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Assessment of the EUNIS heathland, Scrub and tundra habitat probability maps based on Article 17 database

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1 Background and objectives

1.1 Background

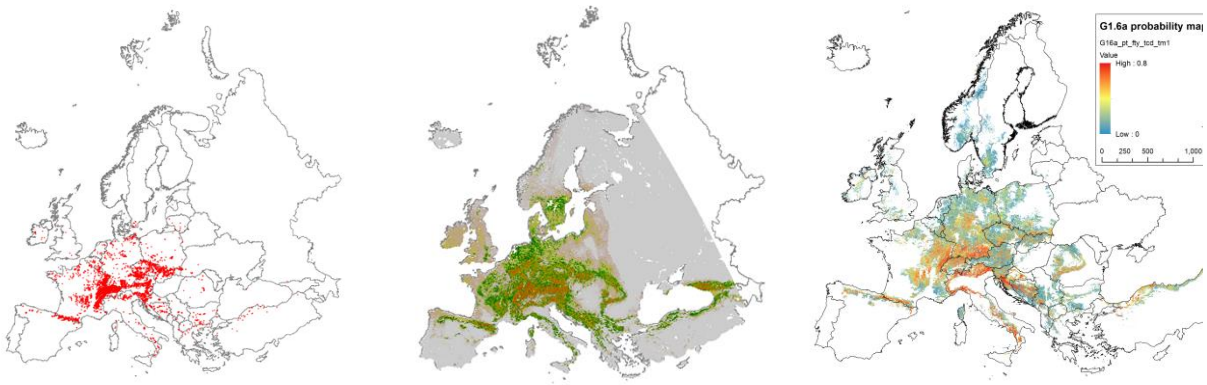
In a former ETC/BD study (Mücher et al. 2015) a methodology was developed to model the spatial distribution of EUNIS forest habitat types for entire Europe at a very high spatial resolution based on in-situ vegetation relevés from the EVA database (European Vegetation Archive), the Copernicus High Resolution Layers (HRL) Forest type and cover and other topographic, climatic and environmental data layers. The same methodology has been used to produce 38 heathland, scrub and tundra habitat probability maps. In short, the habitat probability maps are created by downscaling the potential habitat suitability maps (Schaminée et al., 2013, 2014, 2015, 2016) towards the actual situation by using land cover information and other data sources.

For the habitat suitability modelling, the widely used software Maxent for maximum entropy modelling of species geographic distributions was used (Philips et al. 2006). 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 habitats, e.g. EUNIS or Habitats directive Annex I, have particular species compositions, they are assumed to respond even more specifically to specific ecological conditions than individual species, allowing to generate more precise estimates of geographic distribution of habitats. And those specific habitats represent a wide range of species above and below the ground that are never being monitored individually.

In summary the methodology for the production of the habitat probability maps consists of a 3 step approach:

1. The production of distribution maps based on measured vegetation plots in the field that have been standardized and stored in the EVA database (European Vegetation Archive);
2. The production of habitat suitability maps, which is in fact an environmental modelling exercise based on the Maxent model (Phillips et al., 2006) using as an input the vegetation plots translated to EUNIS habitats at level 3 and many climatic and environmental data layers, such as annual precipitation, mean temperature, potential evapotranspiration, soil organic carbon content, etc.;
3. The production of the habitat probability maps, based on the refinement of habitat suitability maps indicating the potential range of the habitat by actual information from remote sensing. The remote sensing information is the first place based on the Copernicus land cover information, such as the Copernicus high resolution layers or the Corine land cover information. And by adding hard decision rules such as distance to rivers or masking areas out covered by the Copernicus HRLs Forest, Imperviousness and permanent waterbodies. But the use of RS-enabled EBVs such as phenology and vegetation height can also play a role y refining the actual occurrence of a certain habitat type (Skidmore et al., 2015, Pettorelli et al., 2016.

The vegetation relevés are assigned to the EUNIS habitat classes at level 3 by using expert rules. An expert rule defines the floristic composition on 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 This revision did also lead to redefining some of the EUNIS habitat classes at level 3 (Schaminée et al., 2013, 2014, 2015, 2016).



Distribution → *Suitability →* *Probability*

Figure 1.1 Summary of the three-step methodological approach of producing distribution, suitability and probability habitat maps. In this example for Eunis habitat type G1.6a: Fagus woodland on non-acid soils (Mücher et al, 2015)

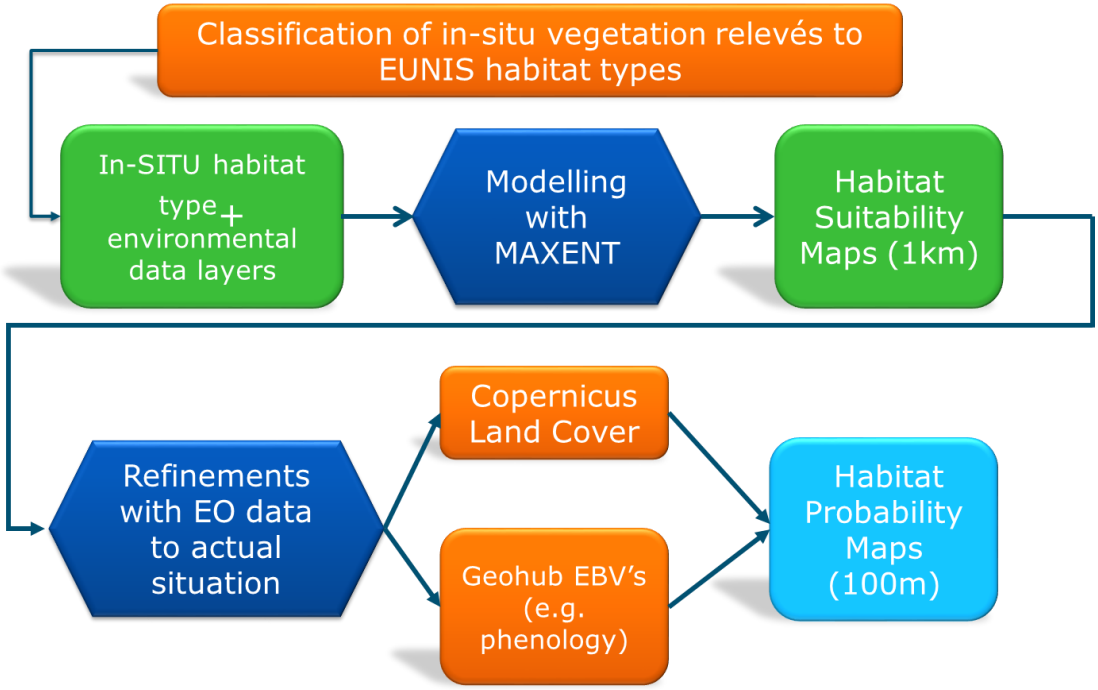


Figure 1.2 Flowchart of the methodology implemented to obtain habitat probability maps

While the habitat suitability maps have a spatial resolution of 1km, the habitat probability have a refined resolution of 20 – 100 meter, depending on the Copernicus land cover data source that has been used.
To better understand the quality of the produced EUNIS heathland, scrub and tundra habitat probability maps it was recognized that it would be wise to make a European wide assessment. This resulted in the idea to make a comparison between the Article 17 database which contains amongst others a European 10 km grid with the presence and absence of all Annex I habitat types – and the produced EUNIS heathland, scrub and tundra probability maps.

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

1.2 Objectives

As a contribution to the task 1.7.5A Ecosystem mapping and assessment as formulated in the 2017 ETC/BD Action Plan, the main objective here is the assessment of our produced EUNIS heathland, scrub and tundra habitat probability maps based on Article 17 database.

The article 17 database is here considered as the ground truth, although translation of Annex I habitat types into EUNIS habitat types is not always straightforward due to the many to many relationships that do not always completely overlap.

The Article 17 spatial database includes information on the presence of Annex I habitats not only in Natura 2000 sites but also beyond them across the entire country. Although the complication is that a few countries had limited the info to the Natura 2000 sites. As stated by the EEA: the Article 17 database contains tabular data as reported by Member States for the 2007-2012 period; this includes habitat areas, population sizes, trends, pressures and threats, and conservation status at the national biogeographical level.

Table 1.1 lists the 38 EUNIS habitat types (at EUNIS level 3) for heath, scrub and tundra for which we have produced the habitat probability maps at a 100 meter spatial resolution and that will be assessed on basis of the Article 17 database on a 10 km grid level. Unfortunately, as stated in Table 1.2, only 29 EUNIS habitat probability maps could be linked to the Article 17 Annex I habitat types (crosswalks), and only those 29 habitat probability maps have been assessed in this report.

