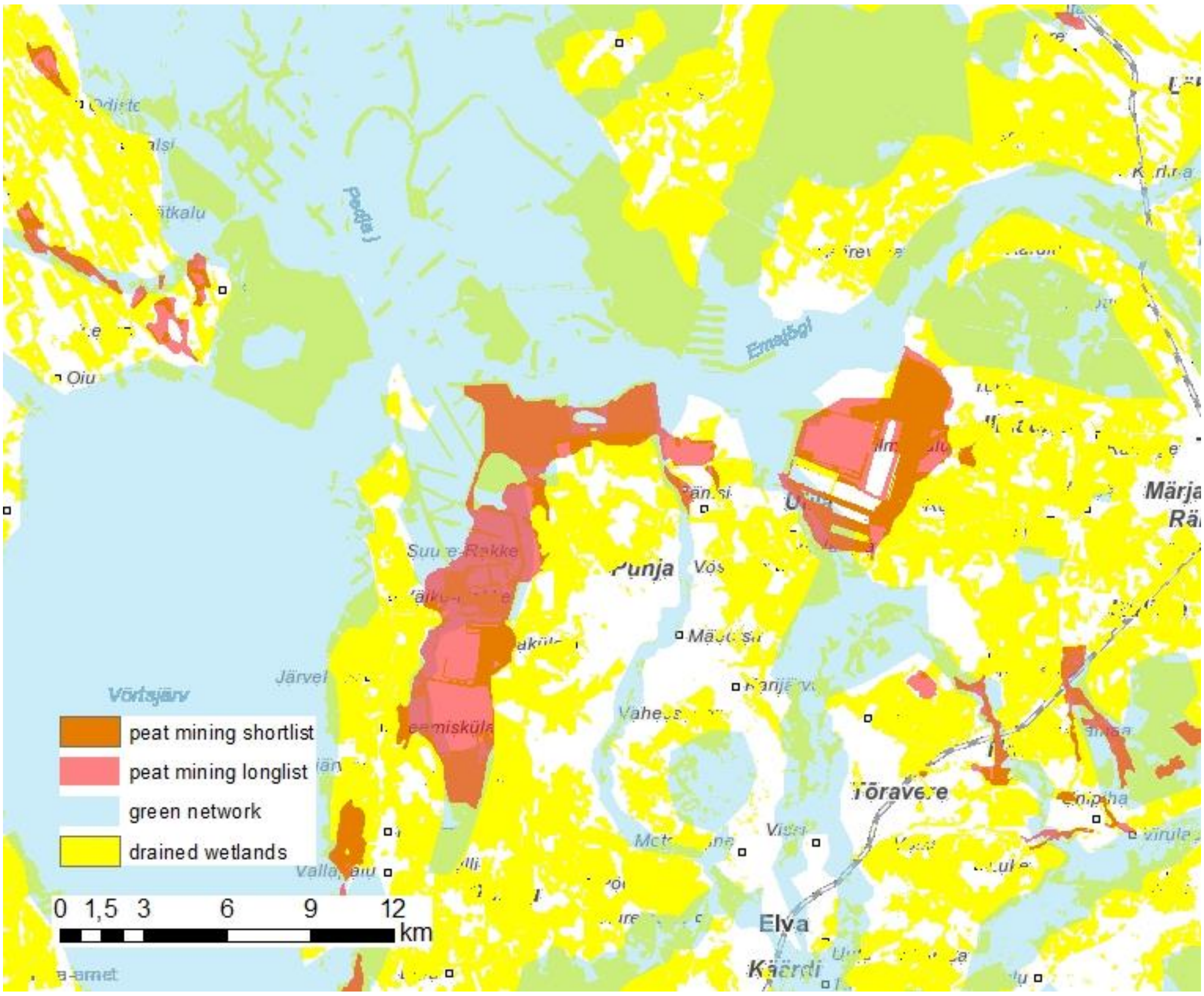


Figure 13. Peat mining longlist, green networks and drained areas in Estonia

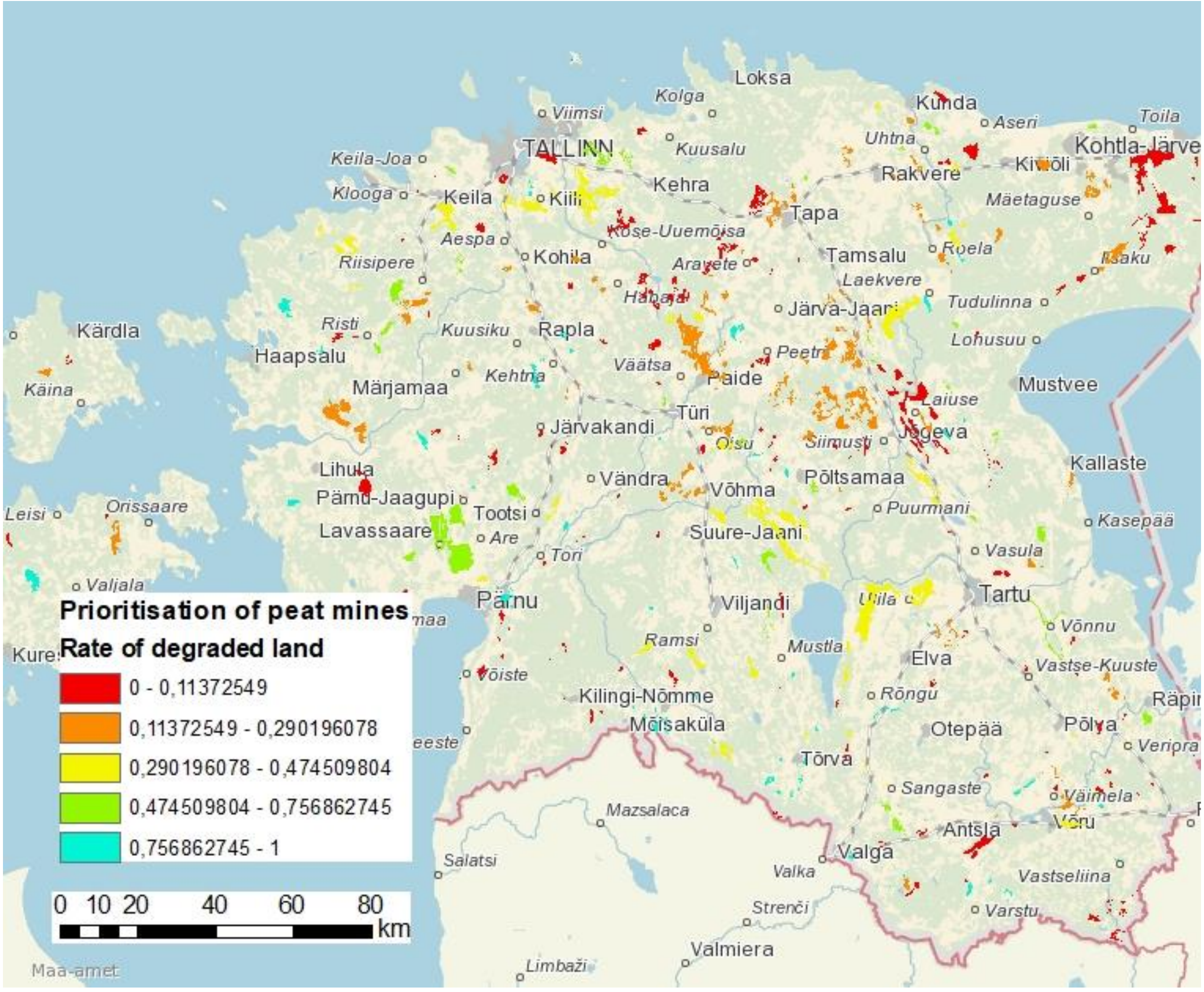


Figure 14. Prioritisation of peat mines

From the peat mining 'longlist' of 145 481 ha, just 24 457 ha was shortlisted for mining.

Logistics and potential end-users

We assumed that a suitable paludiculture site must be fully within 30 min distance from the potential primary users such as husbandry farms or boiler houses. This assessment included locations of roads and paths (Figure 15.) as well a data of primary users. This analysis excluded remote areas as logistically unfeasible.

