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Modelling habitat probability maps for EUNIS habitat types heathland, scrub and tundra based on vegetation relevés, environmental data and Copernicus land cover data

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1 Background and objectives

1.1 Background

This report is part of the assignment of Wageningen Environmental Research (Alterra) for the European Topic Centre Biological Diversity (ETC/BD). The European Topic Centres (ETCs) are international consortia brought together to support the European Environment Agency (EEA) in its mandate on environmental information. ETCs are according to the EEA regulation and in practice, an important instrument in supporting the EEA through the execution of sizeable, continuous, well-defined tasks with the involvement of member countries. In particular ETCs support EEA data centres for the issues related to air, climate change, water, biodiversity and land use and may provide help to EEA in supporting other data centres coordinated by Eurostat and JRC. The ETC/BD is an international consortium working with the European Environment Agency under a framework partnership agreement. The main tasks of ETC/BD are to:

1. Assist the EEA in its task of reporting on Europe's environment by addressing state and trends of biodiversity in Europe.
2. Provide the relevant information to support the implementation of environmental and sustainable development policies in Europe in particular for EU nature and biodiversity policies (DG Environment: Nature and Biodiversity).
3. Build capacity for reporting on biodiversity in Europe, mainly through the European Information and Observation Network (Eionet).

More information about ETC/BD can be found at: http://bd.eionet.europa.eu/

1.2 Objectives

This report is affiliated with task 1.7.5A from the ETC/BD Action Plan 2016. The general objectives of this task are:

- To support the preparation of EEA contributions to ecosystems assessments and their conditions based on existing information and data to support the 2020 EU Biodiversity Strategy (and its targets), in particular relevant data gathered from the Nature Directives, Agriculture and Forests, in close dialogue with the MAES process.
- To contribute to the biodiversity knowledge base by gathering evidence on the main drivers of biodiversity loss and biological characterisation of ecosystems helping a better understanding on links between pressures and conditions.
- To explore the contribution of Copernicus on the monitoring of habitats, species and the Natura 2000 network.
- To explore the results of the Article 12 (Birds Directive) and Article 17 (Habitats Directive) contained in the EEA State of Nature report – for diverse assessment purposes.
- To support thematic assessments including agricultural, forest, marine and freshwater assessments.
- To support the work on further convergence of the assessments between Water, Nature Directives and biodiversity information flows.

More specifically, the objective in relation to this report is: **to enhance the spatial delineation of ecosystems with remote sensing data, environmental data and in-situ vegetation relevés to produce habitat probability maps for heathlands, scrublands and tundra.** Starting point are the habitat suitability maps ‘Distribution and habitat suitability maps of revised EUNIS heath, scrub and tundra types’ delivered within the 2015 EEA contract (Hennekens & Schaminée, 2016). Next to the EEA report ‘Review of EUNIS heathland-scrub-tundra habitats’ (Schaminée et al., 2015). This review report has been made to underpin the EUNIS classification with well-documented information on the highly diverse European vegetation. Crosswalks have been developed between level 3 EUNIS terrestrial habitat types and vegetation syntaxa. More specifically, the project reviewed the description and classification of level 3 of **habitat group F** of **EUNIS Heathland, scrub and tundra** as well as heathland and scrub included under **habitat group B** (B1.5: Coastal dune heaths; B1.6: Coastal dune scrub; B2.5: Shingle and gravel beaches with scrub). Proposals were made for improving the EUNIS classification and the above reports were used as point of departure for the study in this report.

Table 1.1 List of the revised EUNIS heath, scrub and tundra habitat types at level 3

EUNIS-3 code	**EUNIS-3 habitat name**
F1.1	Shrub tundra
F1.2	Moss and lichen tundra
F2.1	Subarctic and alpine dwarf Salix scrub
F2.2a	Alpine and subalpine ericoid heath
F2.2b	Alpine and subalpine Juniperus scrub
F2.2c	Balkan subalpine genistoid scrub
F2.3	Subalpine deciduous scrub
F2.4	Subalpine Pinus mugo scrub
F3.1a	Lowland to montane temperate and submediterranean Juniperus scrub
F3.1b	Temperate Rubus scrub
F3.1c	Lowland to montane temperate and submediterranean genistoid scrub
F3.1d	Balkan-Anatolian montane genistoid scrub
F3.1e	Temperate and submediterranean thorn scrub
F3.1f	Low steppic scrub
F3.1g	Corylus avellana scrub
F3.1h	Temperate woodland clearing scrub
F4.1	Wet heath
F4.2	Dry heath
F4.3	Macaronesian heath
F5.1-2	Arborescent matorral and maquis
F5.3	Submediterranean pseudomaquis
F5.4	Spartium junceum fields
F5.5	Thermo-Mediterranean scrub
F6.1a	Western basiphilous garrigue
F6.1b	Western acidophilous garrigue
F6.2	Eastern garrigue
F6.6	Supra-Mediterranean garrigue
F6.7	Mediterranean gypsum scrub
F6.8a	Mediterranean halo-nitrophilous scrub
F6.8b	Caspian halo-nitrophilous scrub