Table 1.1 Overview of the 38 produced habitat probability maps for heath, scrub and tundra and related Copernicus land cover information (Mücher et al., 2017)

Nr	EUNIS-3 code	EUNIS-3 habitat name	Relationship to CLC (D. Moss) and EVA relevés (distribution data)
1	F1.1	Shrub tundra	Sparsely vegetated (333), moors and heath lands (322), bare rocks (332)
2	F2.1	Subarctic and alpine dwarf Salix scrub	Sparsely vegetated (333), bare rocks (332)
3	F2.2a	Alpine and subalpine ericoid heath	Moors and heathland (322), natural grasslands (321), moors and heath lands (322), bare rocks (332)
4	F2.2b	Alpine and subalpine Juniperus scrub	Moors and heathland (322), natural grasslands (321), moors and heath lands (322), transitional woodland-scrub (324)
5	F2.3	Subalpine deciduous scrub	Moors and heathland (322), natural grasslands (321), bare rocks (332), Sparsely vegetated (333), transitional woodland-scrub (324)
6	F2.4	Subalpine Pinus mugo scrub	Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324), Sparsely vegetated (333),
7	F3.1a	Lowland to montane temperate and submediterranean Juniperus	Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324), Sparsely vegetated (333),

		scrub	
8	F3.1b	Temperate Rubus scrub	Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324),
9	F3.1c	Lowland to montane temperate and submediterranean genistoid scrub	Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324), sclerophyllous vegetation (323)
10	F3.1e	Temperate and submediterranean thorn scrub	Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324)
11	F3.1f	Low steppic scrub	Sparsely vegetated (333), transitional woodland-scrub (324),
12	F3.1g	Corylus avellana scrub	Broadleaved-foest (311), coniferous forest (312), mixed forest (313), natural grasslands (321), transitional woodland-scrub (324), bare rocks (332)
13	F3.1h	Temperate woodland clearing scrub	Broadleaved-foest (311), coniferous forest (312), mixed forest (313), natural grasslands (321), Moors and heathland (322), transitional woodland-scrub (324)
14	F4.1	Wet heath	natural grasslands (321), Moors and heathland (322), peat bogs 9412)
15	F4.2	Dry heath	natural grasslands (321), Moors and heathland (322), peat bogs 9412)
16	F5.2	Arborescent matorral and maquis	Sclerophyllous vegetation (323), transitional woodland-scrub (324),
17	F5.3	Submediterranean pseudomaquis	Sclerophyllous vegetation (323), Broadleaved-foest (311), coniferous forest (312), mixed forest (313), natural grasslands (321), Sclerophyllous vegetation (323), transitional woodland-scrub (324),
18	F5.4	Spartium junceum fields	Moors and heathland (322), natural grasslands (321), Sclerophyllous vegetation (323), transitional woodland-scrub (324),
19	F5.5	Thermo-Mediterranean scrub	Sclerophyllous vegetation (323)
20	F6.1a	Western basiphilous garrigue	Sclerophyllous vegetation (323), natural grasslands (321), Moors and heathland (322),), transitional woodland-scrub (324),
21	F6.1b	Western acidophilous garrigue	Sclerophyllous vegetation (323), natural grasslands (321), transitional woodland-scrub (324), beaches, sand and dunes (331)
22	F6.2	Eastern garrigue	Sclerophyllous vegetation (323), natural grasslands (321), transitional woodland-scrub (324), sparsely vegetated areas (333)
23	F6.6	Supra-Mediterranean garrigue	Sclerophyllous vegetation (323), natural grasslands (321), transitional woodland-scrub (324), bare rocks (332), sparsely vegetated areas (333)
24	F6.7	Mediterranean gypsum scrub	Moors and heathland (322), Sclerophyllous vegetation (323), sparsely vegetated areas (333)
25	F6.8a	Mediterranean halo-nitrophilous scrub	Moors and heathland (322), Sclerophyllous vegetation (323),
26	F7.1	Western Mediterranean coastal garrigue	Sclerophyllous vegetation (323), beaches, sand and dunes (331)
27	F7.3	Eastern Mediterranean spiny heath (phrygana)	Sclerophyllous vegetation (323), natural grasslands (321), beaches, sand and dunes (331), sparsely vegetated areas (333)
28	F7.4a	Western Mediterranean mountain hedgehog-heath	Sclerophyllous vegetation (323), Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324), sparsely vegetated areas (333)
29	F7.4b	Central Mediterranean mountain hedgehog-heath	Sclerophyllous vegetation (323), natural grasslands (321), sparsely vegetated areas (333)
30	F7.4c	Eastern Mediterranean mountain hedgehog-heath	Sclerophyllous vegetation (323), Moors and heathland (322), transitional woodland-scrub (324), sparsely vegetated areas (333)
31	F9.1a	Arctic, boreal and alpine riparian scrub	Moors and heathland (322), natural grasslands (321), transitional woodland-scrub (324), sparsely vegetated areas (333)
32	F9.1b	Temperate riparian scrub	Moors and heathland (322), natural grasslands (321), beaches, sand

			and dunes (331), water courses (511)
33	F9.2	Salix fen scrub	Moors and heathland (322), natural grasslands (321), Sclerophyllous vegetation (323),
34	F9.3	Mediterranean riparian scrub	Moors and heathland (322), natural grasslands (321), Sclerophyllous vegetation (323),
35	B1.5a	Atlantic and Baltic coastal Empetrum heaths	Moors and heathland (322), natural grasslands (321), beaches, sand and dunes (331)
36	B1.5b	Atlantic coastal Calluna and Ulex heaths	Moors and heathland (322), natural grasslands (321), beaches, sand and dunes (331)
37	B1.6a	Atlantic and Baltic coastal dune scrub	Moors and heathland (322), natural grasslands (321), beaches, sand and dunes (331)
38	B2.5	Shingle and gravel beaches with scrub	Moors and heathland (322), natural grasslands (321), beaches, sand and dunes (331), salt marshes (421)

The table below provides the cross-walk between the EUNIS Heathlands, scrub and tundra habitat types with the Annex I habitat types, which is not an easy exercise since the relationships are not always straightforward. This cross-walk is based on information from eunis.eea.europa.eu/habitats, and expert information from amongst others Doug Evans, John Janssen, Joop Schaminee, Stephan Hennekens. Since the relationship between EUNIS and Annex I habitats is not always straightforward (one to many and many to one relationships, in addition to larger or smaller overlaps), the table below should be considered as a best-guess crosswalk and is of course subject for improvements. Any different crosswalk can have a large impact on the result of the assessment. Note also that for 9 of the 38 EUNIS habitat probability maps we could not identify any relationship with the Annex I habitats, which limited the assessment to 29 EUNIS habitat probability maps.

Table 1.2 Crosswalk between the EUNIS heathland, scrub and tundra habitats (level 3) and the associated Annex I habitat types. The number in the first column indicates those EUNIS habitat types for which an assessment has been performed. In other cases the EUNIS habitat types were not modelled due to a lack of vegetation plots or a lack of any relationship with Annex I

Nr	EUNIS	EUNIS description	Annex I habitat type	Annex I habitat description	Remarks
	F1.1	Shrub tundra	-		not Annex I but possibly included in 4060by some countries
	F1.2	Moss and lichen tundra	6150	Siliceous alpine and boreal grasslands	6150 & 6170 are mostly grassland types (E). Small overlap with Annex I
			6170	Alpine and subalpine calcareous grasslands	
1	F2.1	Subarctic and alpine dwarf Salix scrub	6150	Siliceous alpine and boreal grasslands	snowpatches with Salix herbacea are part of 6150
2	F2.2a	Alpine and subalpine ericoid heath	4060	Alpine and Boreal heaths	
3	F2.2b	Alpine and subalpine Juniperus scrub	4060	Alpine and Boreal heaths	

	F2.2.c	Balkan subalpine genistoid scrub	4060	Alpine and Boreal heaths	
4	F2.3	Subalpine deciduous scrub	4080	Sub-Arctic Salix spp scrub	
5	F2.4	Subalpine Pinus mugo scrub	4070	Bushes with Pinus mugo and Rhododendron hirsutum (Mugo-Rhododendretum hirsuti)	
6	F3.1a	Lowland to montane temperate and submediterranean Juniperus scrub	5130	'Juniperus communis formations on heaths or calcareous grasslands	
	F3.1b	Temperate Rubus scrub	-		No relation. Not Annex I (although may be included as part of forest habitats if forest clearings)
7	F3.1c	Lowland to montane temperate and submediterranean genistoid scrub	5120	Mountain Cytisus purgans formations	EUNIS is broader
8	F3.1e	Temperate and submediterranean thorn scrub	40A0	Subcontinental peri-Pannonic scrub	Small overlap
9	F3.1f	Low steppic scrub	40A0	Subcontinental peri-Pannonic scrub	Possibly also 40C0
			40C0	Ponto-Sarmatic deciduous thickets	
	F3.1g	Corylus avellana scrub	-		Not Annex I
	F3.1h	Temperate woodland clearing scrub	-		Not Annex I (although may be included as part of forest habitats)
10	F4.1	Wet heath	4010	Northern Atlantic wet heaths with Erica tetralix	4020 is a subset of 4010
			4020	Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix	
11	F4.2	Dry heath	4030	European dry heaths	Mostly 4030, 4040 is a subset of 4030 while others are dune types probably better associated with B habitats, eg B1.5 - Coastal dune heaths
			4040	Dry Atlantic coastal heaths with Erica vagans	
12	F5.2	Arborescent matorral and maquis	5210	Arborescent matorral with Juniperus spp	
			5230	Arborescent matorral with Laurus nobilis	
			5310	Laurus nobilis thickets	
			5330	Thermo-Mediterranean and pre-desert scrub	

			5390		
13	F5.3	Submediterranean pseudomaquis	5110	Stable xerothermophilous formations with Buxus sempervirens on rock slopes	
	F5.4	Spartium junceum fields	-		No relationship. Not Annex I
14	F5.5	Thermo-Mediterranean scrub	5220	Arborescent matorral with Zyziphus	
			5330	Thermo-Mediterranean and pre-desert scrub	
15	F6.1a	Western basiphilous garrigue	5330	Thermo-Mediterranean and pre-desert scrub	EUNIS small part overlap
			5140	Cistus palhinhae formations on maritime wet heaths	
16	F6.1b	Western acidophilous garrigue	5330	Thermo-Mediterranean and pre-desert scrub	similar vegetation in dunes may be considered 2260; elsewhere may have been included in 5330 by some countries
	F6.2	Eastern garrigue	-		
	F6.6	Supra-Mediterranean garrigue	-		
17	F6.7	Mediterranean gypsum scrub	1520	'Iberian gypsum vegetation (Gypsophiletalia)	
18	F6.8a	Mediterranean halo-nitrophilous scrub	1430	Halo-nitrophilous scrubs (Pegano-Salsoletea)	
19	F7.1	Western Mediterranean coastal garrigue	5320	Low formations of Euphorbia close to cliffs	
			5410	West Mediterranean clifftop phryganas (Astragalo-Plantaginetum subulatae)	
			5430	Endemic phryganas of the Euphorbio-Verbascion	
20	F7.3	Eastern Mediterranean spiny heath (phrygana)	5430	Endemic phryganas of the Euphorbio-Verbascion	
			5420	Sarcopoterium spinosum phryganas	
21	F7.4a	Western Mediterranean mountain hedgehog-heath	4090	Endemic oro-Mediterranean heaths with gorse	
			5120	Mountain Cytisus purgans formations	
22	F7.4b	Central Mediterranean mountain hedgehog-heath	4090	Endemic oro-Mediterranean heaths with gorse	
23	F7.4c	Eastern Mediterranean mountain hedgehog-heath	4090	Endemic oro-Mediterranean heaths with gorse	
24	F9.1a	Arctic, boreal and alpine riparian scrub	3230	Alpine rivers and their ligneous vegetation with Myricaria germanica	