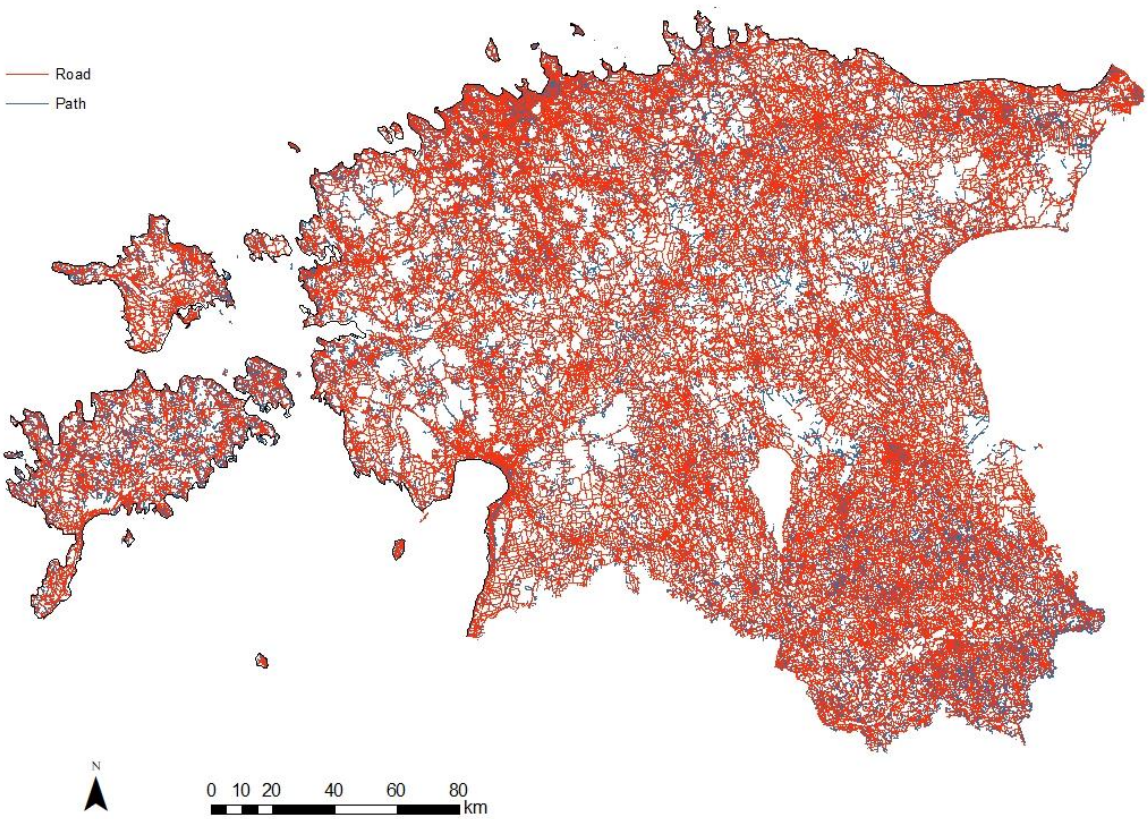


Figure 15. Estonian roads

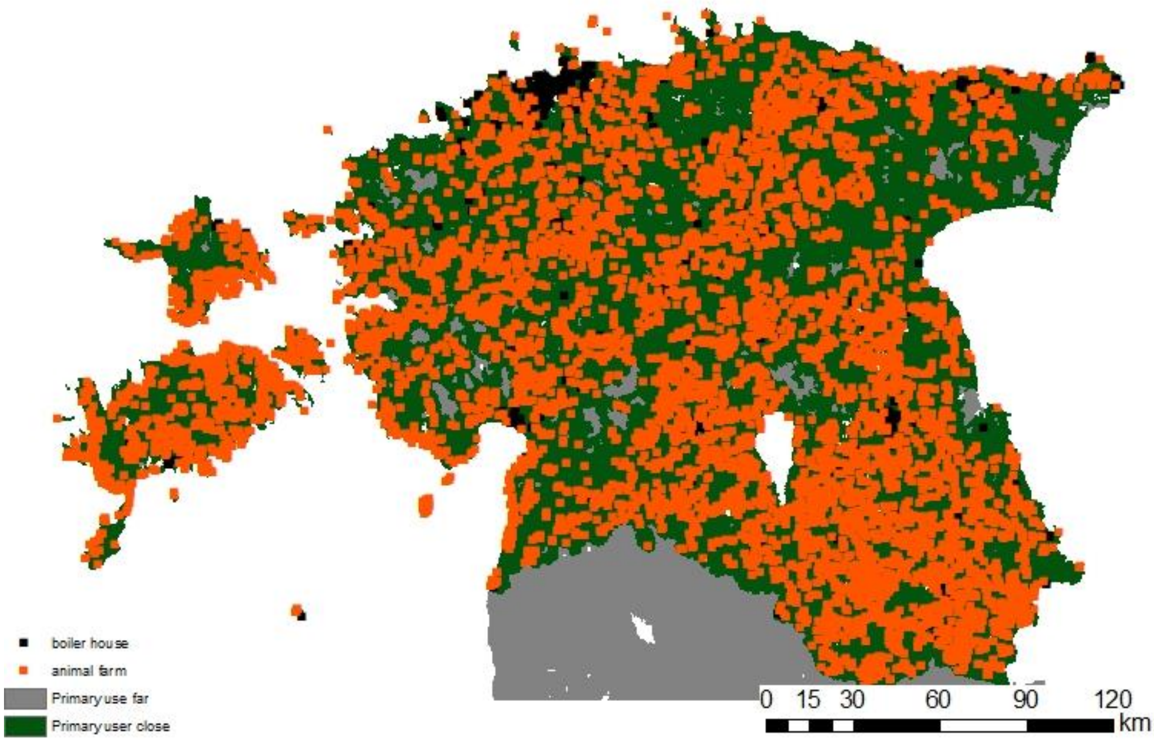


Figure 16. Potential collection areas for paludifarms

All boiler houses and animal farms were defined as potential primary users for paludifarms. It was assumed in our model that a logistically feasible paludiculture sites must be close to any primary user. For such assessment, transportation cost was assigned to various road types (Table 2.)

Table 2. Transportion costs assigned to road types in Estonia

Road type	Transportation cost, sec/km
Road	72
Trail	180
Landscape	1200

Our model was assigned to find the least cost path from each pixel to the nearest primary user. This assessment step excluded some very remote areas (Figure 16. white).

Main results of GIS analyses in Estonia

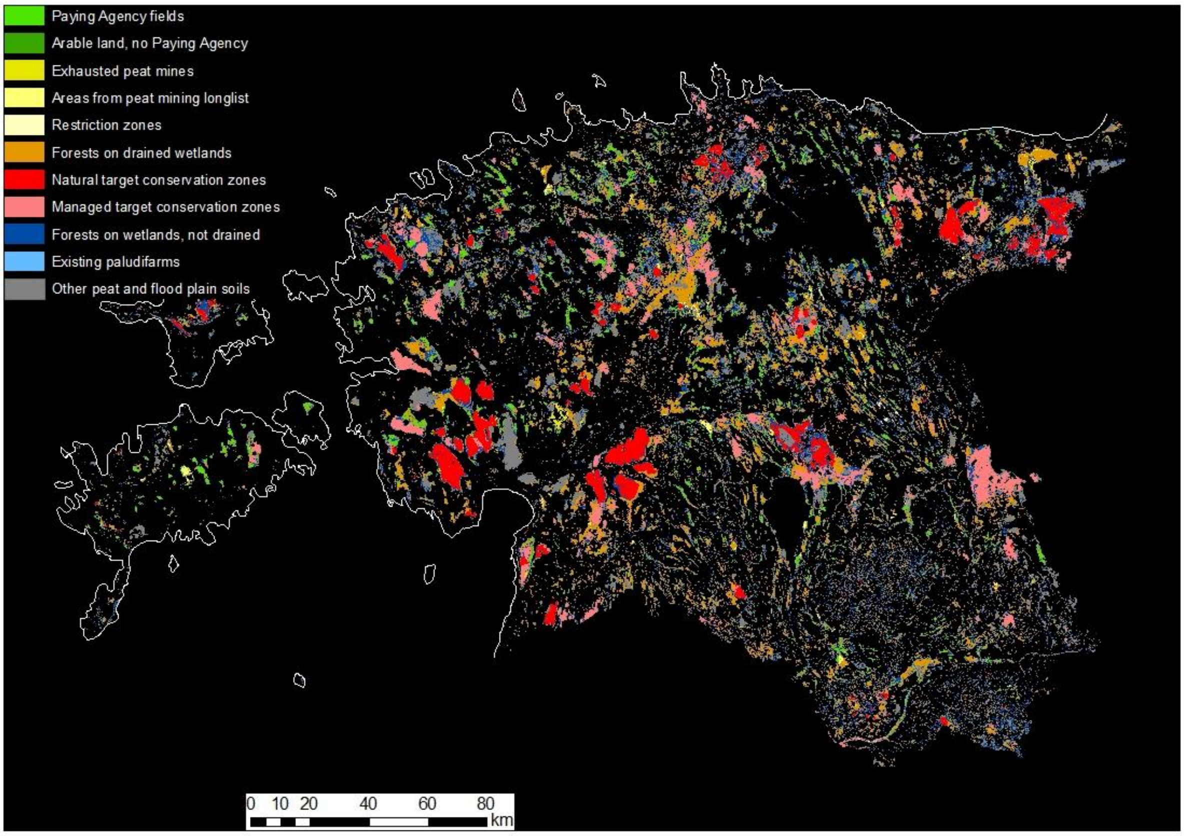


Figure 17. Suitability of Estonian wetland soils for paludiculture

The modelling steps 1 and 2 resulted with 760 km^2 of land suitable for paludiculture (green see Figure 17, Table 3.).

Table 3. Suitability for paludicultures Subtype classes and their total area in Estonia

Color	Subcolor	Subtype code	Subtype name	Area, ha
Green	**a: light green**	1	Paying Agency fields	72 712
Green	**b: dark green**	2	Arable land, no Paying Agency	3 877
yellow	**a: lime yellow**	3	Exhausted peat mines	5 492
yellow	**c: light yellow**	4	Areas from peat mining longlist	7 938
Orange	**orange**	5	Forests on drained wetlands	282 557
yellow	**b: dark yellow**	6	Protected areas, restriction zone	1 209
Red	**a: dark red**	7	Target conservation zones: natural	109 427
Red	**b: light red**	8	Target conservation zones: managed	106 478
Blue	**a: dark blue**	9	Forests on wetlands, not drained	195 850
Blue	**b: light blue**	10	Existing paludifarming	2 390
Gray	**gray**	0	Other peat and flood plain soils	229 791

Preselection of potential pilot sites

While large share of Estonian forests are owned by state, agricultural areas are mostly private (Figure 18. orange colour). However, we seeked pilot sites from publicly owned agricultural areas (Table 4., Figure 18. green colour). Final stage for selecting pilot sites depends on outcomes from negotiations between land owners and ELF.

Table 4. Criteria for preselection of potential pilot sites (agreement sites) for future paludiculture pilots in Estonia

	Step 1	Primary user (animal farm, boiler house)	Land ownership	Neighbourhood	Stakeholder attitude
Agreement sites	Green	Close	Public	Coherent	Positive