F7.1	Western Mediterranean coastal garrigue
F7.3	Eastern Mediterranean spiny heath (phrygana)
F7.4a	Western Mediterranean mountain hedgehog-heath
F7.4b	Central Mediterranean mountain hedgehog-heath
F7.4c	Eastern Mediterranean mountain hedgehog-heath
F7.4d	Canarian mountain hedgehog-heath
F8.1	Canary Island xerophytic scrub
F8.2	Madeiran xerophytic scrub
F9.1a	Arctic, boreal and alpine riparian scrub
F9.1b	Temperate riparian scrub
F9.2	Salix fen scrub
F9.3	Mediterranean riparian scrub
B1.5a	Atlantic and Baltic coastal Empetrum heaths
B1.5b	Atlantic coastal Calluna and Ulex heaths
B1.6a	Atlantic and Baltic coastal dune scrub
B1.6b	Mediterranean and Black Sea coastal dune scrub
B1.6c	Macaronesian coastal dune scrub
B2.5	Shingle and gravel beaches with scrub

1.3 Content of the report

This report on the production of the EUNIS habitat probability maps at level 3 for Heathland, Scrub and Tundra has 4 chapters. Chapter 1 describes the background and the objectives of the project. Chapter 2 is an introduction on the habitat modelling, starting with the distribution maps, followed by habitat suitability and habitat probability. The integration of in-situ vegetation relevés, environmental data layers and remotely sensed information, such as high resolution land cover information, plays an important role in the overall methodology. Chapter 3 explains how the EUNIS habitat suitability maps have been produced. Chapter 4 describes how the habitat probability maps (100 m resolution) have been derived from the habitat suitability maps (on a 1km resolution). Annex I shows all 38 habitat probability maps for Heathland, Scrub and Tundra, including the habitat distribution and suitability maps, and a detailed example of the habitat probability maps.

2 Introduction to habitat modelling

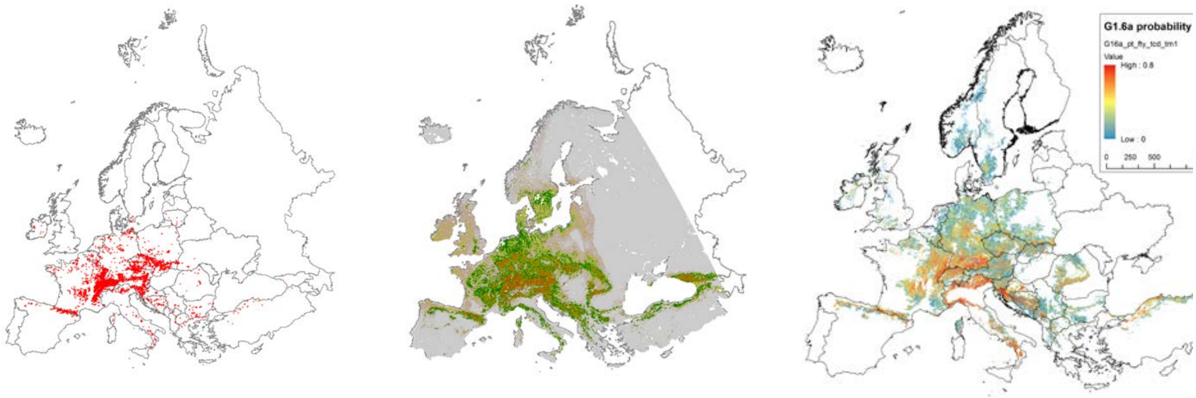
Although it is rare to record or map EUNIS habitat types in the field, there are many data sources which allow mapping of their distribution. The most important single source of information are vegetation plots (also known as relevés), given areas in which all plant species occurring are recorded. In the past few years a large number of national and regional databases with such data have been brought together within the European Vegetation Archive project (http://euroveg.org/eva-database). Together with other sources of data, they allow the production of several types of distribution map as explained below.

Distribution - maps of known occurrences based on the locality of plots which can be assigned to the EUNIS habitat class. They show localities where the habitat is known to occur (at least at the time of survey), but give an incomplete record of the actual distribution.

Suitability - modelling of areas where the environment is suitable for the habitat.

Probability - the modelled suitability map is refined by using information on land cover.

2.1 Methodology



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Distribution → ***Suitability →*** ***Probability***

Figure 2.1 G1.6a: Fagus woodland on non-acid soils

The road from individual vegetation relevés to finally a probability map of a EUNIS class, roughly comprises three steps (see also figure 2.1).

1. Relevés stored in the European Vegetation Database (EVA) are assigned to EUNIS classes using expert rules. An expert rule defines the floristic composition (which species should be present and which species should be absent) of a class and is used to select those relevés that meet the imposed condition. The selection is used to create a **distribution map,** as far as the geographic location is tied to the relevés.
2. The distribution, by means of geographic locations of the relevés, is used in the second step, the distribution model. For the modelling the distribution data are related to climate and soil data, environmental data that is stored in grid maps at a European scale. The modelling software Maxent (Phillips et al., 2006) calculates which environmental layers have the largest contribution to the model, in other words, explains the distribution of the vegetation relevés (thus the EUNIS class) the best. One of the outcomes of the model is a **suitability map**. This map indicates how suitable, in terms of climate and soil conditions an area is for the EUNIS class concerned. This on a scale of 0 to 1 with colors running from white, via green to red.