			3240	Alpine rivers and their ligneous vegetation with Salix elaeagnos	
			4080	Sub-Arctic Salix spp scrub	
	F9.1b	Temperate riparian scrub	-		No relationship
	F9.2	Salix fen scrub	-		No relationship. 40B0 does not include Salix scrub F9-2 not included in Annex I
25	F9.3	Mediterranean riparian scrub	92D0	Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)	92D0 both scrub & forest
26	B1.5a	Atlantic and Baltic coastal Empetrum heaths	2140	Decalcified fixed dunes with Empetrum nigrum	2140
27	B1.5b	Atlantic coastal Calluna and Ulex heaths	2150	Atlantic decalcified fixed dunes (Calluno-Ulicetea)	2150
28	B1.6a	Atlantic and Baltic coastal dune scrub	2150	Atlantic decalcified fixed dunes (Calluno-Ulicetea)	2150
29	B2.5	Shingle and gravel beaches with scrub	1220	Perennial vegetation of stony banks	possibly included in 1220 in some countries

2 Assessment of the EUNIS heathland, scrub and tundra habitat probability maps based on Article 17 database

In the assessment, each EUNIS heathland, scrub and tundra habitat type is presented by three maps:

1. The first map is the original habitat probability map that we have produced indicating with a percentage chance (probability) that the specific EUNIS habitat is present within a specific 100 m grid cell based upon our methodology.
2. The second map is an aggregation of the original habitat probability map (first map) to a 10 km grid cell using the counts of 100 m grid cells that have a probability greater than 0 for that specific habitat type in a specific 10 km grid. In each 10 km grid cell 10,000 100 m grid cells fit (% presence = count/10,000). The second map is easier to compare with the reference map (third map which is limited to EU member states).
3. The third map is the reference map derived from the Article 17 database (obtained through the EU member states for Habitats directive reporting) for which each time one or more Annex I habitats have been selected that are affiliated with our specific EUNIS habitat type (see also Table 1.2).

These maps are followed by a table with a compact accuracy assessment, also called error matrix or contingency table, on the presence or absence of a specific habitat type with the 10km grid cells. The accuracy assessment is using the Art 17 habitat maps as a reference for the assessment of our EUNIS habitat probability maps. The error matrix (sometimes called a confusion or a contingency table) is well explained and derived from Lillesand and et al., 2008. Error matrices compare, on a category-by-category basis, the relationship between known reference data (ground truth) and the corresponding results of the classification or modelling exercise (Lillesand and et al., 2008). *Producer's Accuracy* is a measure of omission error and *User's Accuracy* is measure of commission error. Errors of commission result when pixels associated with a class are incorrectly identified as other classes, or from improperly separating a single class into two or more classes. Errors of omission occur whenever pixels that should have been identified as belonging to a particular class were simply not recognized as present.

- The user accuracy indicates for example for F2.1 Subarctic and alpine dwarf Salix scrub indicates that 78.3 % of the identified gridcells belonging to the specific EUNIS habitat probability type is really occurring in those specific grid cells according to Article 17 database.
- The producer's accuracy is indicating how much of the Article 17 grid cells are identified by our EUNIS habitat probability maps. In some cases the producer's accuracy is lower than the user's accuracy, indicating that our models do not identify every grid cell where the habitat occurs according to Art 17, but if it is predicted it is predicted quite well.
- The total accuracy is determined by the presence as well as by the absence of the habitat type for any of the 47,967 10 km grid cells. The overall accuracy is seen as poor if the percentage is lower than 70% which luckily occurred only for 3 out of the 29 habitat probability maps

If the Article 17 database misses some habitats in the wider country side, the producer accuracy is seen as more reliable than the user accuracy. The producer accuracy is based on the amount of real recorded habitats according to Article 17 database and indicates how much of Habitats Directive Annex I habitat types (observed ground truth) are spatially identified by our independent EUNIS habitat probability maps. The Article 17 directive can be of variable accuracy from habitat distribution across the whole country up to habitat distribution based largely or entirely on the

designated sites. And means that if we have classified at a certain location a certain EUNIS habitat type and according to the Art 17 database the habitat is not present at that spot we are still not sure if our classification was wrong on that spot (since it might just not have been recorded outside Natura 2000), and means that the user accuracy is less reliable than the producer accuracy.