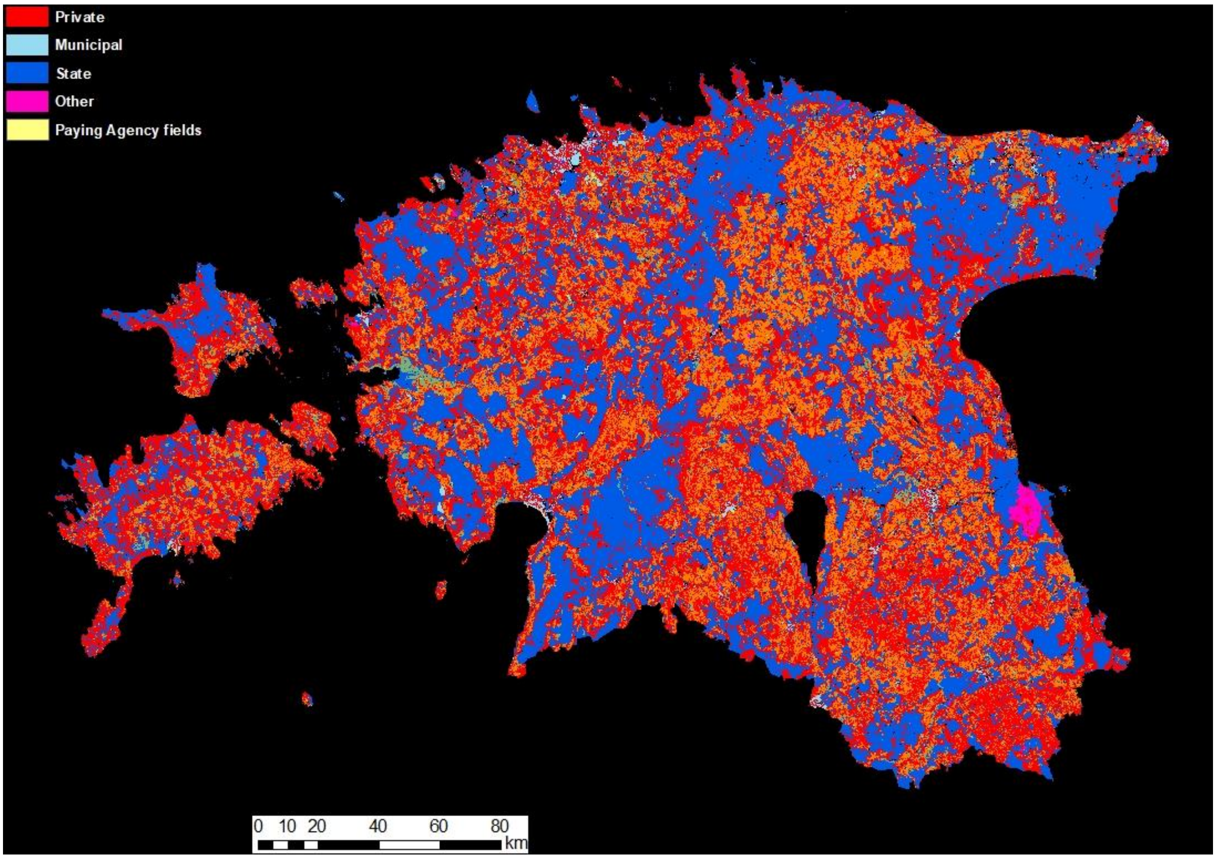


Figure 18. Land ownership and Paying Agency fields in Estonia

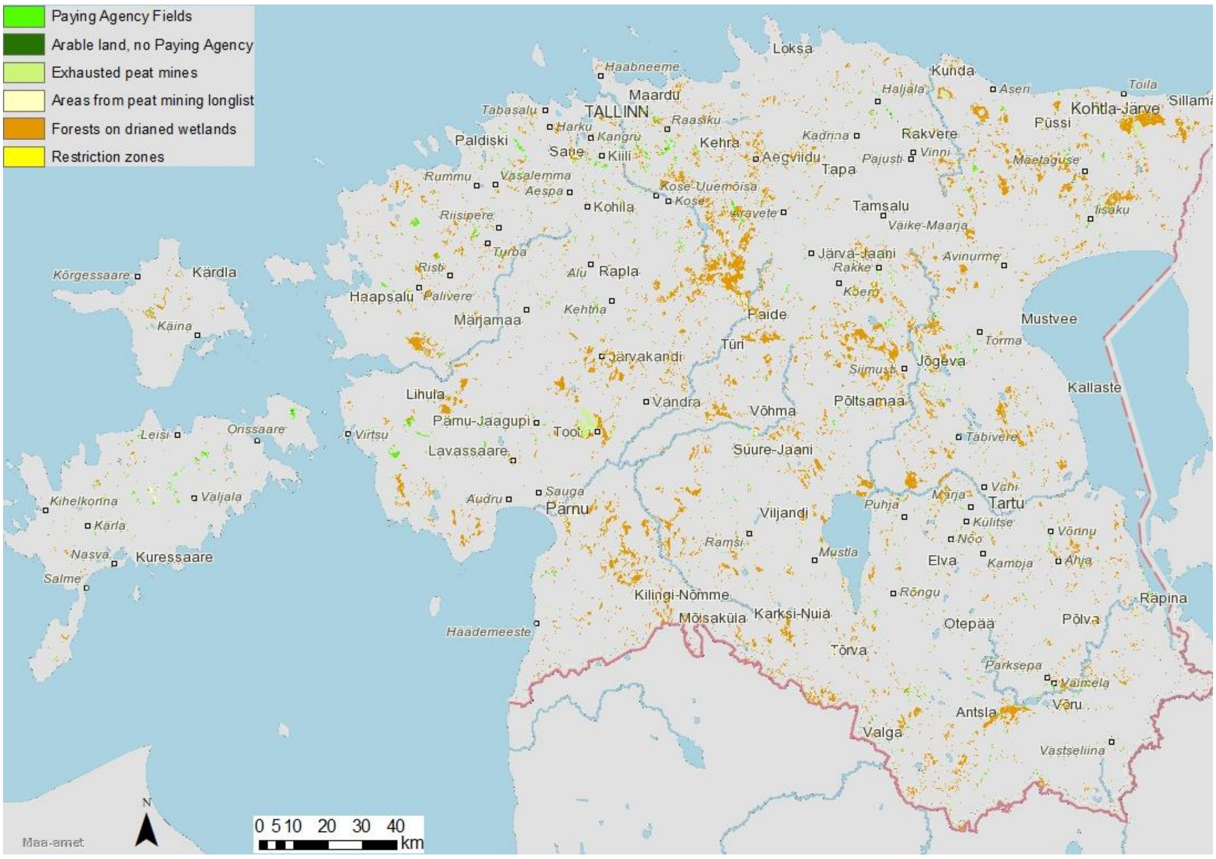


Figure 19. Suitable sites in state-owned areas. Intermediate results from step 3

Land ownership assessment gave many large forest areas to orange colour. Of green and yellow colour, the number of sites was much more limited (Figure 19., Figure 20.).

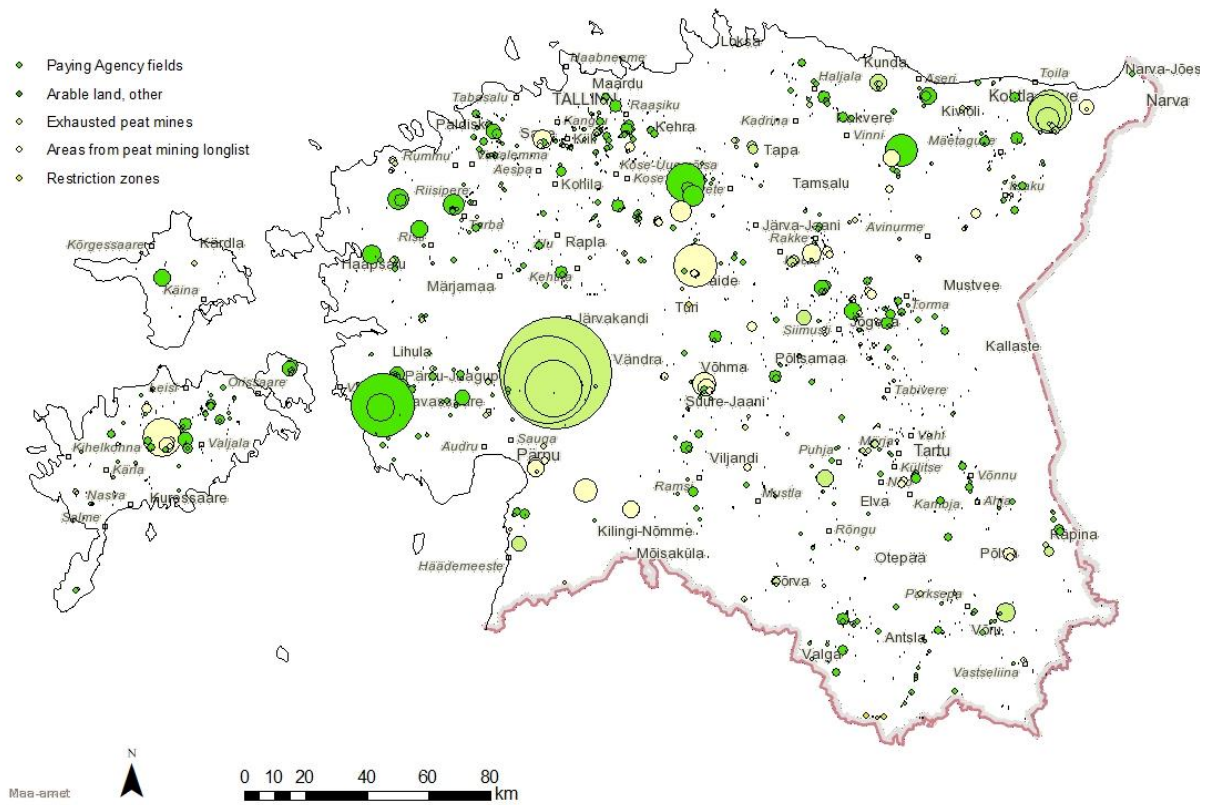


Figure 20. Green and yellow sites in state land. Symbol size indicates area of the site

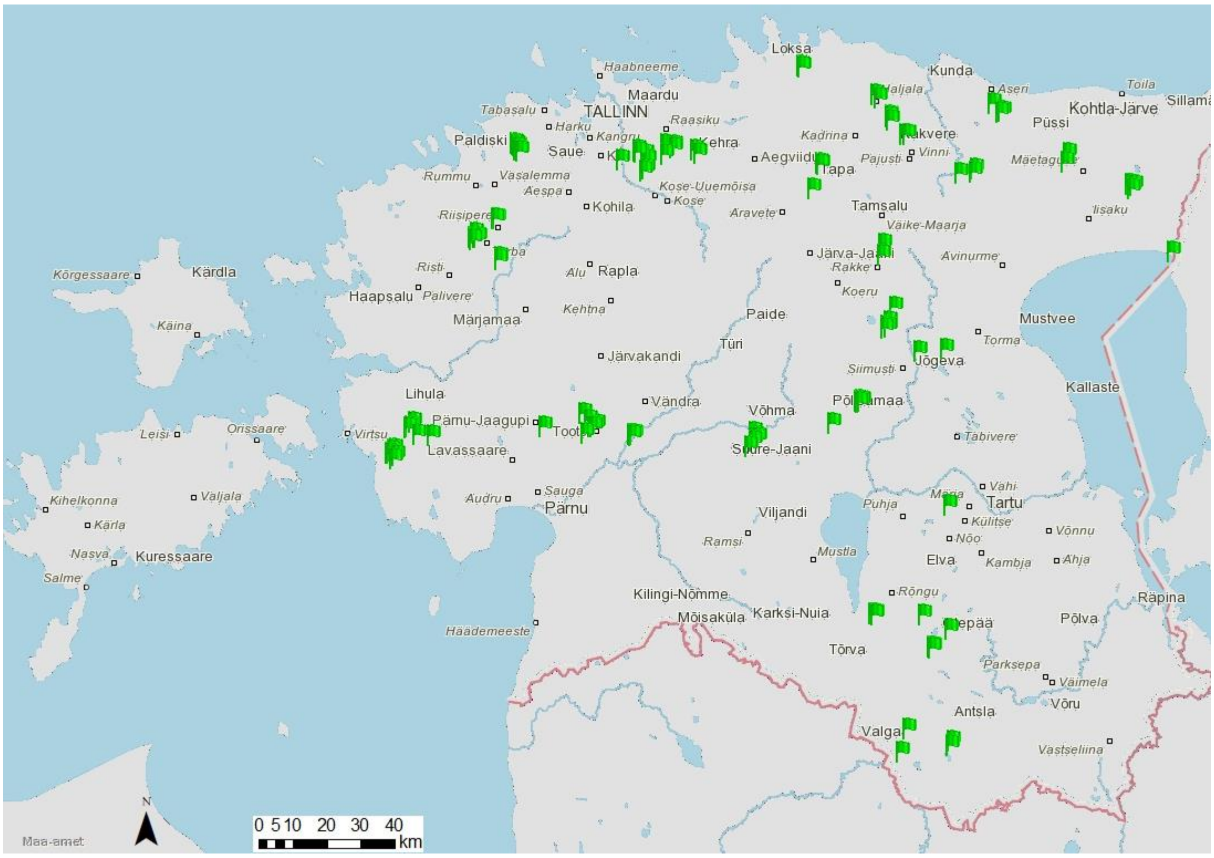


Figure 21. Suitable areas from step 3

The final procedure in step 3 was 'coherence assessment' which evaluated suitability, considering neighbourhood. Instead of modelling, this was proceeded according to remote sensing, using various maps and ortophotos. The most prevailing exclusion reason was risk of over flooding of neighbouring cultivated areas. The number of remaining areas is 118, total area of such pilot sites 4 065 ha (Figure 21.).

Latvian section

Methodology

Modelling of climate-smart management and utilisation of peatlands in Latvia was carried out using available geospatial data and various GIS tools. The compiled data base comprises:

- Soil type and soil subtype for agricultural lands provided by Ministry of Agriculture;
- Mining permit areas from project LIFE REstore;
- Bog/fen database provided by Latvian Environment, Geology and Meteorology Centre;
- Exhausted peat mines data from project LIFE REstore;
- NATURA 2000 database;
- Management plan of protected areas provided by The Nature Conservation Agency;
- Micro-reserve database provided by The Nature Conservation Agency;
- Rural Support Service database about croplands;
- Forest Registry database provided by Ministry of Agriculture;
- Road network provided by Latvian Geospatial Information Agency;
- Animal farm data provided by Agricultural Data Centre;
- Biomass heating plant data provided by Latvian Environment, Geology and Meteorology Centre;
- Straw pellet factory data were obtained using google search engine.

Aim of GIS analysis was to classify all peatlands into 11 comparable categories following the Estonian approach (Estonian section). These categories are later merged into to generalised and merged to the four classes of the Lithuanian approach (Lithuanian section) for the Pan-Baltic overview (Figure 32).