3. Where step 1 and 2 are bottom-up approaches, the third step is a top-down approach, where all kind of land cover data (earth observation data like high resolution satellite data), and in some cases abiotic data (e.g. distance to rivers, presence of podzolls), is used to filter the suitability map to eventually get to a refined **probability map**. As such the probability map is a refinement of the suitability map.

While the suitability map can be considered as a potential distribution map, the probability map presents more the actual distribution. Still the latter map represents a modelled distribution and overestimates the actual distribution.

All three steps are explained more in detail in the unpublished report 'Modelling the spatial distribution of EUNIS forest habitat types' by Mücher, C.A., Hennekens, S.M., Schaminée, J.H.J & Halada, L. (2015).

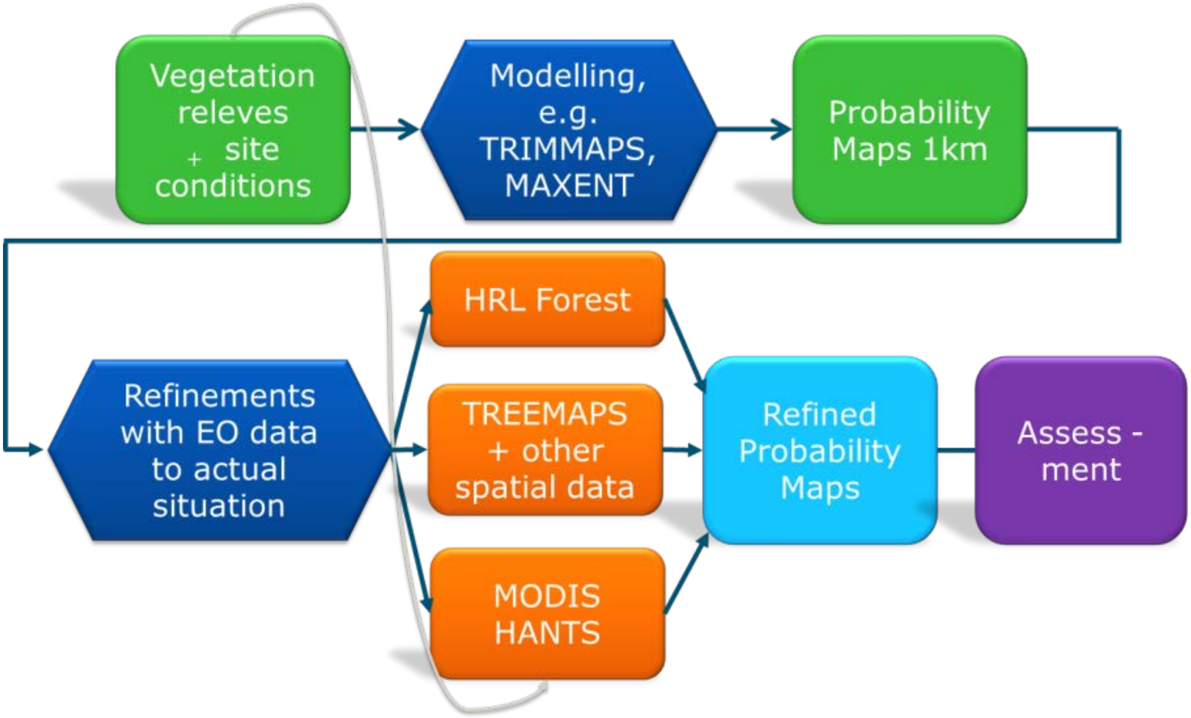

Figure 1.2 General workflow for the processing of refined EUNIS forest habitat probability maps (Mücher et al., 2015)

3 Habitat suitability maps

For the habitat suitability modelling, the widely used software Maxent for maximum entropy modelling of species' geographic distributions was used. Maxent is a general-purpose machine-learning method with a simple and precise mathematical formulation, and has a number of aspects that make it well-suited for species distribution modelling when only presence (occurrence) data but not absence data are available (Philips et al. 2006). Because EUNIS habitats have a particular species composition, they are assumed to respond to specific ecological requirements, allowing to generate correlative estimates of geographic distributions. Modelling habitats that have been floristically defined is a well-known procedure for ecological modelling at local scales, and a promising technique to be applied also at the continental level.

The Maxent method considers presence data (known observations of a given entity) and the so-called background data. Background data comprise a set of points used to describe the environmental variation of the study area according to the available environmental layers. It is assumed that these layers represent well the most important ecological gradients on a European scale. These layers were selected from meaningful environmental predictors commonly used for modelling non-tropical plant and vegetation diversity, and are not mutually strongly correlated.