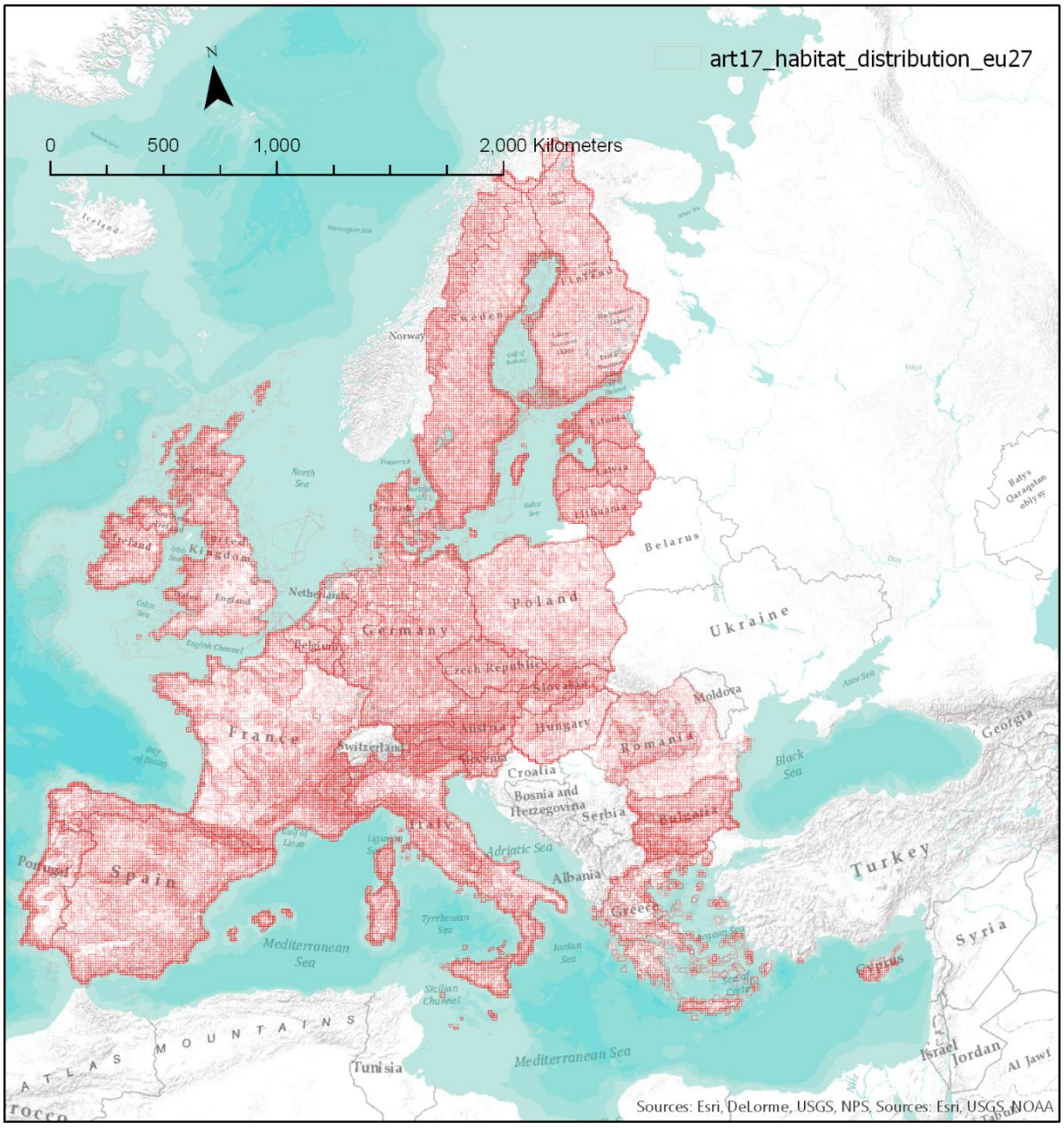


Figure 2.1 Coverage of the Article 17 database for all habitats

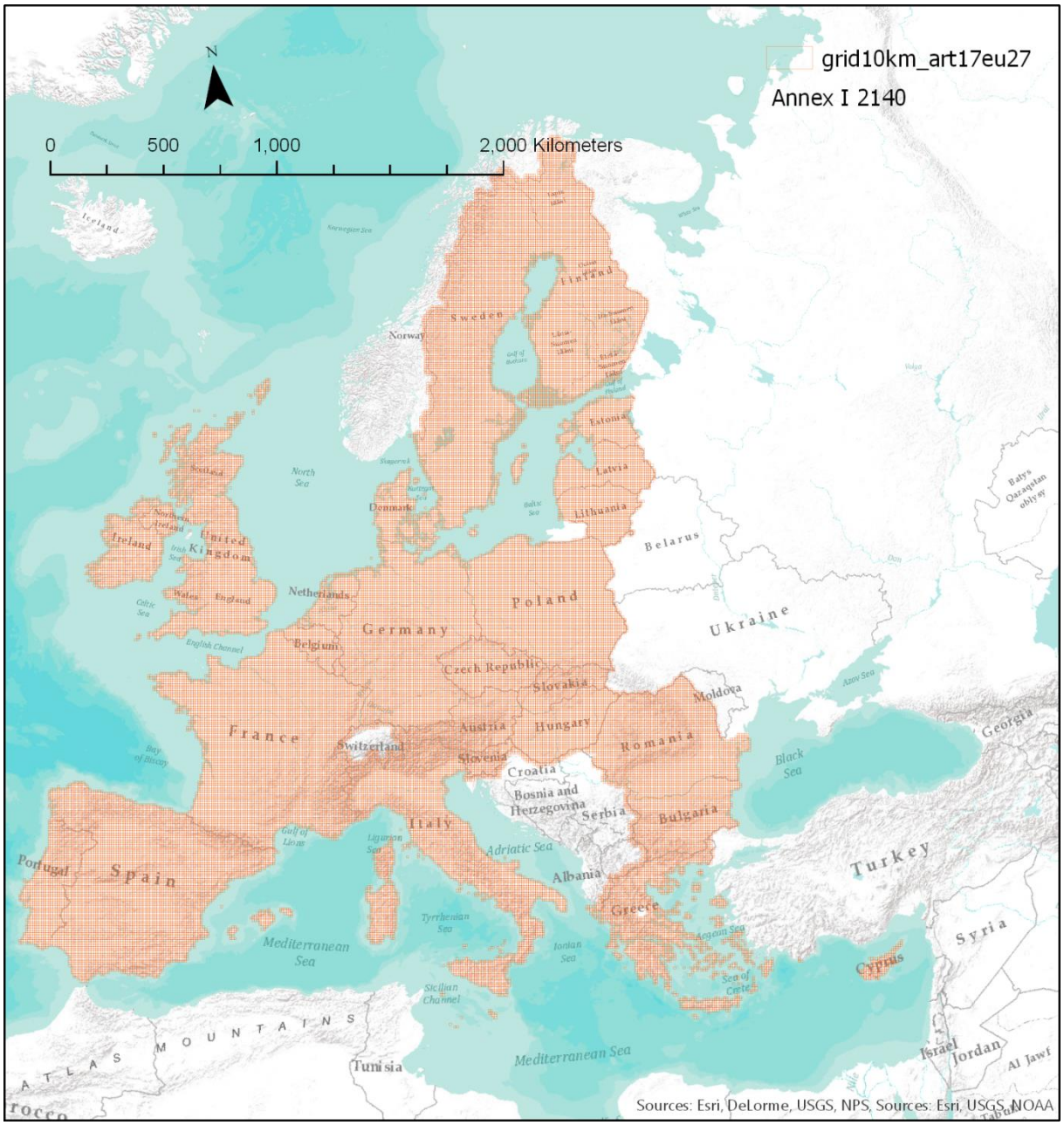


Figure 2.2 Coverage of our analysis. This figure shows the produced regular 10km grid which has been used to compare the EUNIS habitat probability maps with the Article 17 database. In total this grid contains 47,967 10 km grid cells covering an area of 4,796,700 km2, which were all analysed for every habitat type

For every habitat type we produced spatial models in ARCGIS Pro that we needed to run to obtain the final error matrix. In summary, we produced four major spatial models that we did run after each other in sequence for each EUNIS habitat type and are explained briefly below.

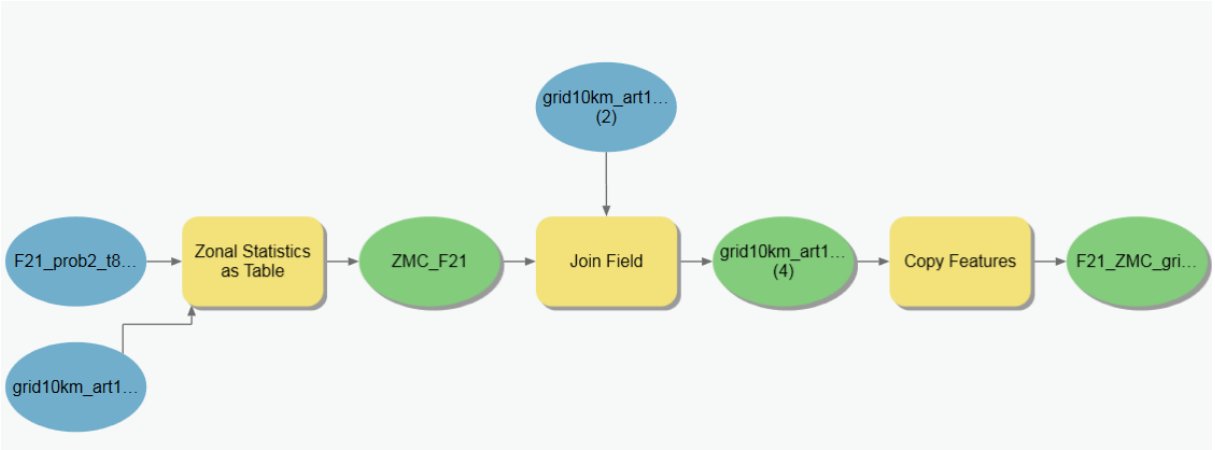


Figure 2.3 Spatial model 01 which calculates the ZonalStatistics for every 10 km gridcell based on the original 100 meter resolution EUNIS habitat probability map

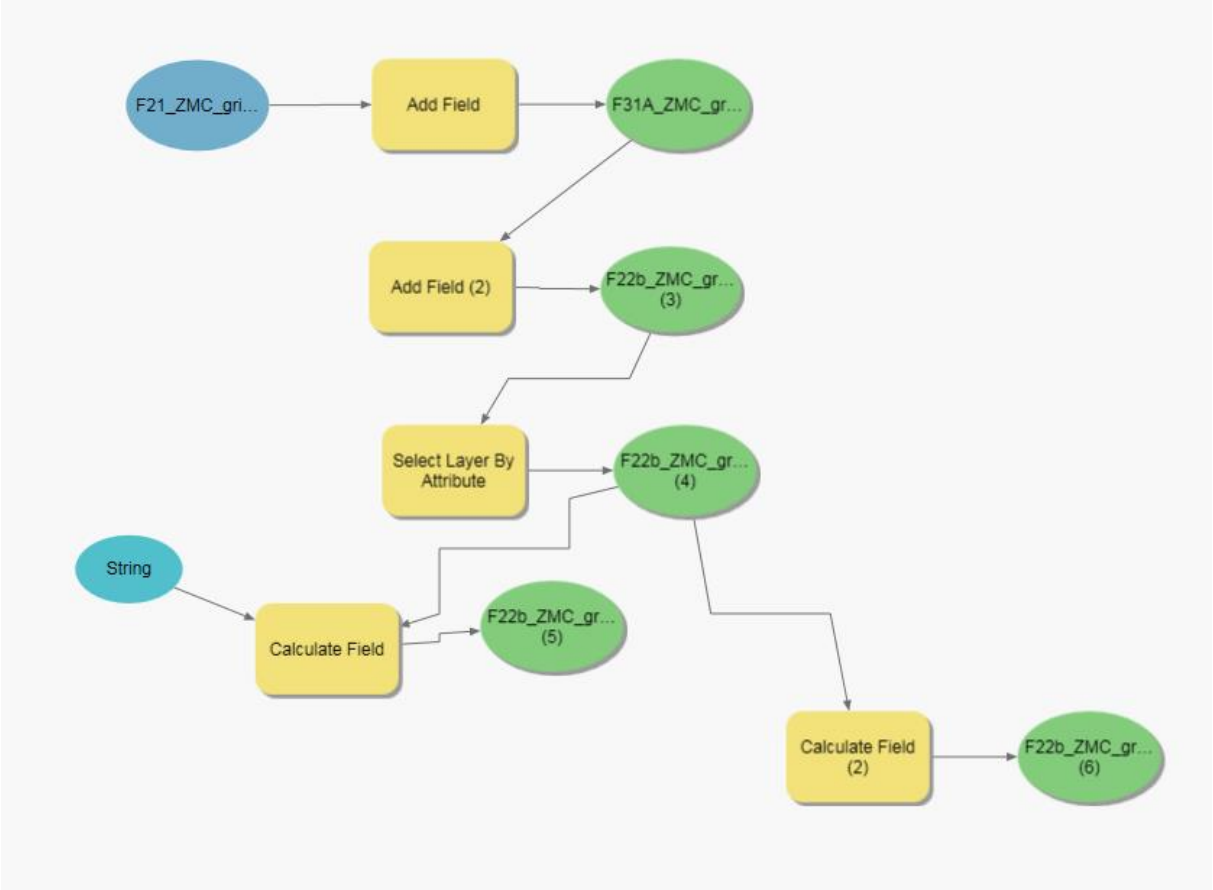


Figure 2.4 Spatial model 02 where the EUNIS habitat probability map attributes are attached to the 10 km grid. Spatial model 01 and 02 are closely linked

Running spatial model 1 and 2 in sequence leads to a EUNIS habitat probability map recalculated as percentage coverage per 10 km grid cell. The result is shown below.