- **Paying Agency fields.** Agricultural land on peatland which is under Rural Support Service scheme;
- **Areas out from Paying Agency.** Agricultural land on peatland which is not under Rural Support Service scheme;
- **Exhausted peat mines**;
- **Areas from peat mining longlist**. Areas with active licences for peat mining;
- **Fields on drained peatlands, protected areas.** Agricultural land on peatlands in protected areas - agriculture is possible under nature conservation restrictions;
- **Forests on wetland soils, not drained.** Areas from Forest Registry database, forests on wet mineral and organic soils, not drained;
- **Forests on drained wetland soils.** Areas from Forest Registry database, forests on wet mineral and organic soils, drained;
- **Natural target conservation zones.** Protected areas that are strictly dedicated for nature conservation. Any land management is prohibited;
- **Managed target conservation zones**. Protected areas that are dedicated for nature conservation. Management plan includes necessary activities for conservation which might include activities related to paludiculture.
- **Potentially existing paludifarms**. Areas from Rural Support Service database where cultivated crop is related to paludiculture. Might include crops like *Phalaris arundinacea*, cranberries, etc. Validity for this class needs careful proof and verification of management practices to be in line with paludiculture principles (e.g. surface near water level management, low or no application of fertiliser, no ploughing, application of soil preserving mearsures and technology etc…);
- **Other wetland soils**. Peatland areas which are not included in above mentioned classes.

Figure 22. shows a logic flow chart that was followed for steps 1 and 3 of the GIS analysis. All data were processed in vector format. In the beginning all datasets describing areas of peatlands were combined in one layer forming “All wetlands” layer. This layer then was used to distinguish all 11 peatland categories for the use of paludiculture. Standard GIS tools and routines had been applied:

- Union – computes a geometric union of the input features. Used to combine similar datasets;
- Intersect – computes a geometric intersection of the input features. Used to distinguish areas that fall into one of the categories;
- Erase – computes a geometric difference between input features. Used to remove previously distinguished areas from “All wetlands” layer to avoid overlapping of features;
- Merge – combines multiple input datasets. Used to combine all 11 category layers into one layer;
- Dissolve – Aggregates features based on specific attributes. Used to dissolve nearby areas of the same category.

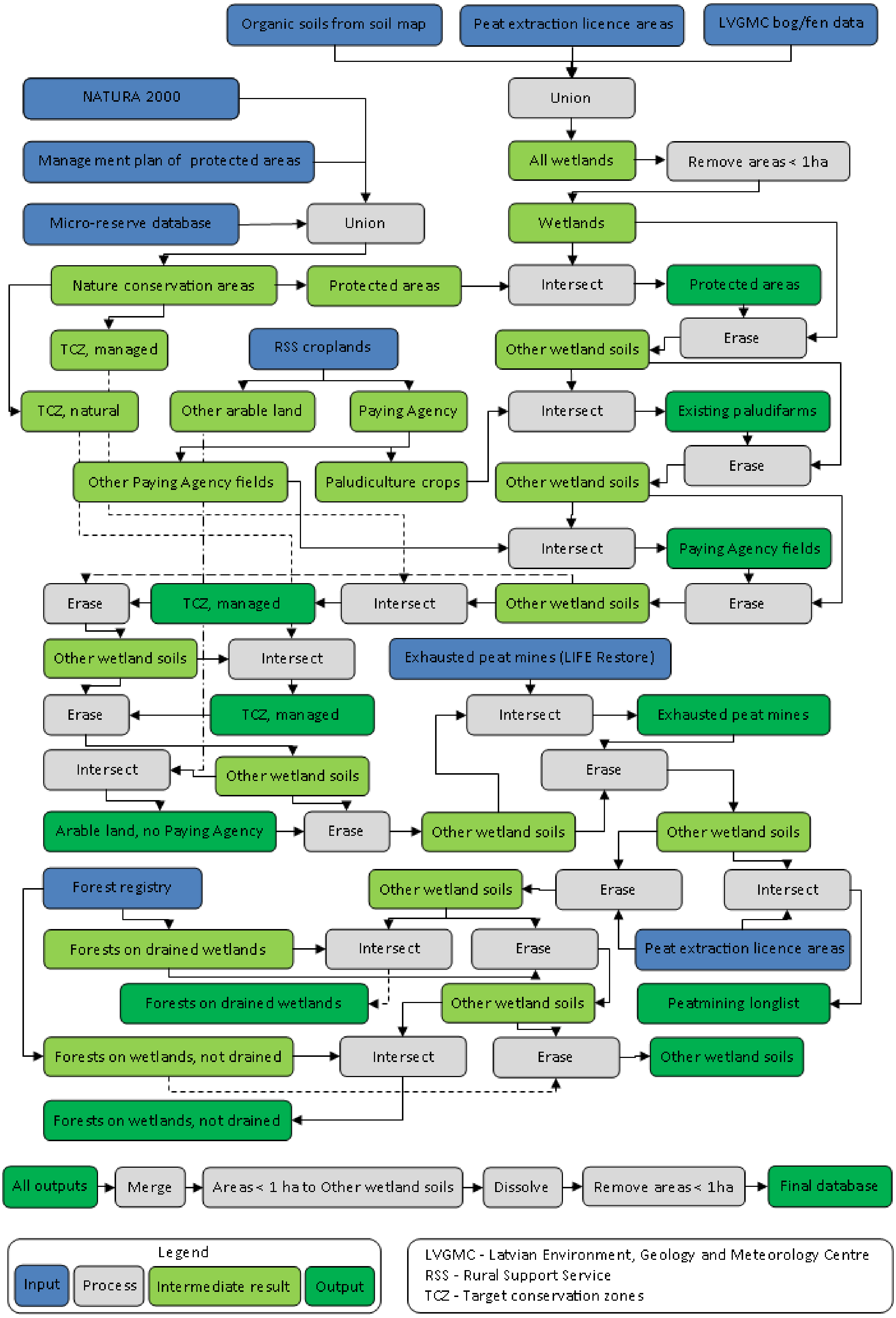


Figure 22. Modelling of paludiculture areas in Latvia, steps 1 and 3

Figure 23. illustrates steps 2 and 3 of the GIS analysis for Latvia. Proximity analysis was conducted for the assessment of potential paludiculture sites to paludiculture biomass consumers like: Straw pellet factories, biomass heating plants, animal farms and others. Proximity analysis used the network analysis tools. For modelling and incorporation of a transport logistic network, a road layer from Latvian Geospatial Information Agency was used. Only asphalt and gravel roads were considered as suitable for the use of biomass transportation. Sub networks were generated to indicate distance from consumer for up to 10 km via roads. Buffer of 1 km then was generated for created subnets to highlight the areas that are within 10 km via roads and up to 1 km off the road from potential paludiculture biomass consumer. The generated buffer then was applied to create a mask to hide out areas that are outside of area of interest. Pilot areas for implementation of paludiculture then were selected based on the proximity between potential consumers and suitable areas.

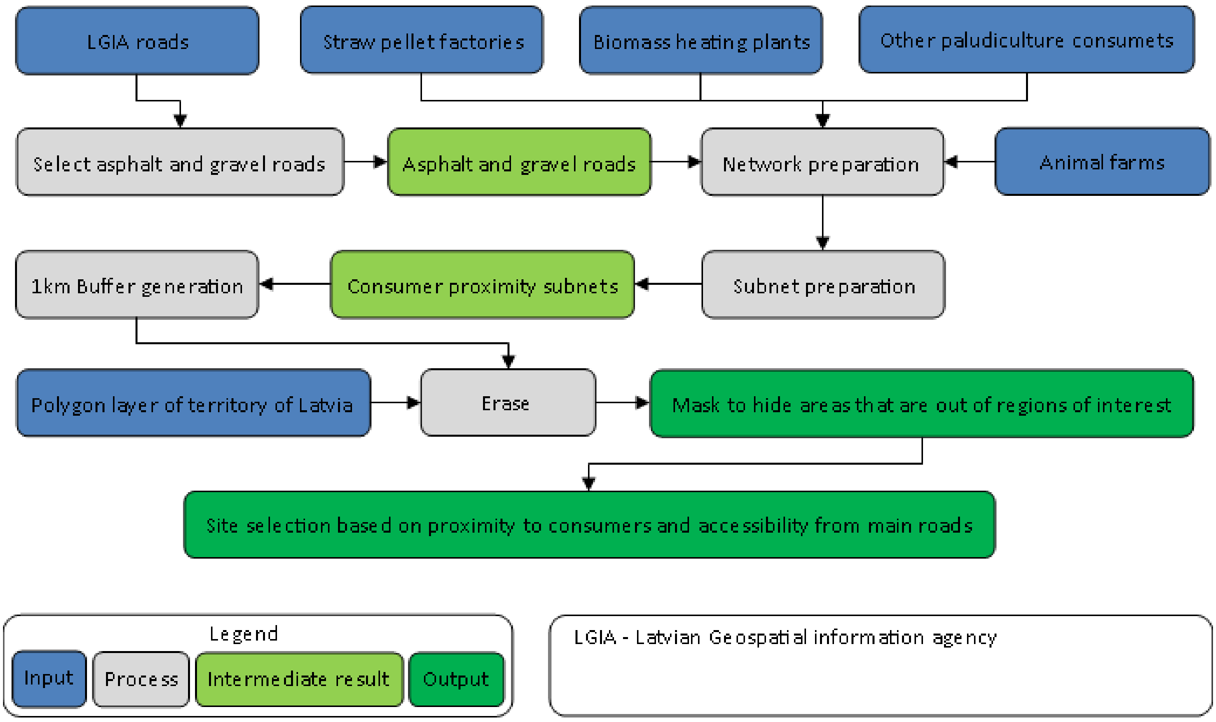


Figure 23. Modelling of paludiculture areas in Latvia, step 2

Distribution of paludiculture categories in Latvia

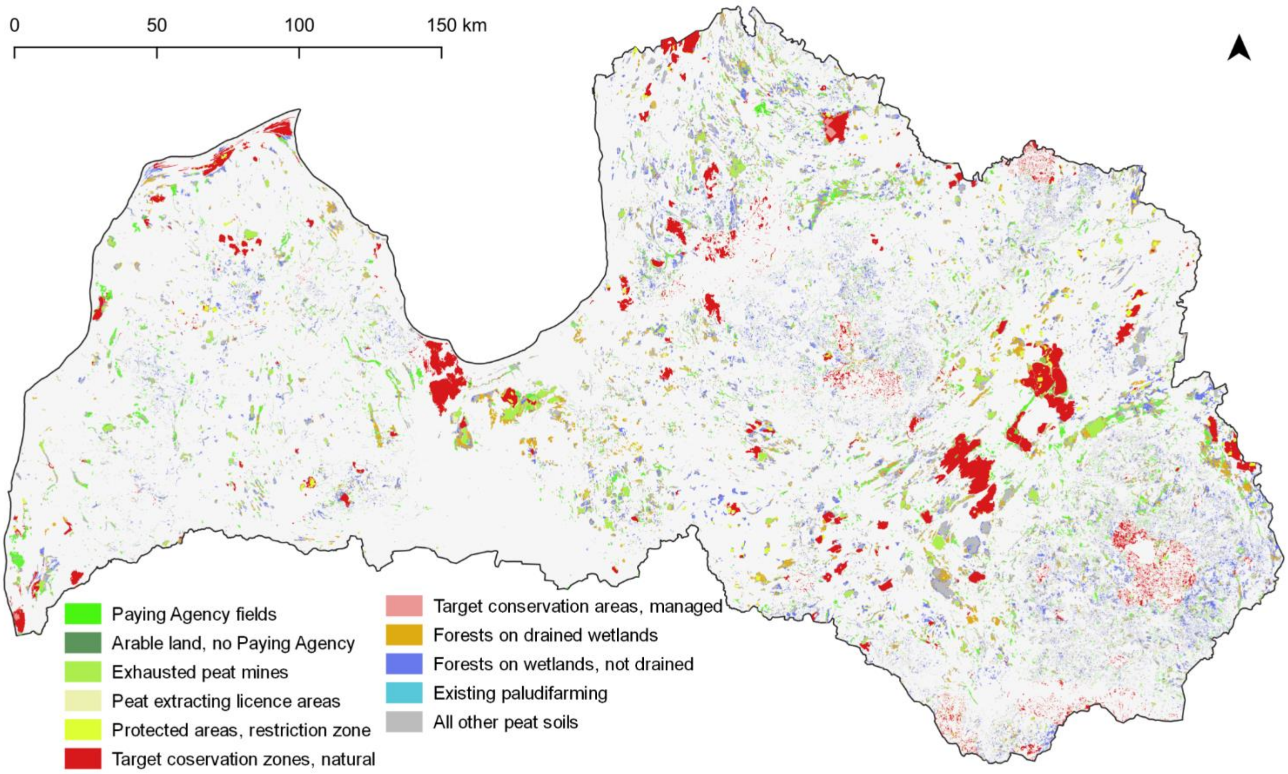


Figure 24. Peatland suitability for paludiculture implementation.