As environmental data (and their sources) the following climate and soil layers have been used:

- Potential Evapotranspiration
  http://www.cgiar-csi.org/data/global-aridity-and-pet-database
  Solar radiation
  http://www.worldgrids.org/doku.php?id=wiki:inmsre3
- Temperature Seasonality (standard deviation *100)
  http://www.worldclim.org/bioclim
- Mean Temperature of Wettest Quarter
  http://www.worldclim.org/bioclim
- Annual Precipitation
  http://www.worldclim.org/bioclim
- Precipitation Seasonality (Coefficient of Variation)
  http://www.worldclim.org/bioclim
- Precipitation of Warmest Quarter
  http://www.worldclim.org/bioclim
- Distance to water (rivers, lakes, sea)
  derived from the shapefile 'Inland_Waters.shp'
- Bulk density of the soil (kg/m^3)
  Hengl et al. 2014
- Cation Exchange Capacity of the soil
  Hengl et al. 2014
- Weight in % of clay particles (<0.0002 mm)
  Hengl et al. 2014
- Volume % of coarse fragments (> 2 mm)
  Hengl et al. 2014
- Soil organic carbon content (‰)
  Hengl et al. 2014
- Soil pH (water)
  Hengl et al. 2014
- Weight in % of silt particles (0.0002-0.05 mm)
  Hengl et al. 2014

- Weight in % of sand particles (0.05-2 mm)
  Hengl et al. 2014

Compared with the habitat suitability models set up for the EUNIS forest types (Schaminée et al. 2014) we have now included 8 recently published soil paramaters (Hengl et al 2014), instead of only one (soil pH).

Maxent is expected to perform well for estimating the geographic distribution of EUNIS habitats in Europe. However, as with any other modelling techniques, this method is sensitive to sampling bias, i.e. when the spatial distribution of presence data is reflecting an unequal sampling effort in different geographic regions. In Maxent, it has been proposed that the best way to account for sampling bias (when bias is known or expected to occur) is to generate background data reflecting the same bias of the presence data. When a complete set of presence data is available, a general recommendation is to generate background points from the occurrences of other species/communities that were sampled in a similar way (Elith et al. 2011).

Two different approaches have been followed for the selection of a maximum of 5,000 locations for the background data, assuming biased and non-biased presence data. For the first approach, 5,000 locations were randomly selected from the heathland, scrub and tundra plot pool, assuming that they reflect the general geographic bias of heathland, scrub and tundra sampling in Europe. The second approach concerns a random selection of 5,000 background points in the whole study area, assuming that the presence data describe a representative subset of the real distribution range of the target habitat.

The two modelling approaches (assuming biased and non-biased data) were evaluated for each of the EUNIS habitat types in order to estimate which assumption is more likely. This evaluation was based on the expert knowledge of the team members of the distribution of heathland, scrub and tundra types by assessing (i) the distribution of the available presence data as an estimate of geographic bias, (ii) the realism of the habitat suitability maps to reflect known distribution of heathland, scrub and tundra, and (iii) the environmental predictors that contribute most substantially to the models. The best performing model was then selected by consensus of the expert team for each habitat type
For 5 EUNIS types (B1.6c, F4.3, F7.4d, F8.1, F8.2) no data was available and for 5 types (B1.6b, F1.2, F2.2c, F3.1d, and F6.8b) there was insufficient data to create a model.

For each EUNIS heathland, scrub and tundra type the following data are presented:

- A distribution map showing the location of the relevés that have been assigned to the EUNIS type concerned and therefore used as presence data.
- A habitat suitability map with colors varying from gray, through green to red, indicating increasingly favorable ecological conditions for the type (expressing the logistic output of the model between 0 and 1).
- AUC, or the "Area Under the Curve", as a general estimate of model performance. This is the probability that the classifier correctly orders two points (a random positive example and a random negative example). In general, AUC values in the range 0.5-0.7 were considered low, 0.7-0.9 were moderate and >0.9 were high, suggesting poor, good and very good model performances, respectively. We provide two estimates of the AUC as calculated by Maxent. 'AUC training' reflects the internal fit between observed and predicted occurrences in the computed model. 'AUC test' provides the mean AUC obtained from a 10-fold cross-validation procedure in which ten different models were computed with a random selection of 90% of data (calibration data set) and 10% for testing the model (validation data set).
- Contribution variables to the Maxent model (%). Indicates to what extent the environmental variables contribute to the model.

The habitat **suitability** maps are used as input to model habitat **probability** maps using amongst others actual land cover, next to the use of topographic information such as, biogeographic regions, countries, distance to coast and rivers.

4 Habitat probability maps

The habitat probability maps are created by downscaling the habitat suitability maps by actual land cover. This report concerns heathland, scrub and tundra and therefore we would like to use very high resolution land cover maps for these land cover types. Unfortunately the Copernicus HRLs (High Resolution Layers with a 20 meter spatial resolution) only exist for the following specific topics: 1) imperviousness 2) forests; 3) permanent waterbodies; 4: grasslands and 5) wetlands. Nevertheless, we have the Copernicus land cover database Corine with a spatial resolution of 100 meter. The most recent version is Corine Land Cover 2012 (CLC2012). Since the minimum mapping unit of CLC is 25 ha, and therefore still quite course for habitat mapping, we decided to use some of the HRLs as a mask for CLC2012, and is further explained below.