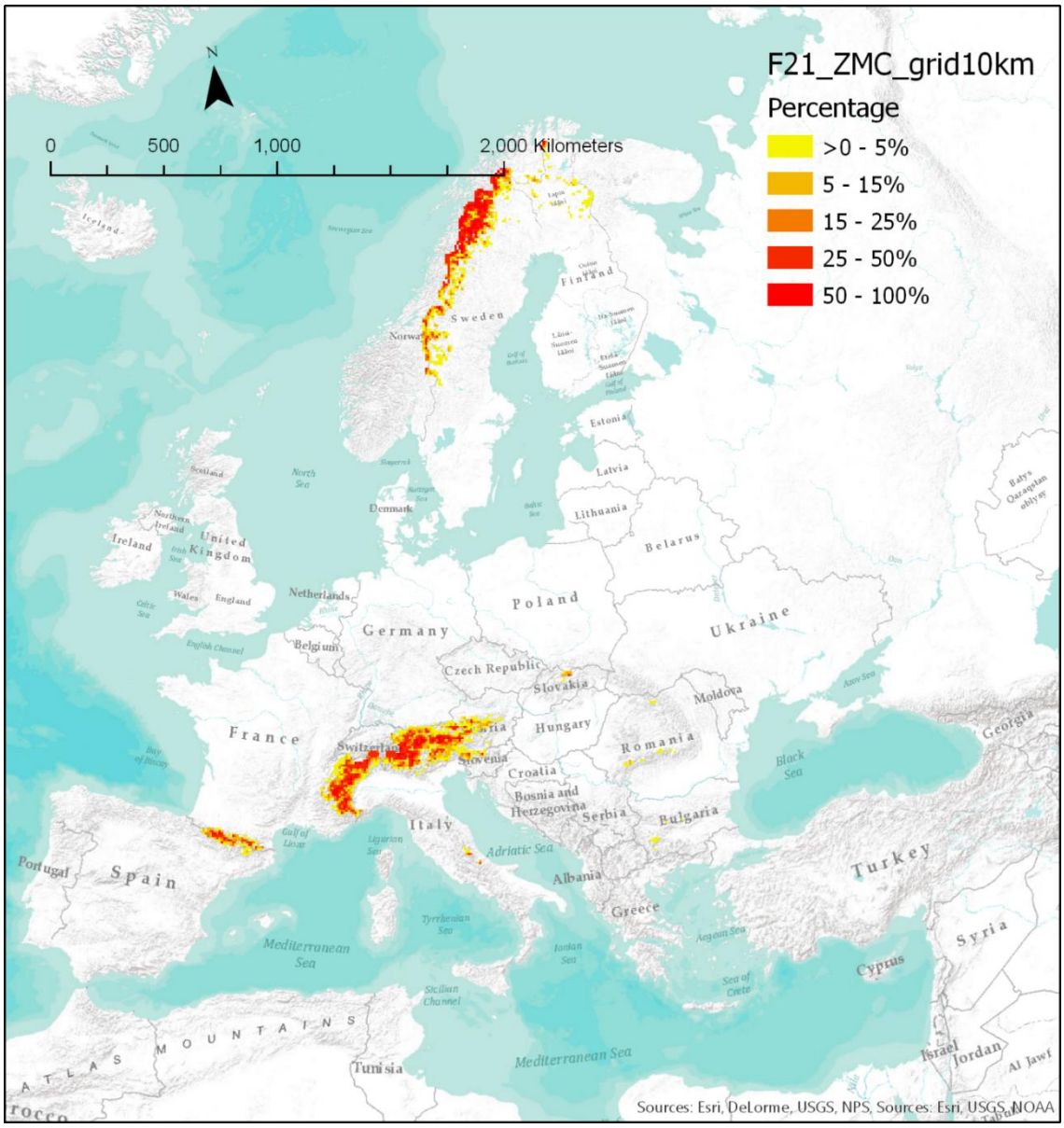


Figure 2.5 Example of the EUNIS habitat probability map recalculated as percentage coverage per 10 km gridcell

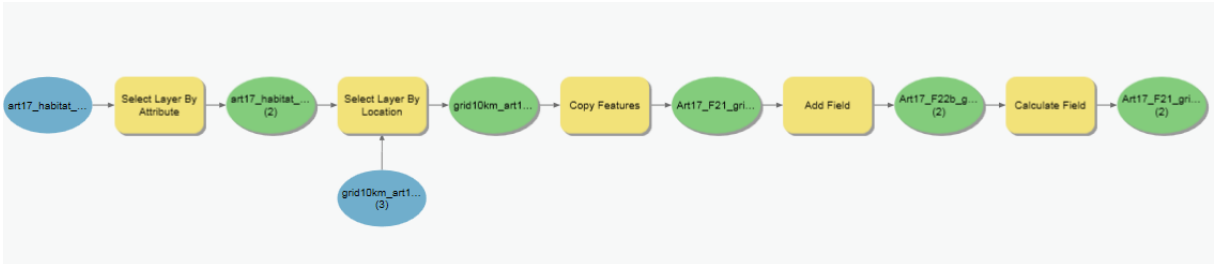


Figure 2.6 Spatial model 03 the related Annex I habitat types from the Article 17 database are attached to the 10 km grid

The result of spatial model 3 is shown below, namely the Article 17 database for a specific habitat type.

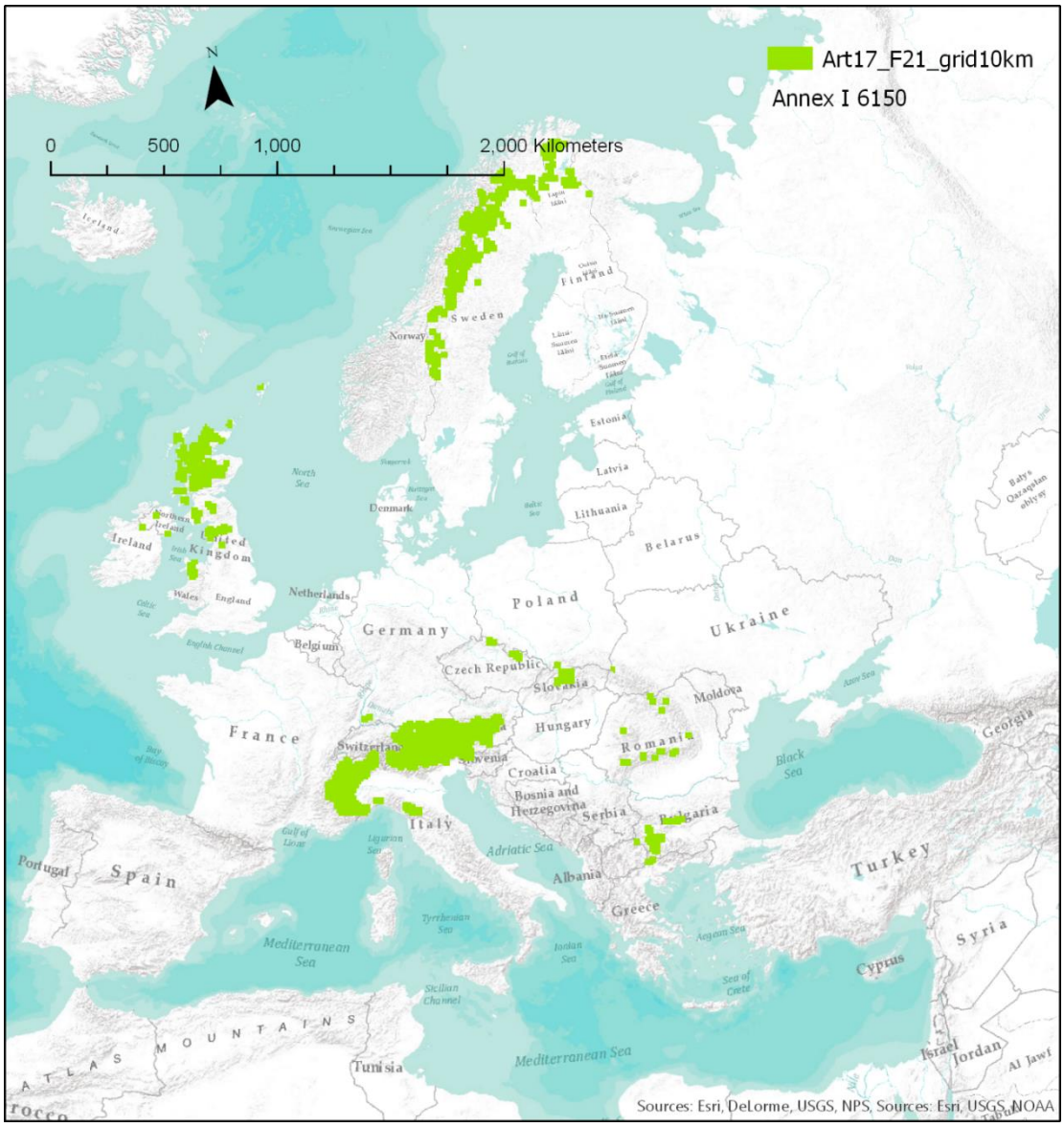


Figure 2.7 **Example of the distribution for a specific EUNIS habitat type as derived from one or more Annex I habitat types from the Article 17 database. This is considered to be the ground thuth**

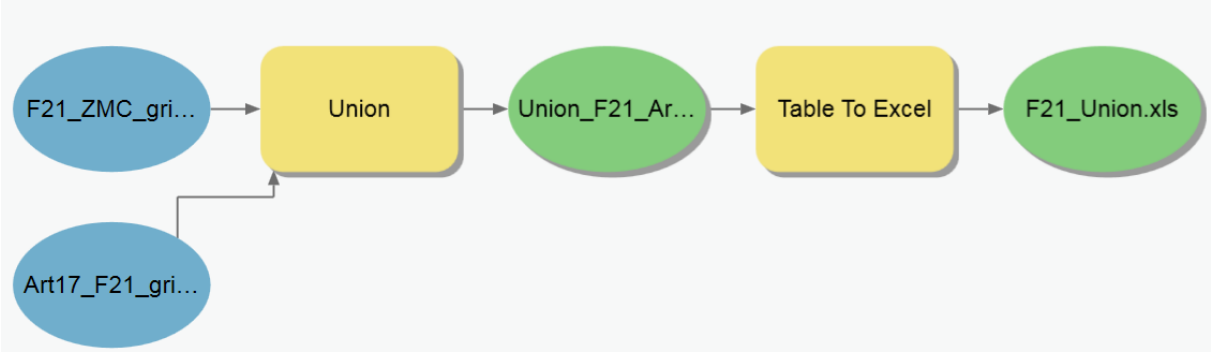


Figure 2.8 **Spatial model 04 union of the EUNIS and Article 17 habitats to the 10km grid for to produce the pivot tables in Excel**

On basis of this this last spatial model we can produce the error matrix as shown below for EUNIS habitat type F2.1 'Subarctic and alpine dwarf Salix scrub' as an example.