Figure 24. shows the resulting overview map for the distribution of peatlands in Latvia and their suitability for paludiculture implementation. Total area of different suitability classes are displayed inTable 5. The largest area is covered by forest or they is protected for nature conservation. However more than 140 000 ha of peatlands in Latvia is directly available for implementation of paludiculture.

Table 5. Area of different peatland suitability classes for paludiculture implementation.

Category	Area (ha)
Paying Agency fields	106 108
Arable land, no Paying Agency	5 282
Exhausted peat mines	39 194
Areas from peat mining longlist	4 535
Forests on drained wetlands	142 936
Protected areas	22 052
Target conservation zones, natural	190 945
Target conservation zones, managed	3 739
Forests on wetlands, not drained	191 887
Existing paludifarms	301
Other wetland soils	285 007

Proximity analyses

An Example of proximity analysis is illustrated inFigure 25. In this case proximity is shown to heating plants that use biomass fuels. Roads that are close to heating plant are shown in dark red colour, but when distance from biomass consumer is becoming larger, colours are fading and becoming grey.

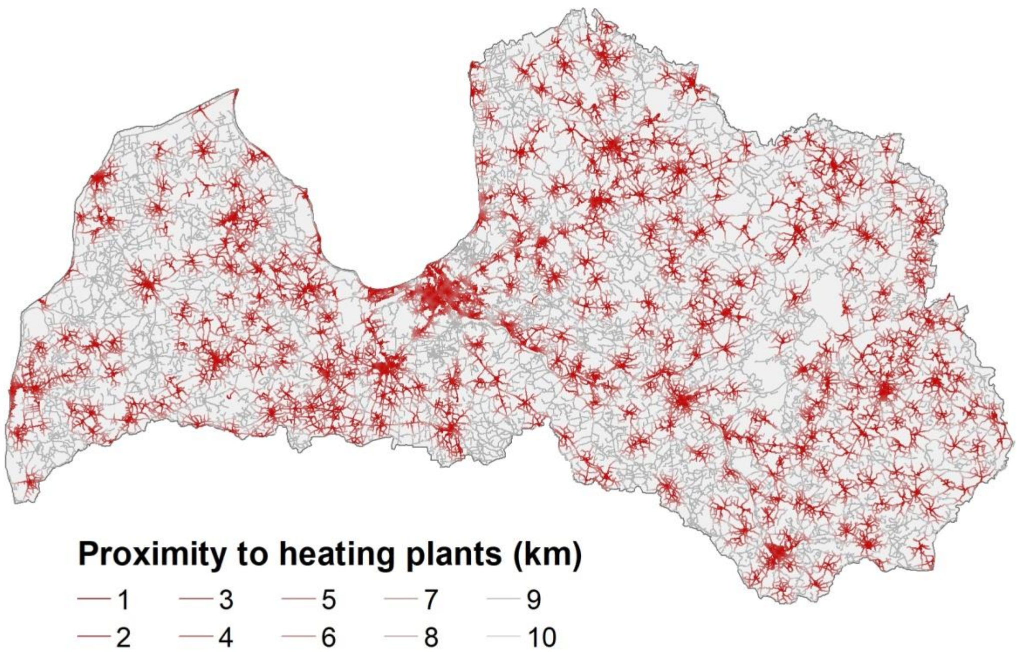


Figure 25. Example of proximity analysis.

Detailed maps for preselection of potential paludiculture sites

Some of results for pilot territory selection for potential paludiculture implementation are shown in Figures Figure 26., Figure 27., and Figure 28. In the centre of Figure 26. a straw pellet factory is located near town of Mazsalaca. In close proximity there are few Paying agency fields that probably can be transformed for paludiculture farming.

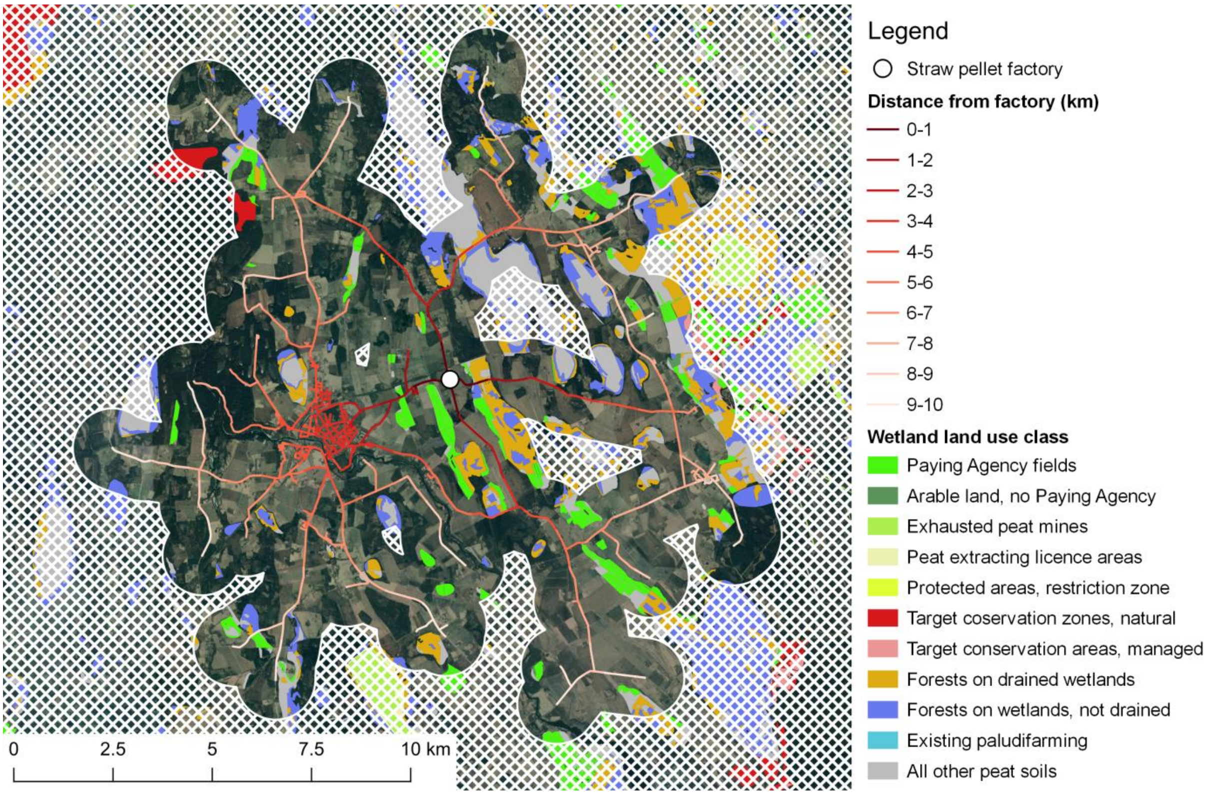


Figure 26. Mazsalaca straw pellet factory.

On the right side of Figure 27 there are town of Tukums there 5 heating plants are operating using biofuels. To the west side of town there is river valley cowered with organic sediments. Agriculture fields there are funded by Paying Agency and potentially are suitable for paludiculture production.

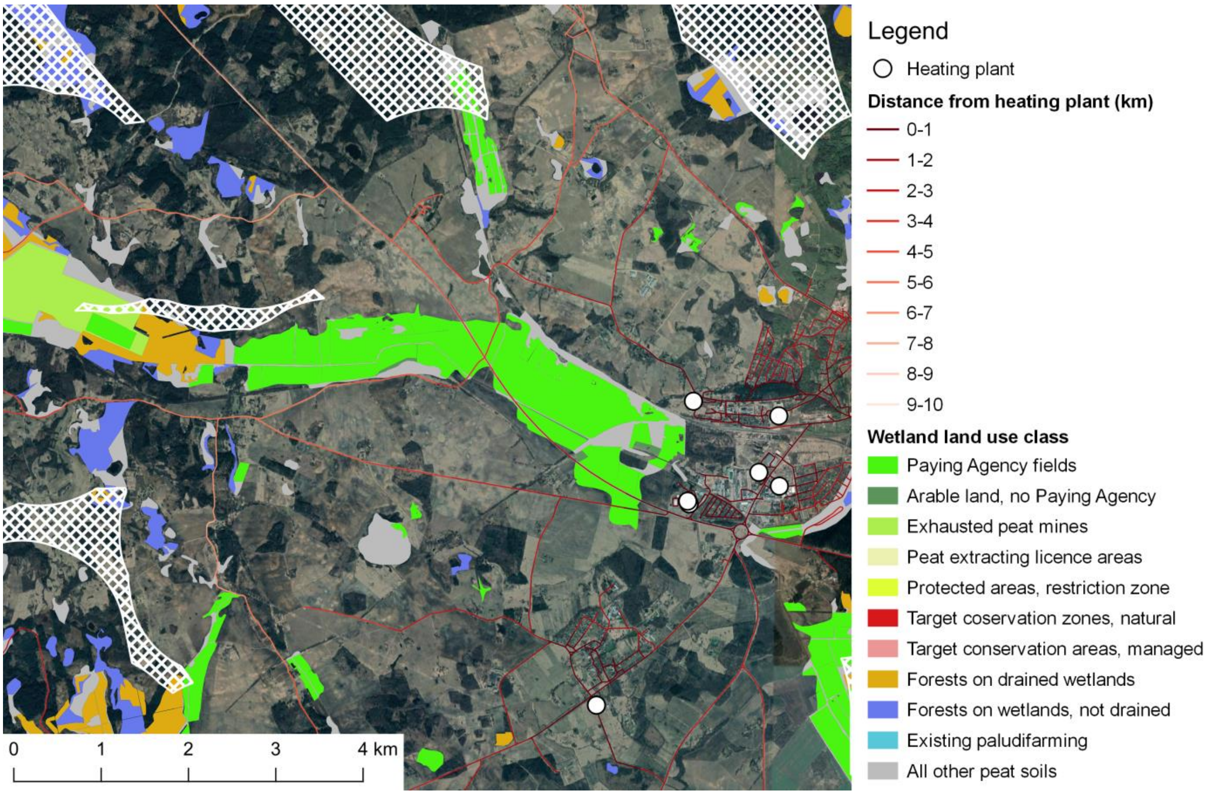


Figure 27. Tukums heating plant.

One more example is shown in Figure 28. White dots are representing animal farms and green areas potentially are suitable for grazing.