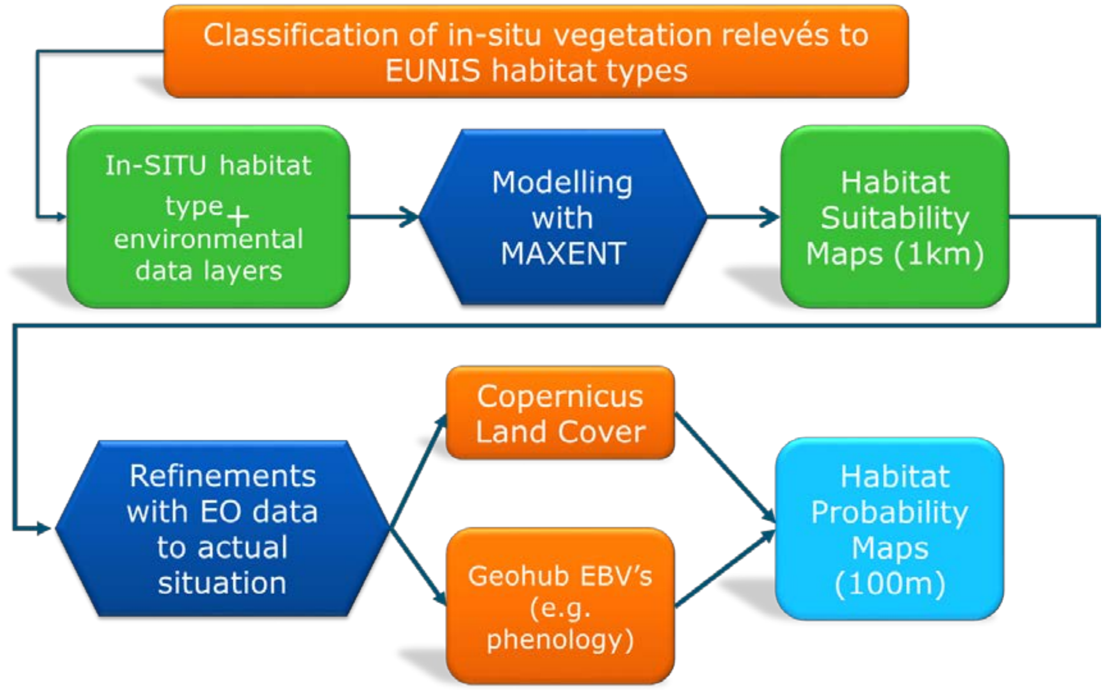

Figure 4.1 Flowchart of the methodology implemented to obtain habitat probability maps

4.1 Land Cover

CLC2012 is the 4th CORINE Land Cover inventory and took 3 years to finalize. The CORINE Land Cover (CLC) inventory was initiated in 1985 (reference year 1990). Updates have been produced in 2000, 2006, and 2012. It consists of an inventory of land cover in 44 classes. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100 m for linear phenomena. Therefore the rasterized version of the original vector based CLC is 100 m. For CLC20102 a dual coverage of satellite images were used. Computer Assisted Photo-Interpretation (CAPI) was the dominating mapping technology. The number of countries using advanced (bottom-up) solutions has slightly increased. All of the EEA39 countries have participated within the official lifetime of the project. It is still possible that minor updates will follow with next version. The product is only partially validated.

Table 4.1 Nomenclature Corine Land Cover

	level 1		Level 2	Code	Level 3 CORINE land cover class	Nr.
1.	Artificial surfaces	1.1	urban fabric	1.1.1	continuous urban fabric	1
				1.1.2	discontinuous urban fabric	2
		1.2	industrial, commercial and	1.2.1	industrial and commercial units	3
			transport units	1.2.2	road and rail networks and associated land	4
				1.2.3	port areas	5
				1.2.4	airports	6
		1.3	mine, dump and	1.3.1	mineral extraction sites	7
			construction sites	1.3.2	dump sites	8
				1.3.3	construction sites	9
		1.4	artificial non-agricultural	1.4.1	green urban areas	10
			vegetated areas	1.4.2	port and leisure facilities	11
2	Agricultural areas	2.1	arable land	2.1.1	non-irrigated arable land	12
				2.1.2	permanently irrigated land	13
				2.1.3	rice fields	14
		2.2	permanent crops	2.2.1	vineyards	15
				2.2.2	fruit trees and berry plantation	16
				2.2.3	olive groves	17
		2.3	pastures	2.3.1	pastures	18
		2.4	heterogeneous agricultural areas	2.4.1	annual cops associated with permanent crops	19
			agricultural areas	2.4.2	complex cultivation patterns	20
				2.4.3	land principally occupied by agriculture with significant natural vegetation	21
				2.4.4	agro-forestry areas	22
3.	Forests and semi-natural	3.1	forest	3.1.1	broad-leaved forest	23
	Areas			3.1.2	coniferous forest	24
				3.1.3	mixed forest	25
		3.2	shrub and/or herbaceous	3.2.1	natural grasslands	26
			vegetation associations	3.2.2	moors and heath lands	27
				3.2.3	sclerophyllous vegetation	28
				3.2.4	transitional woodland-scrub	29
		3.3	open spaces with little or no	3.3.1	beaches, sand, dunes	30
			vegetation	3.3.2	bare rocks	31
				3.3.3	sparsely vegetated areas	32
				3.3.4	burnt areas	33
				3.3.5	glaciers and perpetual snow	34
4	Wetlands	4.1	inland wetlands	4.1.1	inland marshes	35
				4.1.2	peat bogs	36
		4.2	coastal wetlands	4.2.1	salt marshes	37
				4.2.2	salines	38
				4.2.3	intertidal flats	39
5	Water bodies	5.1	inland waters	5.1.1	water courses	40
				5.1.2	water bodies	41
		5.2	marine waters	5.2.1	coastal lagoons	42
				5.2.2	estuaries	43
				5.2.3	sea and ocean	44

In a next step, the CLC2012 has been masked with the HRLs Forest, Imperviousness and permanent waterbodies. This is especially relevant for the semi-natural land cover classes from CLC2012 that have a MMU of 25 ha and in realty more fragmented (by for example small artificial features, waterbodies or forest patches).