Table 2.1 Example of the produced error matrix

Count of 10km grid cells	Ground truth	Article 17 habitat	
Our EUNIS habitat classification	H6150 presence	Absence	Grand Total
F2.1 presence	**1511**	418	1929
F2.1 absence	1987	**44051**	46038
Grand Total	3498	44469	**47967**

In Table 2.1 we can see that according to the Article 17 database (ground truth is represented in the columns), represented by the related Annex I habitat type 6150 'Siliceous alpine and boreal grasslands', that there are 3498 grid cells of 10 by 10 km that contain the habitat type (presence) and 44469 gridcells do not belong to that habitat type (absence). According to our classification method of the EUNIS habitat type F2.1 'Subarctic and alpine dwarf Salix scrub' 1929 gridcells belong to that habitat type (presence) and 46038 gridcells of 10 by 10 km do not belong to that habitat type (absence). The total number of 10 km grid cells is each time fixed, namely 47967. In Table 2.1 it is also clear that for 1511 gridcells both databases agree about the presence of the specific habitat type and that for 44051 gridcells both databases have agree about the absence of the specific habitat type. The overall accuracy in determined by the total amount of gridcells that agree on presence and absence of the specific habitat type divided by the total amount of gridcells.

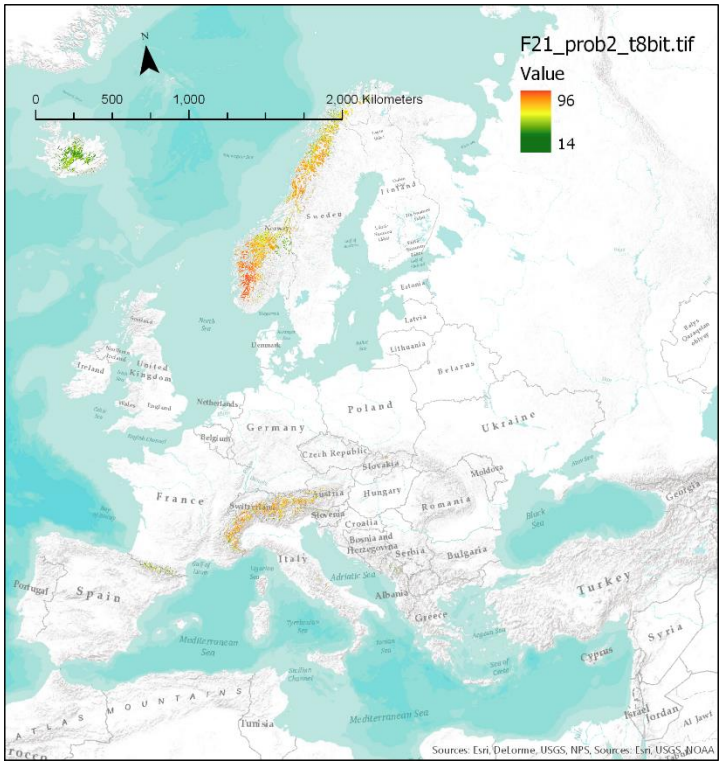
In table 2.1 the user, producer and overall accuracy are calculated as follows:

Components error matrix	**result**	**Explanation how calculated**	**What does it mean?**
User's accuracy	78.3%	1511/1929 = 0.783 * 100 = 78.3%	78.3% of what has been classified by us as EUNIS habitat type F2.1 '1 'Subarctic and alpine dwarf Salix scrub' is according to the Article 17 database indeed EUNIS habitat F2.1.
Producer's accuracy	43.2%	1511/3498 = 0.432 * 100 = 43.2%	43.2% of the real distribution of EUNIS habitat type F2.1 '1 'Subarctic and alpine dwarf Salix scrub' according to the reference database Article 17, has been identified by our classification.
Overall accuracy	95.0%	(1511 + 44051)/47967 = 0.950 *100 = 95.0%	The overall accuracy is the percentage of total amount of 10 km grid cells for which our classification agrees with the Art 17 distribution of the specific EUNIS habitat type in terms of presence and absence.

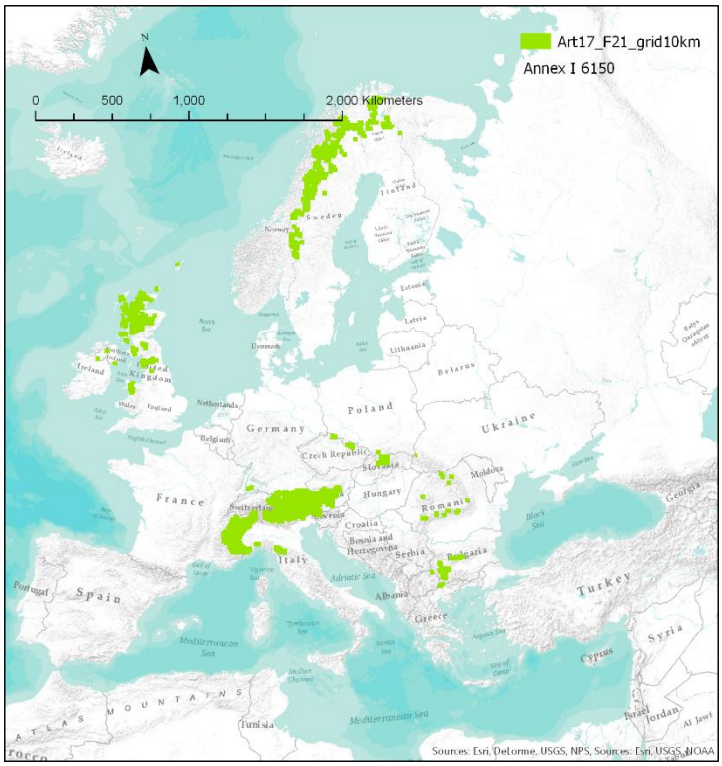
In the Chapter 4 all maps are displayed, concerning:

a) the original produced EUNIS habitat probability map at 100 meter spatial resolution,
b) the ground truth, the article 17 database with all 10 km grid cells in which the related Annex I habitats occur for the specific EUNIS habitat type,
c) our EUNIS habitat probability map recalculated as percentage coverage per 10 km grid cell,
d) the error matrix based on the two former databases/maps and indicating the user's, producer's and overall accuracy of the EUNIS habitat probability map.

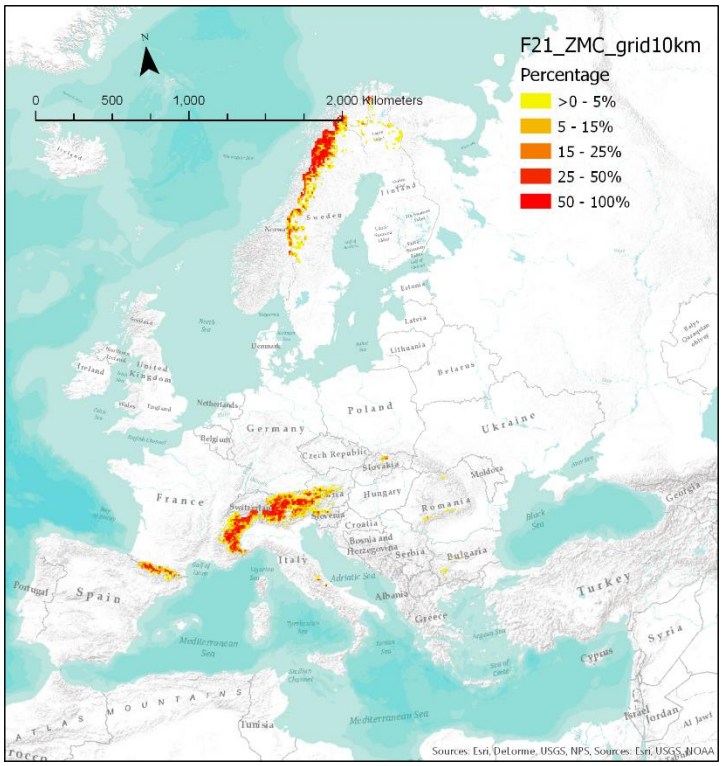
3 Results



Original EUNIS habitat probability map F2.1 Subalpine and alpine dwarf Salix scrub



Article 17 database (ground truth) with the related Annex I habitat type(s). H6150 Siliceous alpine and boreal grasslands