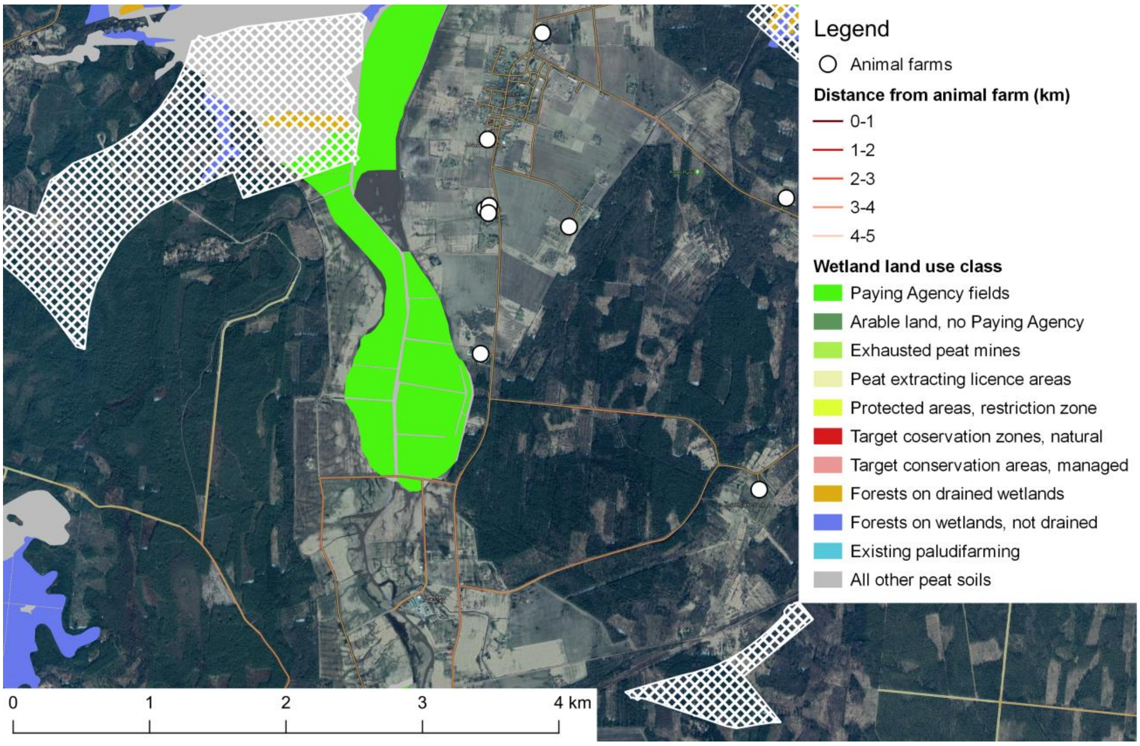


Figure 28. Ance cattle farm.

Lithuanian section

Methodology

Modelling of climate-smart management and utilisation of peatlands in Lithuania used available geospatial data, conversion of non GIS data, and various GIS tools. Analyses were mainly done with , open access data from the Lithuanian peatland data base (*www.geoportal.lt*). Table 6. lists the spatial data sources for analysing peatland distribution in Lithuania (in order of priority).

Table 6. Sources of geospatial data about Lithuania peatlands

Source of data	Area, ha	%
Revised peatland quarry data (Lithuanian Geological Survey 2018)[4]	27 549	4,2
Spatial data set of soils M1: 10000 in Republic of Lithuania (www.geoportal.lt)[5]	447 405	68,4
Data of forest cadaster (State Forest Service 2018)[6]	178 979	27,4

Based on this data base, peatlands were further attributed to 4 main categories. The following criteria (in order of priority) for the categorisation were used:

- Land use category (peatland (hd6), forest (ms0), arable land (az0), perennial grasslands (sd2), peat mining sites (ed0), etc., see also Figure 29);
- Protection status (biosphere reserves; complex managed reserves or cultural managed reserves, biosphere polygons, nature managed reserves, strict nature reserves, etc.);
- Forest group (group II-IV minor restrictions or no restrictions; group I – not suitable for paludiculture);
- Habitat of European importance type (forest and peatland (except 7120) habitats not suitable for paludiculture; the rest types – major restrictions);
- Declared agricultural land.

GIS analysis and establishment of a set of criteria (see figure 1, steps 1 – 2) followed a logical scheme (see Figure 29. Logical flow chart for assessment of the four categories for Paludiculture in Lithuania) to classify all Lithuanian peatlands into four generalised classes which indicate the availability of a drained peatland for paludiculture implementation in Lithuania. The more detailed categories of the Latvian and Estonian approaches for the Panbaltic overview were later matched and merged to the four Lithuanina categories (see Section Combined Results). According to their physical characteristics (peat type, drainage etc.), legal status (protected, not protected), and land use (agriculture, forestry etc.) the categories are defined:

- **1st category (Red)**: Peatlands not suitable for paludiculture, they include nature reserves, EU importance peatland and forest habitats (except habitat 7120), valuable forests (group I);
- **2nd category (Orange)**: Peatlands that face major restrictions on changing the land use, the category consists mainly of forested areas;
- **3rd category (Yellow)**: Peatlands that have less restrictions, it covers abandoned peatlands which are not overgrown by forest;

[4] https://www.lgt.lt/
[5] https://www.geoportal.lt
[6] http://www.amvmt.lt/index.php/kadastras

- **4th category (Green)**: Suitable Peatland sites with no restrictions to land use, mainly drained agricultural areas.

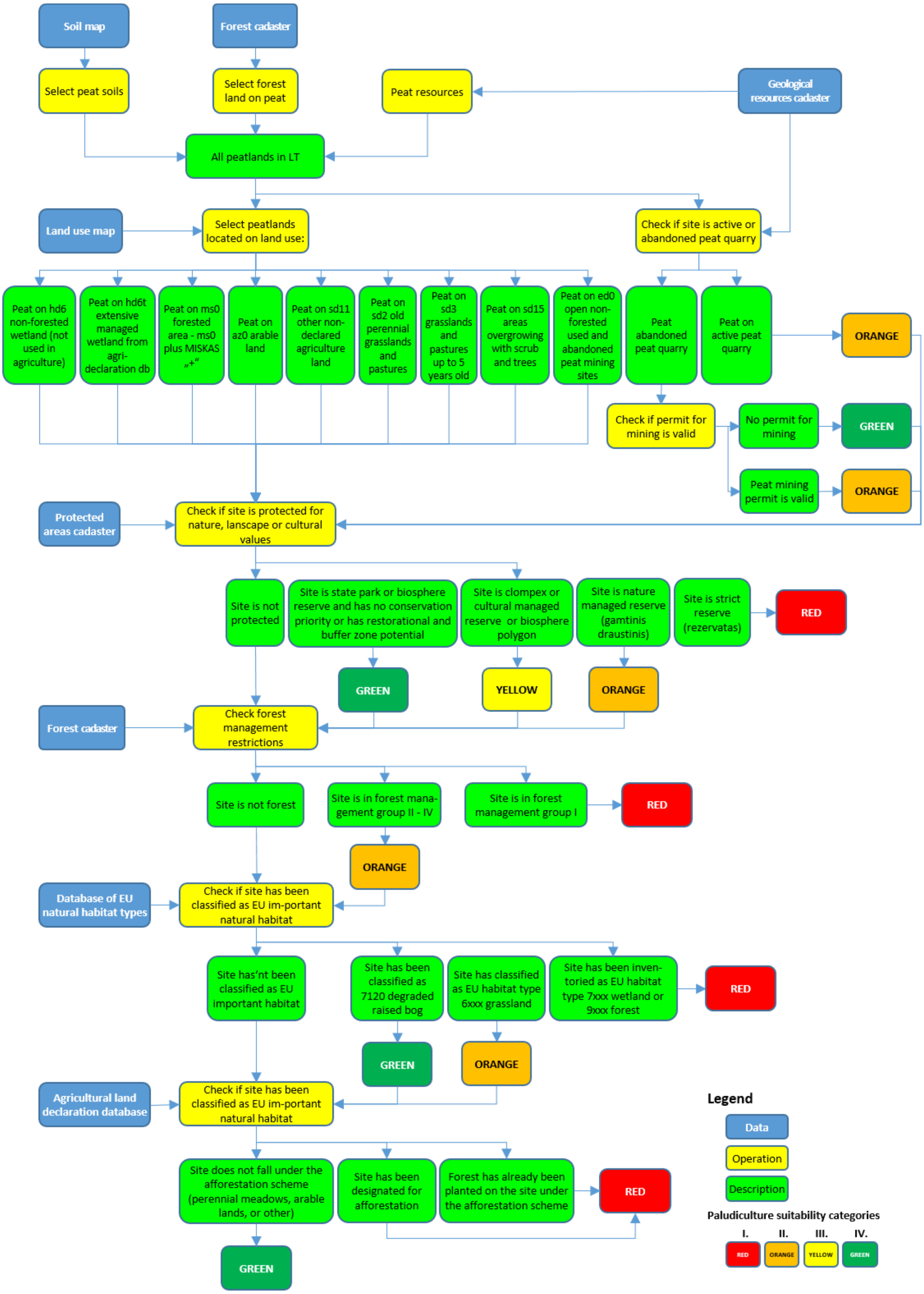


Figure 29. Logical flow chart for assessment of the four categories for Paludiculture in Lithuania

Distribution of paludiculture categories in Lithuania

The largest proportion of the area is grouped in the 4th category (41.0%) and in the 2nd category (38.1%) while slightly less than 18.2% of peatlands is allocated to the 1st category. The 3rd category contains an insignificant share of 2.7% only (TableTable 7. Total area size of the four categories for readiness of paludiculture implementation in Lithuania). This is owed to the methodological approach and the assessment of preconditions for implementing paludiculture, meaning that either peatlands have major restrictions for paludiculture or no restrictions, e.g. majority of forested peatlands were allocated to the 2nd category because of strict restrictions for other types of land use than forestry.

Table 7. Total area size of the four categories for readiness of paludiculture implementation in Lithuania

Category	**Name**	**Area, ha**	**% from all country's peatland area**
I	Areas not suitable for paludiculture	116 959.62	18.2
II	Conditionally suitable areas after consideration of major restrictions	244 054.50	38.1
III	Suitable areas after consideration of restrictions	17 202.12	2.7
IV	Fully suitable areas without restrictions	262 689.53	41.0
Total sum		**640 905.77**[7]	100.0

[7] The difference between total peatland area and peatlands analysed in the study is 13028 ha (total peatland coverage is 653 933,77 ha) because some areas were excluded, e.g. gardens, water bodies, roads etc.

Spatially, Lithuanian peatlands are concentrated in the Eastern and South Western parts of Lithuania with some concentration in the centre of the country. As a decision base for the selection of potential paludiculture implementation sites a map for spatial distribution of the four categories in Lithuania was made (Figure 30.). Bigger peatlands in natural state have status of strict nature reserves (1st category), as it is clearly visible on the map. Peatlands of 2nd category are mainly afforested sites and appointed as so-called forest land. Also, they include all mining sites (active and abandoned), some of them covering rather huge areas (>3 000 ha), located in different parts of the country. 3rd category concentrates in the very South-West part because of landscape parks stretching along the Lithuanian-Polish border.