The use HRLs Forest, Imperviousness and permanent waterbodies are also from 2012. But for all 3 HRLs 2012 we used the aggregated 100m products which have the same spatial resolution as rasterized CLC2012. For Forests we used the HRL forest type (FTY). The forest type product allows to get as close as possible to the FAO forest definition. The FTY distinguishes 3 classes: deciduous, needleleaf and mixed forest. All forests classes were used as a mask. Permanent Water bodies: 1) Permanent Water Bodies; 254: unclassifiable (no satellite image available, or clouds, shadows, or snow); 255: outside area. Only class 1, permanent water bodies, was used as a mask for CLC2012. Imperviousness indicated to built-up areas that are characterized by the substitution of the original (semi-) natural land cover or water surface with an artificial, often impervious cover. These artificial surfaces are usually maintained over long periods of time. The imperviousness HRL captures the spatial distribution of artificially sealed areas, including the level of sealing of the soil per area unit. The level of sealed soil (imperviousness degree 1-100%) is produced using an automatic algorithm based on calibrated NDVI.

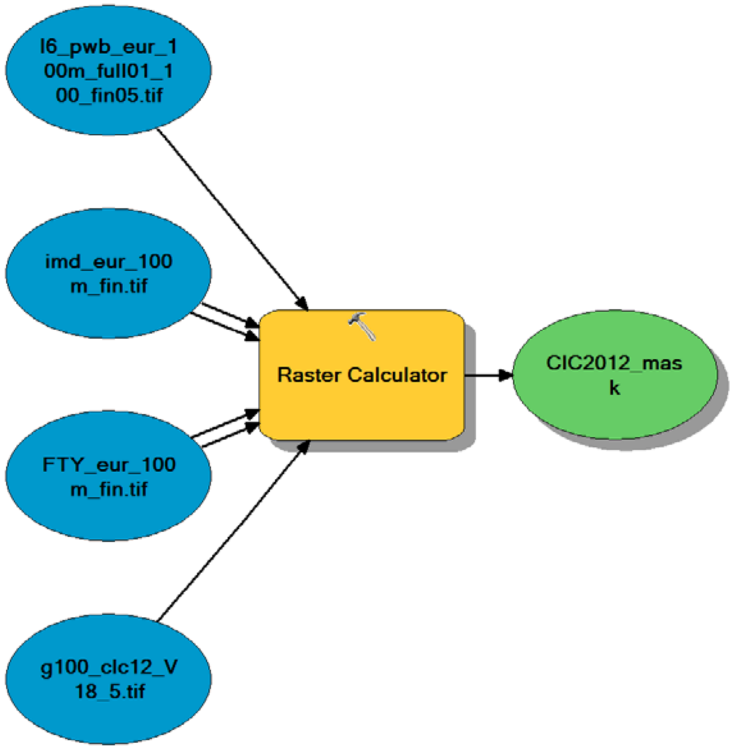

Figure 4.2 Flowchart for the calculation of the CLC20102 masked by imperviousness, water bodies and forests. The conditional in the raster calculator is: Con((("%FTY_eur_100m_fin.tif%" > 0) & ("%FTY_eur_100m_fin.tif%" < 4)),0, Con((("%imd_eur_100m_fin.tif%"> 0) & ("%imd_eur_100m_fin.tif%" < 101)),0, Con("%l6_pwb_eur_100m_full01_100_fin05.tif%" >0,0, "%g100_clc12_V18_5.tif%")))

The result of the CLC2012_mask is shown in Figure 4.3.