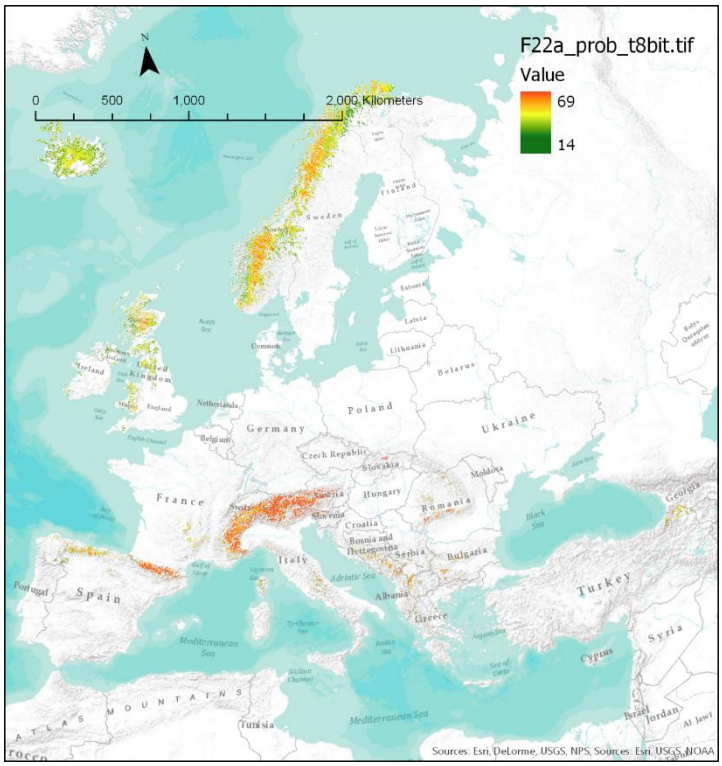


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

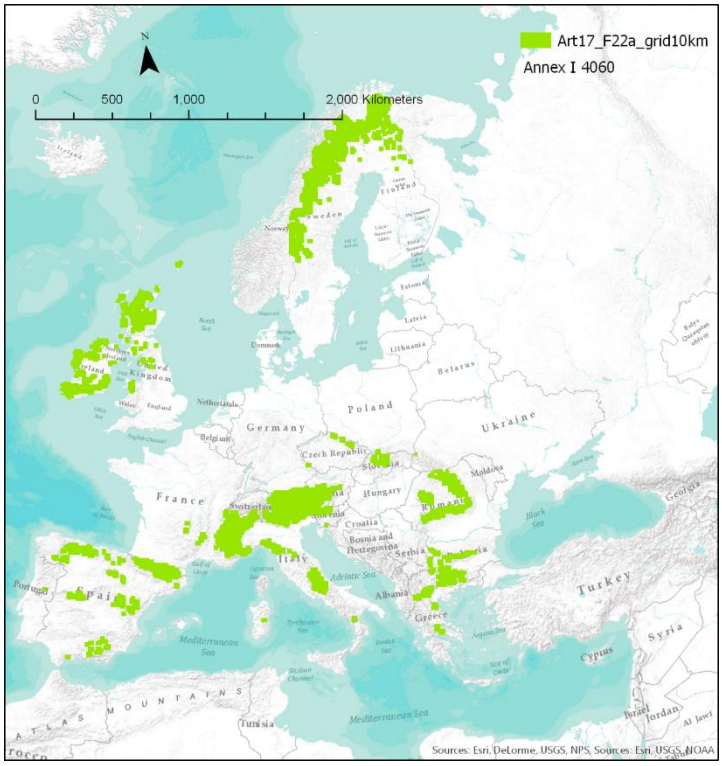
Comparison of the above two figures in an error matrix

Count of 10kmgridcells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H6150 presence	absence	Grand Total
F2.1 presence	**1511**	418	1929
F2.1 absence	1987	**44051**	46038
Grand Total	3498	44469	**47967**

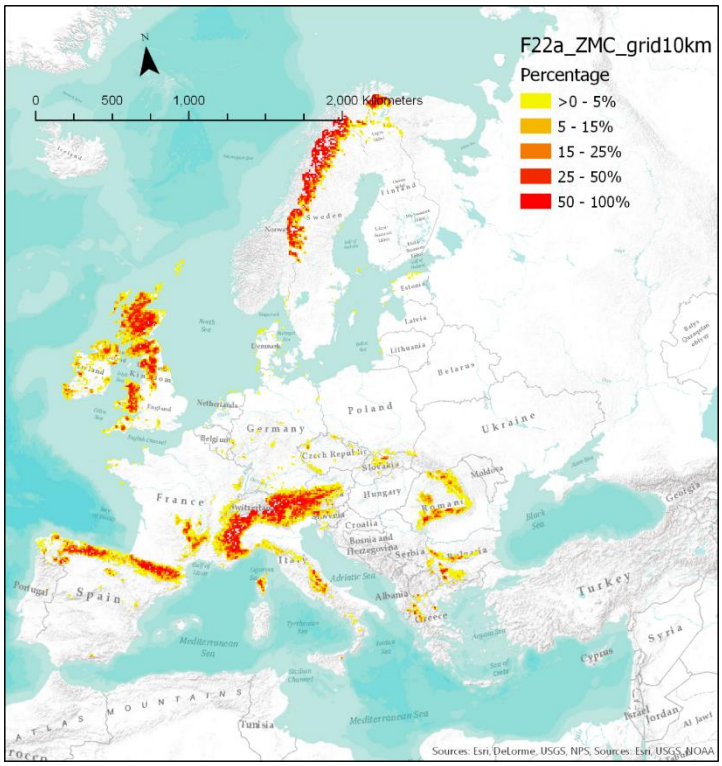
User's accuracy	78.3%
Producer's accuracy	43.2%
Overall accuracy	95.0%



Original EUNIS habitat probability map F2.2a Alpine and subalpine ericoid heath



Article 17 database (ground truth) with the related Annex I habitat type(s). H460 Alpine and Boreal heaths

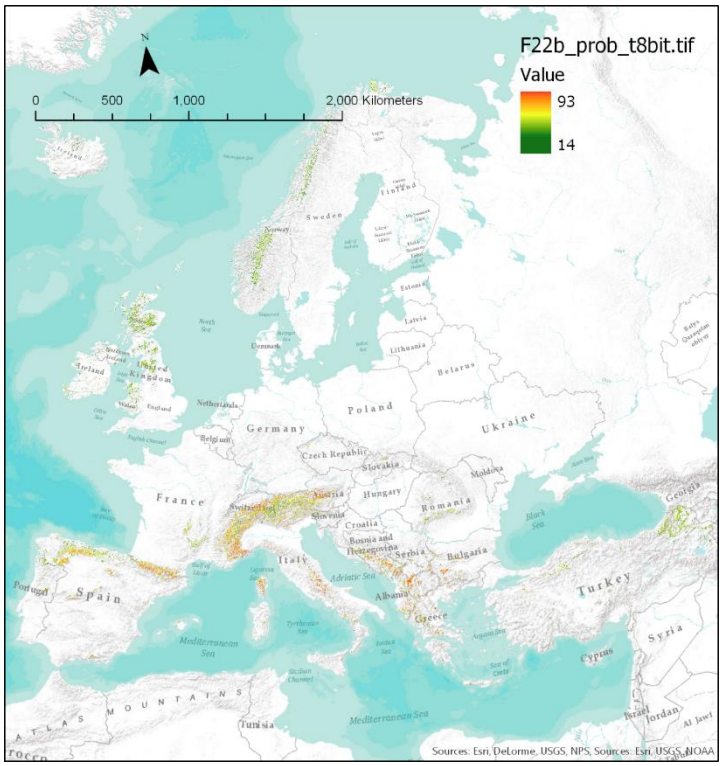


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

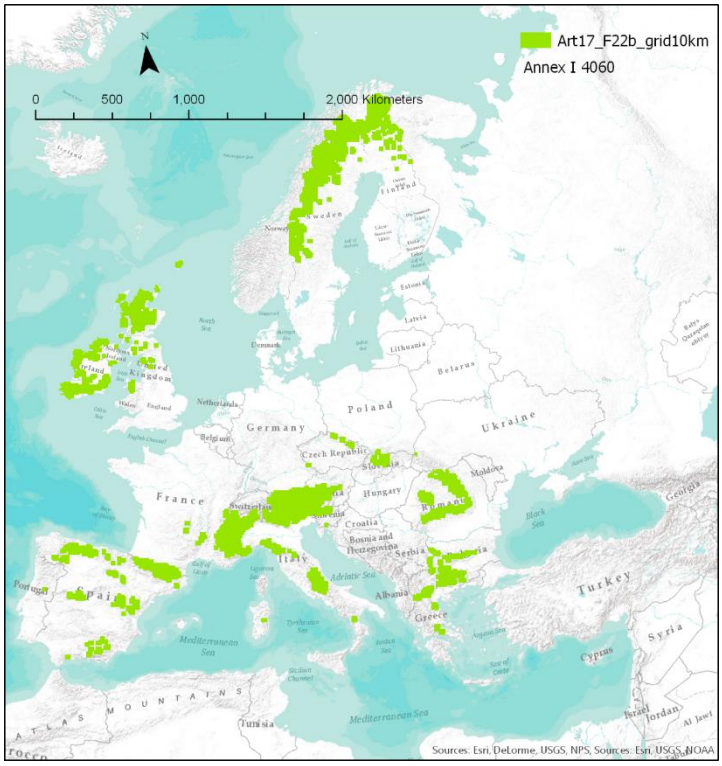
Comparison of the above two figures in an error matrix

Count of 10km grids	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H4060 presence	absence	Grand Total
F2.2a presence	**4909**	2248	7157
F2.2a absence	2638	**38172**	40810
Grand Total	7547	40420	**47967**

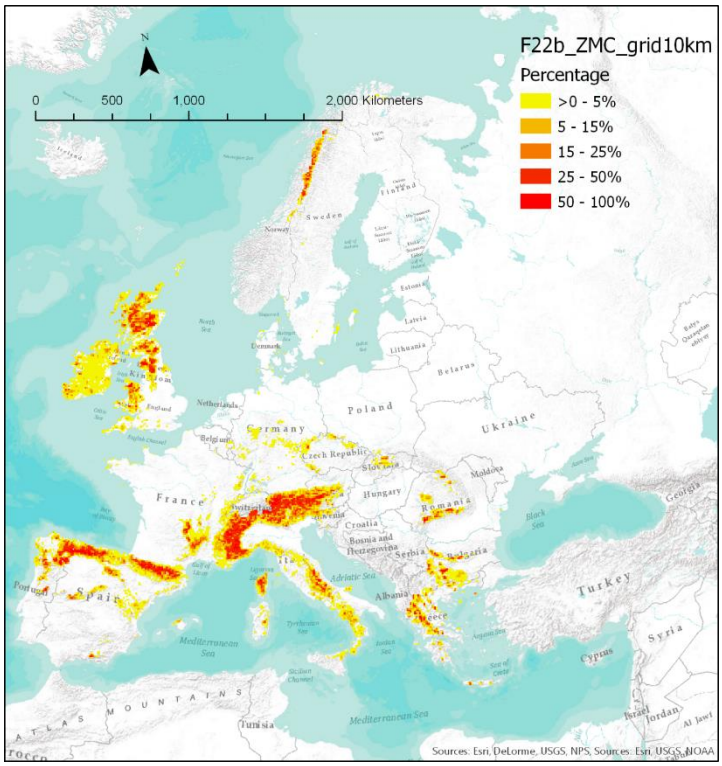
User's accuracy	68.6%
Producer's accuracy	65.0%
Overall accuracy	89.8%