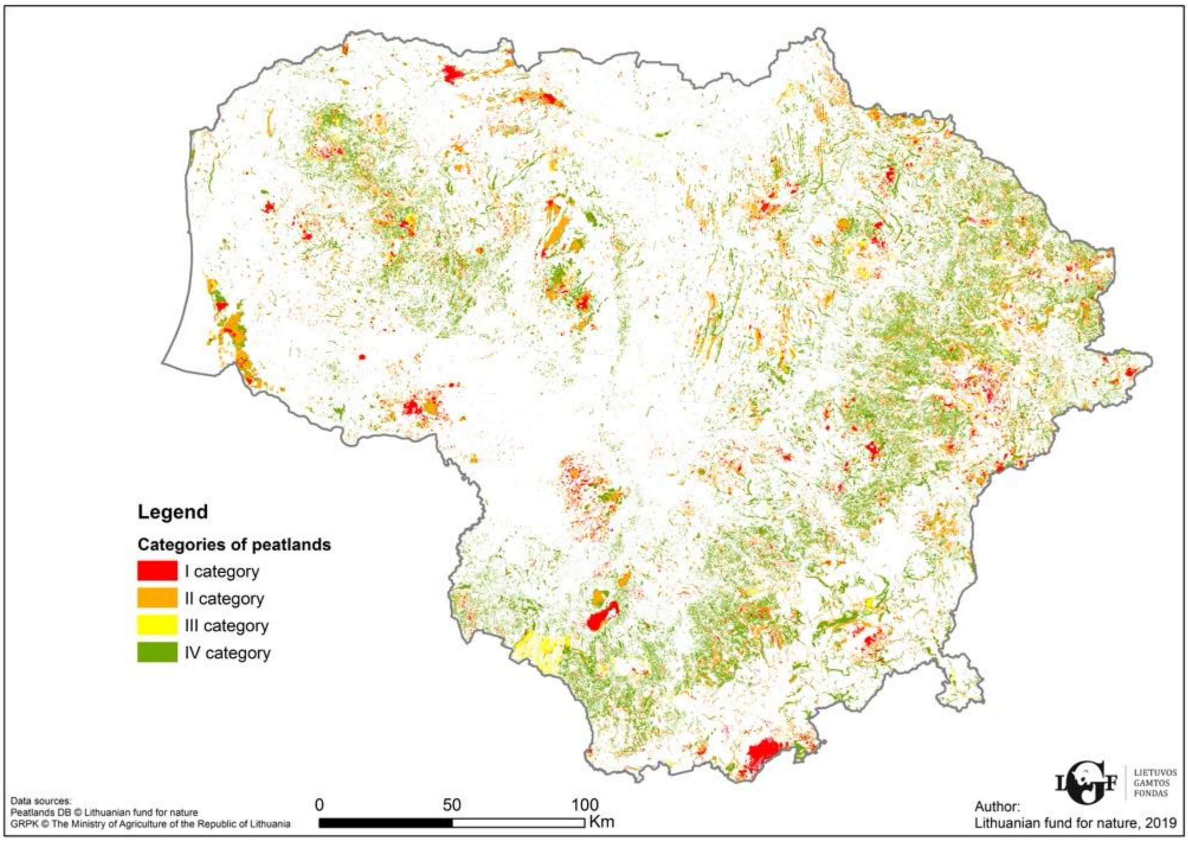


Figure 30. Distribution of paludiculture categories.

Distribution of 4th category

Since the 4th category is the most promising one regarding suitability for paludiculture, more detailed analyses of its distribution were made. Peatlands of 4th category are mainly concentrated in the Eastern, Central, and Southern parts of Lithuania (Figures 30. & 31.) This distribution is partly determined by the natural occurrence of peatlands and intensive agricultural areas in Central Lithuania. Agricultural land use dominates in the 4th category, covering 206 149 ha or 78 % of all peatlands. The rest of the peatlands consists of forests, wetlands, gardens, and scrublands. Abandoned peatlands, which are neither included into forest land cadastre, nor having habitats, or any protection status, are listed in this category as well.

Analysis of peat type distribution in four different paludiculture categories shows, that 4th category is dominated by fen peatland type (96 % of all areas in 4th category). This is partly determined by the fact, that fen mires were drained and turned into agricultural lands very intensively during Soviet period. Whereas, majority of all raised bogs falls into 1st category (63 % of all inventoried raised bogs), as the biggest bog mire complexes in Lithuania have a strict protection status, e.g. as nature reserve, telmological reserve, etc.

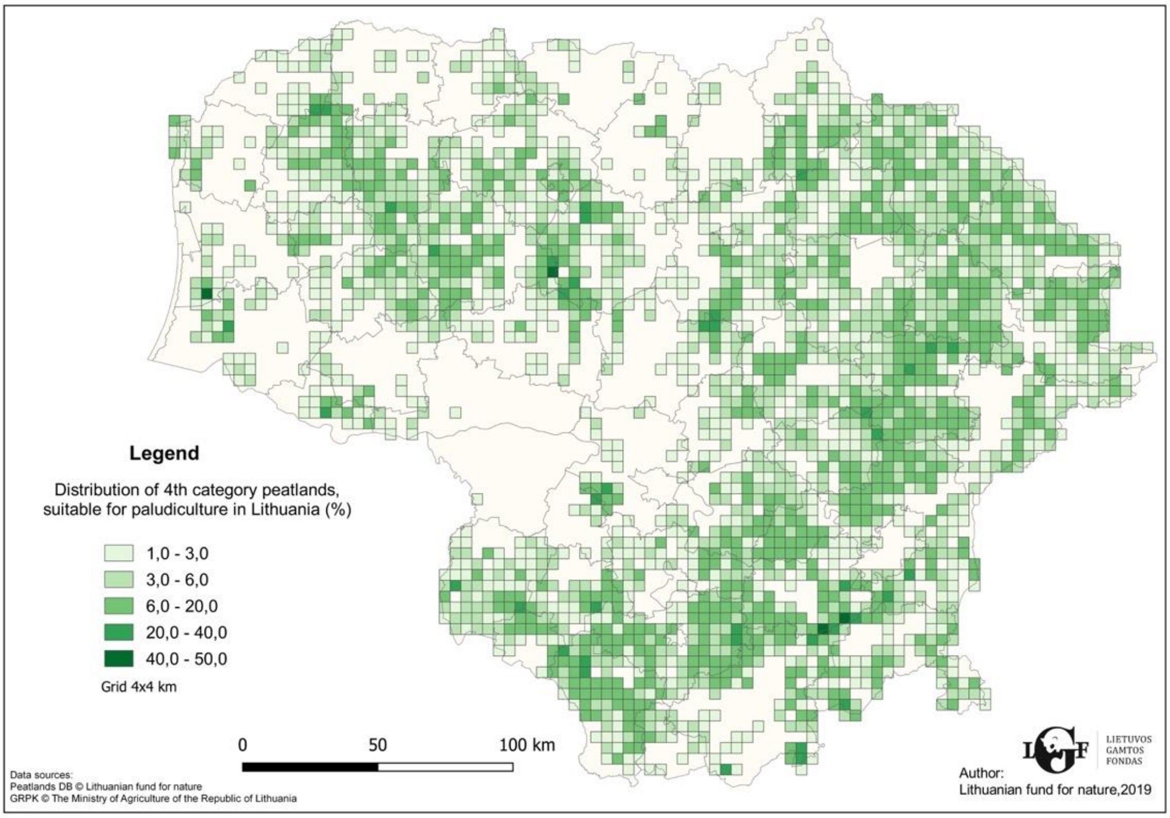


Figure 31. Percentage distribution of 4th category peatlands, suitable for paludiculture in Lithuania.

Distribution of peatlands utilised in peat extraction

Abandoned peat mining sites show good perspectives for the implementation of paludiculture on raised bogs. Currently, the total coverage of abandoned peat mining sites is 17 065 ha (Figure 32.); 108 sites according to the inventory of Lithuanian Geological Service. However, majority is either overgrown by forests (2nd category - 12 942 ha) or has valid permissions for peat mining (3rd category - 879 ha). The rest of the peatlands covering 2005 ha is suitable for paludiculture without any restrictions as it is abandoned and not forested. Figure 32. indicates distribution of cultivated and abandoned peatland mining sites in Lithuania which are bigger than 10 ha.

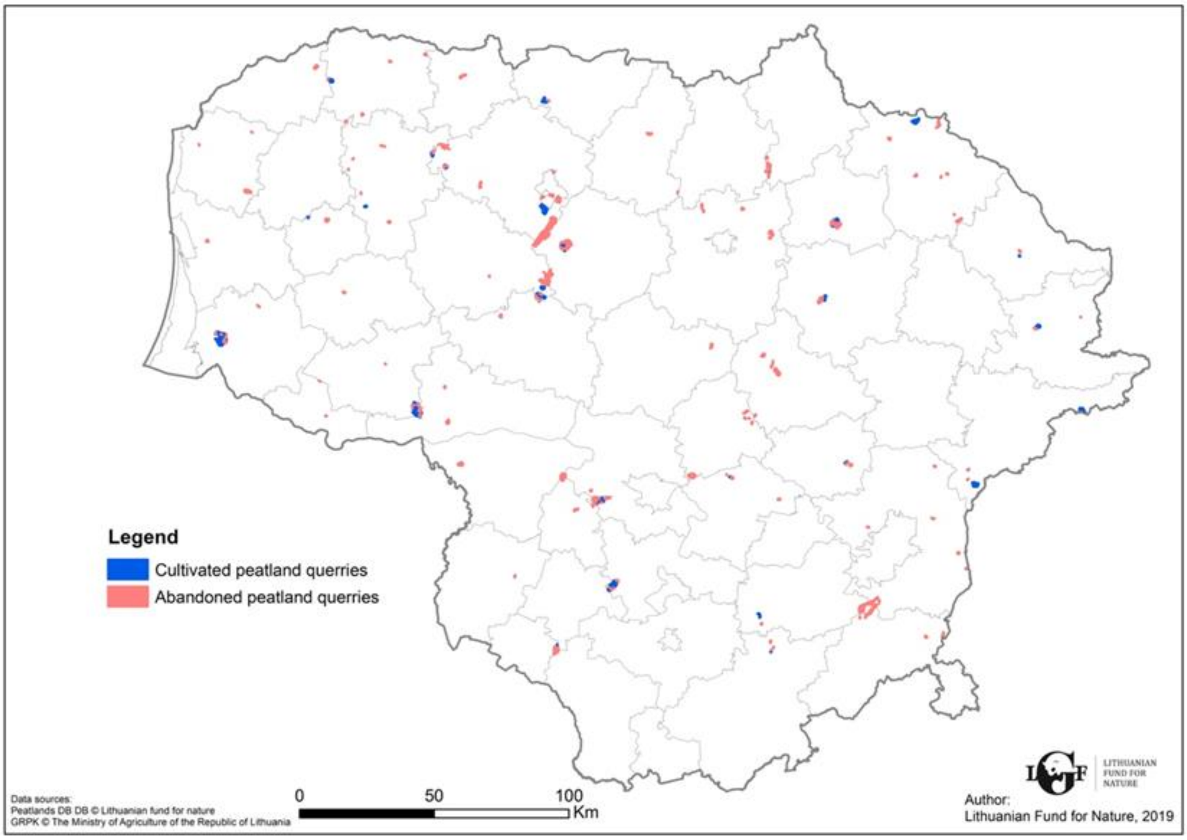


Figure 32. Distribution cultivated and abandoned peatland mining sites in Lithuania (<10 ha).

Distribution of peatlands which can be utilized for energetic purposes

Distance analysis of potential paludiculture biomass resources to heating plants and pelleting factories in Lithuania for the 3rd and 4th category peatlands, were done. It is considered that the transportation of biomass up to 15 km from the place of extraction can be realised cost efficiently. Buffer analysis showed that 205 181 ha of all wetlands and peatlands in Lithuania fall into the buffer zone with 15 km radius to the biomass facilities (see Figure 33.). The assumption was made, that all sites are accessible by roads due to well-developed road network in Lithuania. The most promising areas for development of this activity are perennial meadows and pastures (about 37 969 ha) located in the buffer zones of biomass heating plants. Arable land and other land use categories occupy 35 438 ha and 68 536 ha respectively.