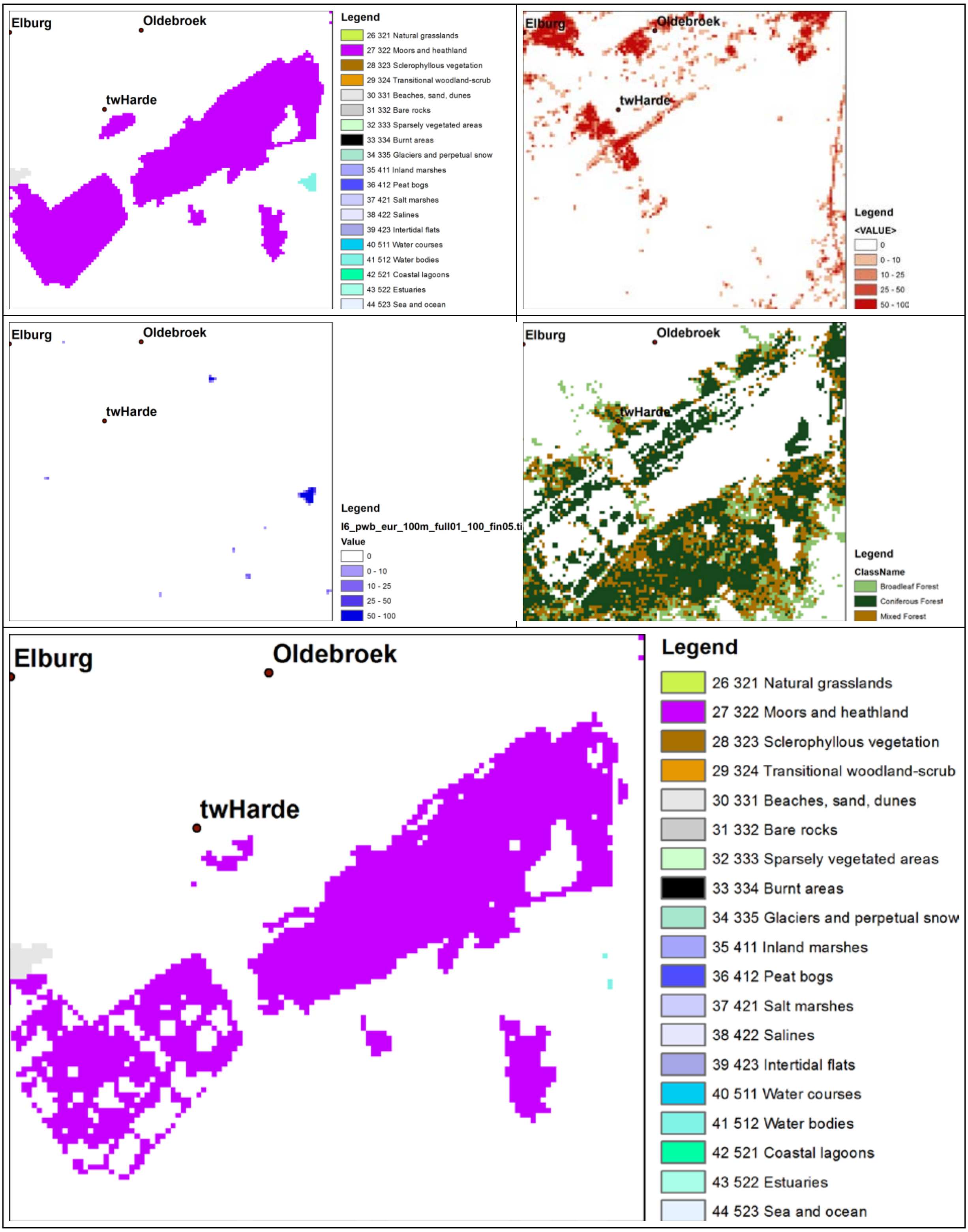

Figure 4.3 Process of masking CLC2012 with HRLs 2012: Imperviousness, Waterbodies and Forest. The results is CLC21012 masked that shows a more realistic fragmented semi-natural land cover

4.2 Relationship CLC with in-situ vegetation relevés

To determine the relationship between the EUNIS habitat types at level 3 and the Corine Land Cover (CLC20102) we used the report of D. Moss (2012) 'A crosswalk between EUNIS habitats Classification and Corine Land Cover' (source: http://biodiversity.eionet.europa.eu) as starting point. However, this report shows a one-to-one relationship, while we know that in most cases the EUNIS habitat types are not related to a single land cover types. Since we have 34,324 vegetation relevés for Heathland, Scrub and Tundra that overlay with CLC20102, we calculated for each EUNIS habitat type with which land cover types their vegetation relevés match (spatial summary statistics).

Thus, if we take EUNIS habitat type F4.1 'Wet heath' as an example, we find the following spatial relationship between the 2290 vegetation relevés and the CLC2012, which is a one-to-many relationship, as show in the table below. Since there can be a spatial mismatch between CLC2012 and the vegetation relevés for several reasons, we did look only at percentages of 5% or higher. And of course we did look at the relationship with CLC2012 only for the semi-natural land cover classes (excluding the forest classes as well). In Table 4.2, this analysis reveals that for EUNIS habitat type F4.1 'Wet heath', there is especially a relationship with CLC2012 classes 26 'natural grasslands' (5.72), class 27 'moors and heath lands'(20.66%) and class 36 'peat bogs' (19.04%). For the nomenclature of CLC20212, see Table 4.1.

Table 4.2 Summary table of the spatial relationships between EUNIS habitat type F4.1 'Wet heath' with 2290 vegetation relevés and CORINE land cover (CLC20102)

F41 (nr= 2290)		
ClC2012	Count	%
2	46	2.01
3	2	0.09
4	2	0.09
6	1	0.04
7	2	0.09
10	1	0.04
11	5	0.22
12	90	3.93
16	1	0.04
17	1	0.04
18	251	10.96
20	107	4.67
21	60	2.62
23	161	7.03
24	218	9.52
25	106	4.63
26	131	5.72
27	473	20.66
29	32	1.40
30	36	1.57
31	2	0.09
32	41	1.79
35	39	1.70
36	436	19.04
39	4	0.17
41	9	0.39
42	10	0.44
44	23	1.00
	2290	100.00

Table 4.3 shows the overall summary of the relationships between each EUNIS habitat type and CLC2012 (as indicated by D. Moss but also from our spatial analysis) and additional filters that we used to model the habitat probability.

Table 4.3 Overview of the habitat probability maps for heath, scrub and tundra and the applied Copernicus land cover information and additional filters that have been used

Nr	EUNIS-3 code	EUNIS-3 habitat name	Relationship to CLC (D. Moss)	Relationship to CLC (relevés)	BGR filter	Topo filter
1	F1.1	Shrub tundra	Sparsely vegetated (333)	32 + 27, 31	Yes	No
2	F2.1	Subarctic and alpine dwarf Salix scrub	Sparsely vegetated (333)	32 + 31	Yes	No
3	F2.2a	Alpine and subalpine ericoid heath	Moors and heathland (322)	32+ 26, 27, 31	No	No
4	F2.2b	Alpine and subalpine Juniperus scrub	Moors and heathland (322)	32 + 26, 27, 29	No	No
5	F2.3	Subalpine deciduous scrub	Moors and heathland (322)	27 + 26, 31, 32, 29	No	No
6	F2.4	Subalpine Pinus mugo scrub	Moors and heathland (322)	27 + 26, 29, 32	No	No
7	F3.1a	Lowland to montane temperate and submediterranean Juniperus scrub	Moors and heathland (322)	27 + 26, 29, 32	No	No
8	F3.1b	Temperate Rubus scrub	Moors and heathland (322)	27 + 26, 29	No	No
9	F3.1c	Lowland to montane temperate and submediterranean genistoid scrub	Moors and heathland (322)	27 + 26, 28, 29	No	No
10	F3.1e	Temperate and submediterranean thorn scrub	Moors and heathland (322)	27 + 26, 29	Yes	No
11	F3.1f	Low steppic scrub	Sparsely vegetated (333)	32 + 29	Yes	No
12	F3.1g	Corylus avellana scrub	?	23, 24, 25, 26, 29, 31	Yes	No
13	F3.1h	Temperate woodland clearing scrub	Sparsely vegetated (333)	23, 24, 25, 26, 27, 29	No	No
14	F4.1	Wet heath	Moors and heathland (322)	27 + 26, 36	No	No
15	F4.2	Dry heath	Moors and heathland (322)	27 + 26, 36	No	No
16	F5.2	Arborescent matorral and maquis	Sclerophyllous vegetation (323)	28 + 29	Yes	No
17	F5.3	Submediterranean pseudomaquis	Sclerophyllous vegetation (323)	28 + 23, 24, 25, 26, 28, 29	Yes	No
18	F5.4	Spartium junceum fields	Moors and heathland (322)	27 + 26, 28, 29	Yes	No
19	F5.5	Thermo-Mediterranean scrub	Sclerophyllous vegetation (323)	28	Yes	No
20	F6.1a	Western basiphilous garrigue	Sclerophyllous vegetation (323)	28 + 26, 27, 29	No	Yes
21	F6.1b	Western acidophilous garrigue	Sclerophyllous vegetation (323)	28 + 26, 29, 30	No	Yes
22	F6.2	Eastern garrigue	Sclerophyllous vegetation (323)	28 + 26, 29, 32	No	Yes
23	F6.6	Supra-Mediterranean garrigue	Sclerophyllous vegetation (323)	28 + 26, 29, 31, 32	No	Yes
24	F6.7	Mediterranean gypsum scrub	Moors and heathland (322)	27 + 28, 32	Yes	No

25	F6.8a	Mediterranean halo-nitrophilous scrub	Moors and heathland (322)	27 + 28	Yes	Np
26	F7.1	Western Mediterranean coastal garrigue	Sclerophyllous vegetation (323)	28 + 30	No	Yes
27	F7.3	Eastern Mediterranean spiny heath (phrygana)	Sclerophyllous vegetation (323)	28 + 26, 30, 32	No	Yes
28	F7.4a	Western Mediterranean mountain hedgehog-heath	Sclerophyllous vegetation (323)	28 + 26, 27, 28, 29, 32	No	Yes
29	F7.4b	Central Mediterranean mountain hedgehog-heath	Sclerophyllous vegetation (323)	28 + 26, 32	No	Yes
30	F7.4c	Eastern Mediterranean mountain hedgehog-heath	Sclerophyllous vegetation (323)	28 + 27, 29, 32	No	Yes
31	F9.1a	Arctic, boreal and alpine riparian scrub	Moors and heathland (322)	27 + 26, 29, 32	Yes	Yes
32	F9.1b	Temperate riparian scrub	Moors and heathland (322)	27 + 26, 30, 40		Yes
33	F9.2	Salix fen scrub	Moors and heathland (322)	27 + 26, 28	No	No
34	F9.3	Mediterranean riparian scrub	Moors and heathland (322)	27 + 26, 28	Yes	Yes
35	B1.5a	Atlantic and Baltic coastal Empetrum heaths	Moors and heathland (322)	27 + 26, 30	Yes	Yes
36	B1.5b	Atlantic coastal Calluna and Ulex heaths	Moors and heathland (322)	27 + 26, 30	Yes	Yes
37	B1.6a	Atlantic and Baltic coastal dune scrub	Moors and heathland (322)	27 + 26, 30	Yes	Yes
38	B2.5	Shingle and gravel beaches with scrub	Moors and heathland (322)	27 + 26, 30, 37	No	Yes

Annex I shows all 38 habitat probability maps for Heathland, Scrub and Tundra, including the habitat distribution and suitability maps, and a detailed example of the habitat probability maps. In total 152 maps (38 x 4).

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Annex I: the EUNIS heath, scrub and tundra habitat probability maps