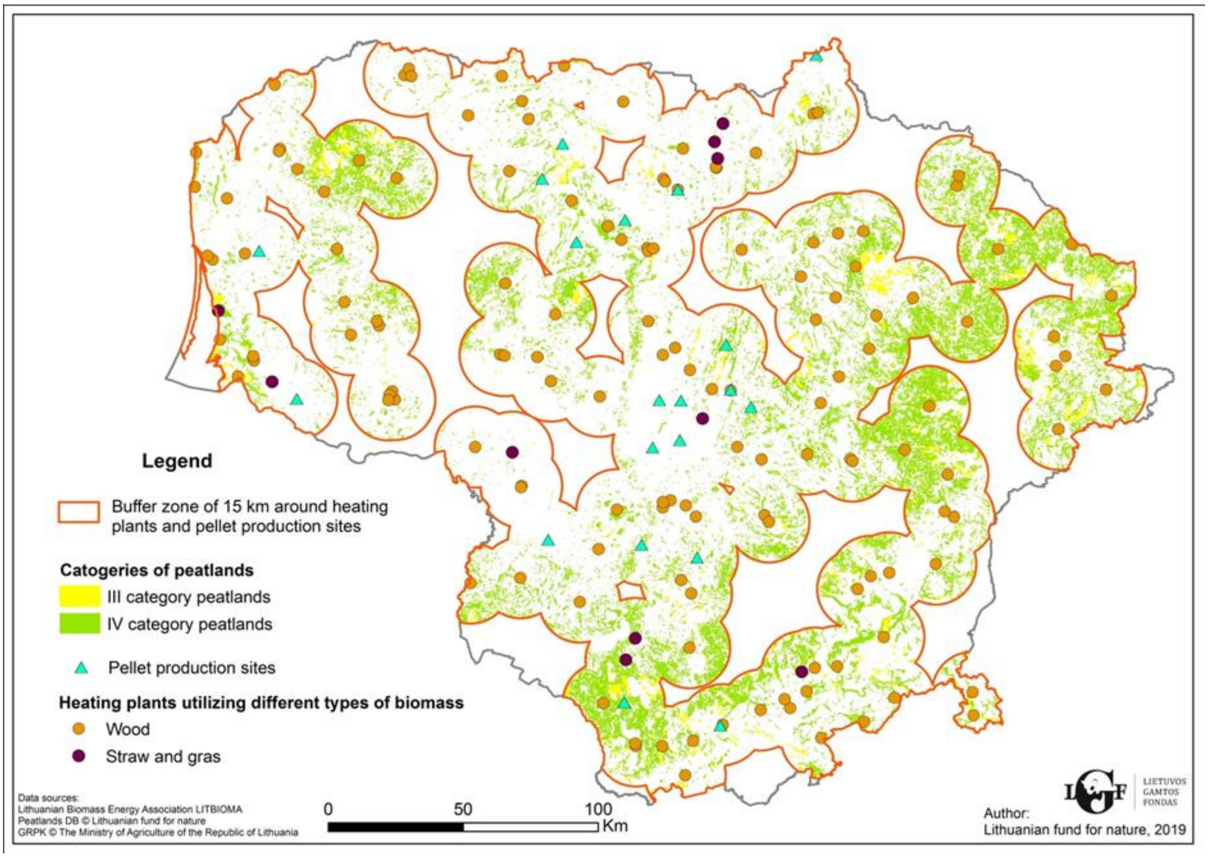


Figure 33. Spatial distribution of Category III and IV wetlands and peatlands within 15 km buffer around biomass heating plants and pelleting factories in Lithuania.

Biomass harvesting in protected areas

Based on recent data[8], nature management plans were implemented until 2019 in 30 peatlands (Figure .34), which totally cover approx. 8 thousand ha (based on www.biomon.lt and personal collection of data). However, majority of these actions are focused on restoration of hydrological regimes, while biomass harvesting for habitat quality management is not the first priority (especially in case of damaged raised bogs restoration). Biomass is harvested in approx. 6 peatlands, mainly clearing of trees and bushes according to the management plan. The volume of removed regrowth of vegetation generates insignificant amounts of biomass.

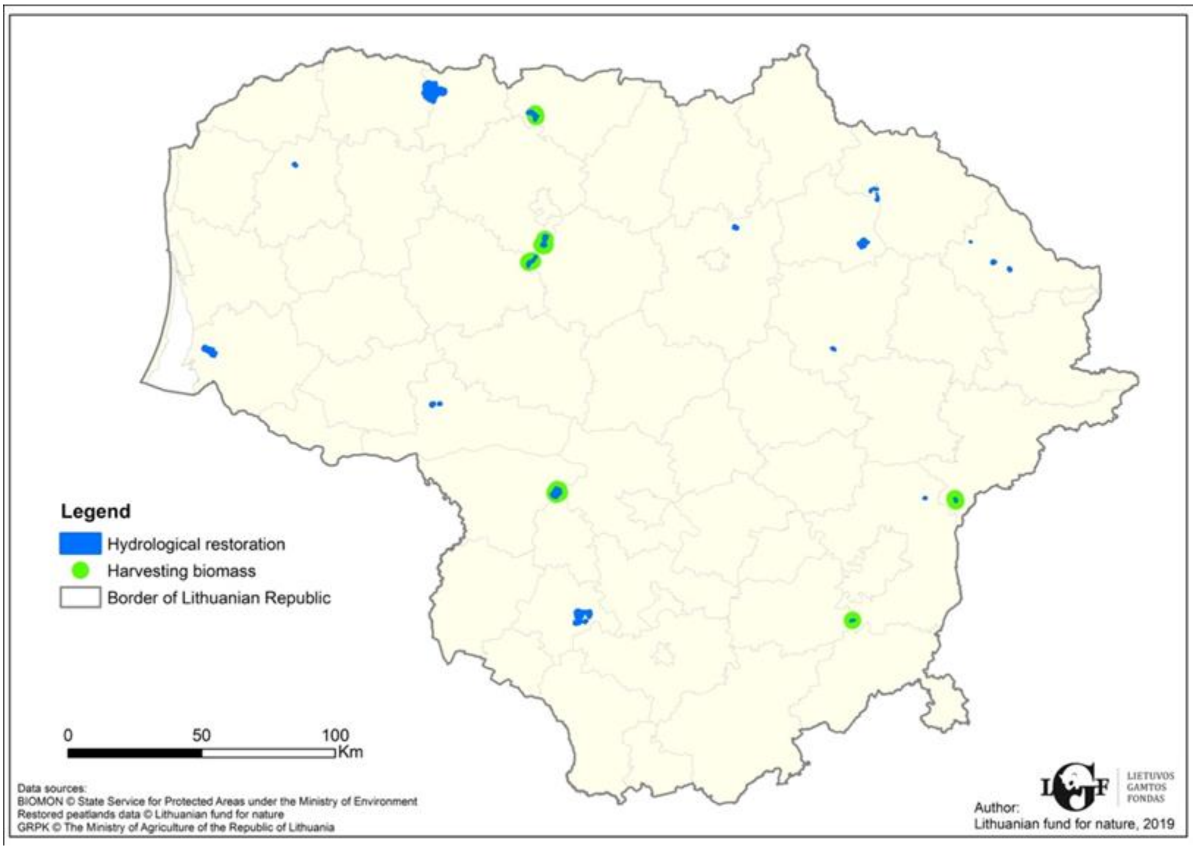


Figure 34. Management activities in protected peatlands in Lithuania.

[8] https://biomon.lt/maps/index.php

Combined results

For all three Baltic countries together in total 450 668 ha in the ’green’ category were calculated from 95 656 areas (polygons). An average plot size was 6,2 ha. The maximum size was 4596 ha.

Table 8. Numbers of areas (# areas) and total area size of the four readiness classes identified for the Pan-Baltic overview and country wise total areas sizes.

	# areas	Area EE [ha]	Area LV [ha]	Area LT [ha]	∑ area [ha]
Red	47 702	215 906	194 684	116 960	527 550
Orange	78 857	282 557	142 936	244 055	669 548
Yellow	40 831	14 639	65 781	17 202	97 622
Green	95 656	76 588	111 390	262 690	450 668
Total	263 046	589 690	514 791	640 907	1 745 388

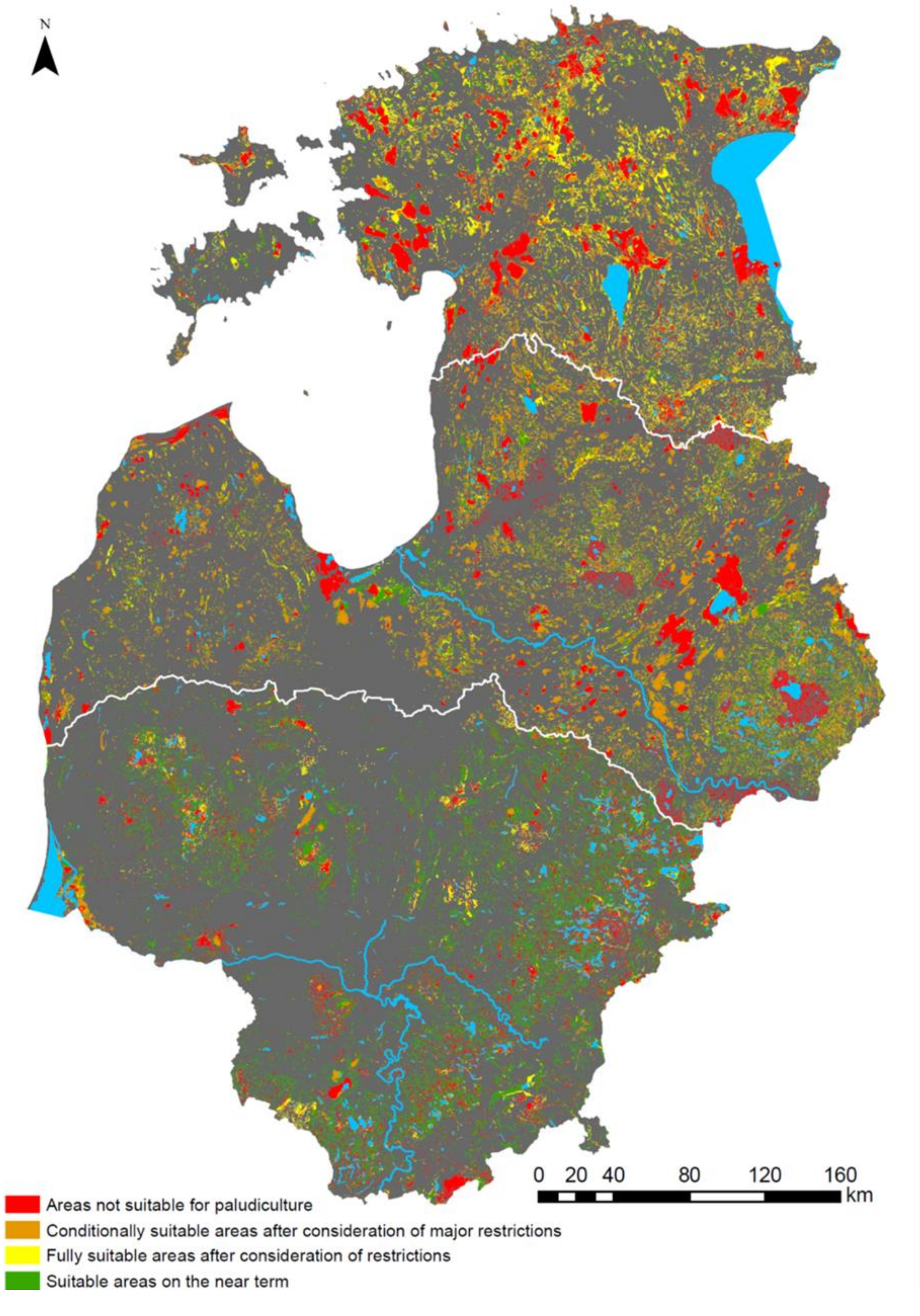


Figure 32. Suitability of land for paludiculture in Estonia, Latvia and Lithuania