Original EUNIS habitat probability map F2.2b Alpine and subalpine Juniperus scrub



Article 17 database (ground truth) with the related Annex I habitat type(s). H4060 Alpine and Boreal heaths

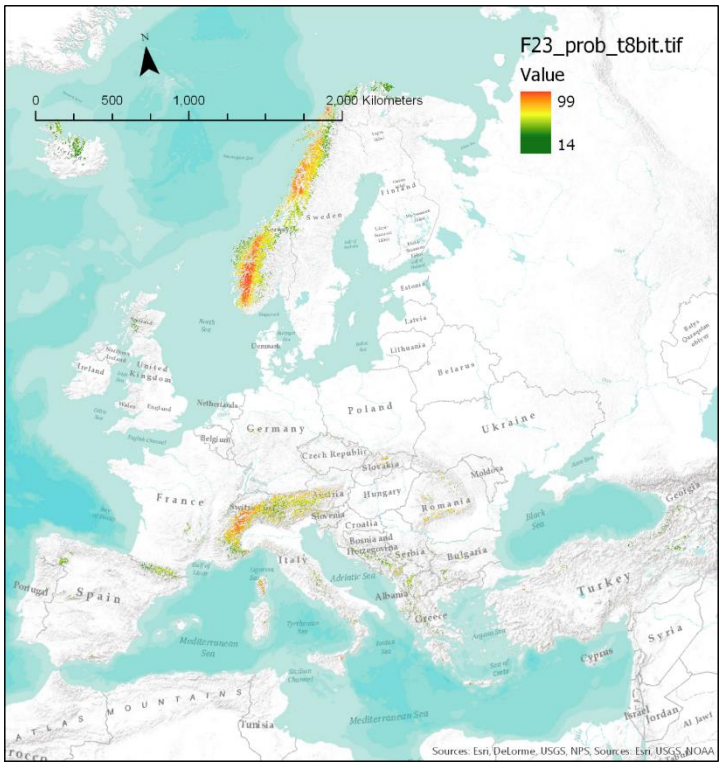


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

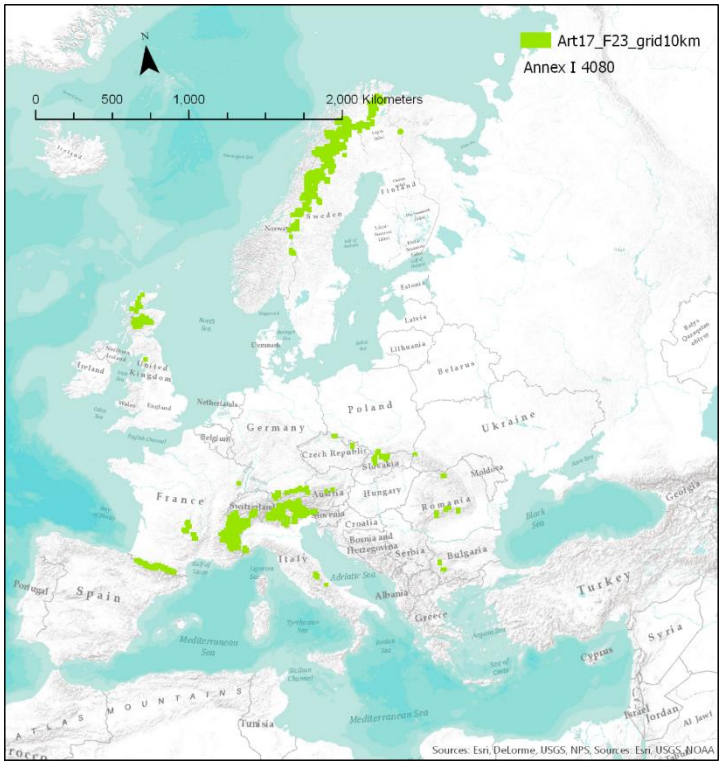
Comparison of the above two figures in an error matrix

Number of 10km grids	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H4060 presence	absence	Grand Total
F2.2b presence	**4209**	3375	7584
F2.2b absence	3338	**37045**	40383
Grand Total	7547	40420	**47967**

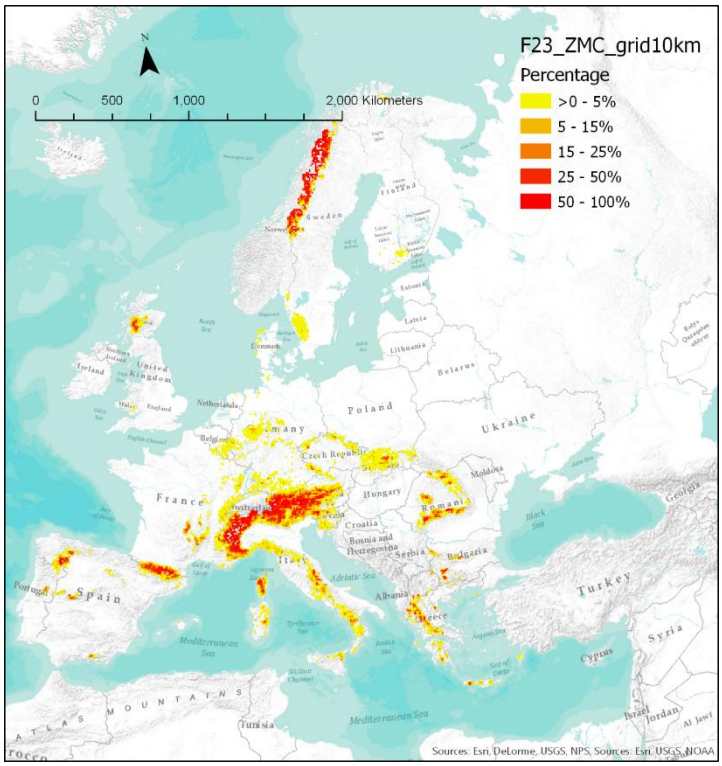
User's accuracy	55.5%
Producer's accuracy	55.8%
Overall accuracy	86.0%



Original EUNIS habitat probability map F2.3 Subalpine deciduous scrub



Article 17 database with the related Annex I habitat type(s). H4080 Sub-Arctic Salix spp scrub

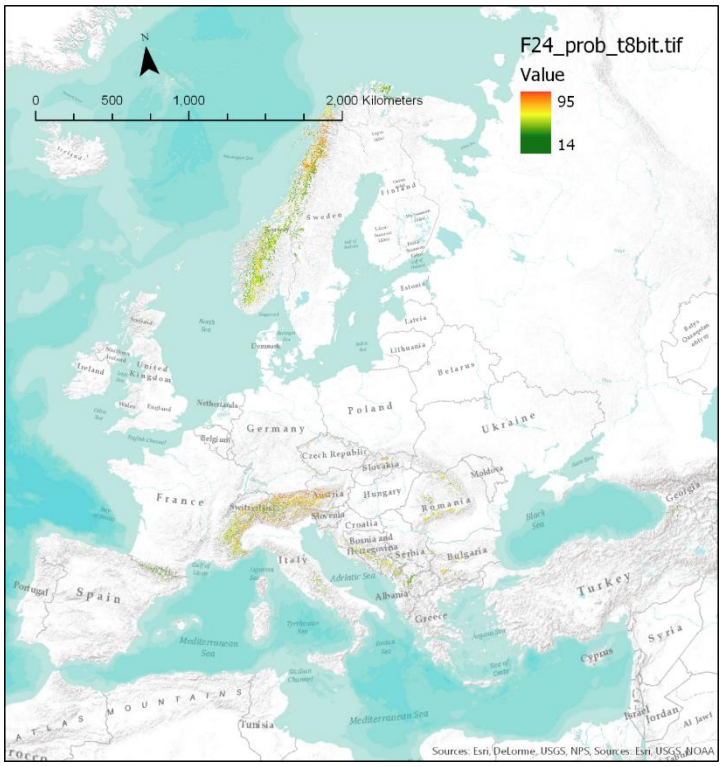


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

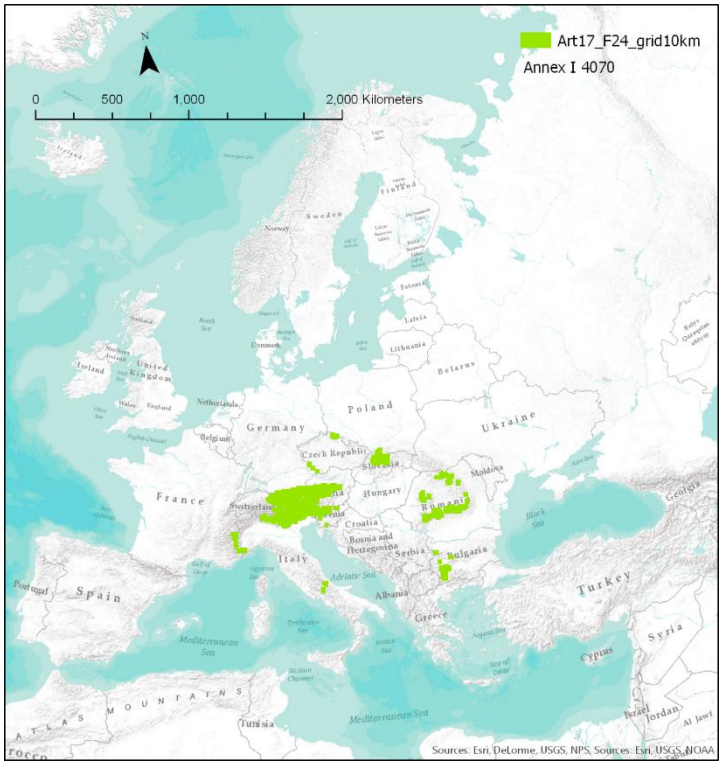
Comparison of the above two figures in an error matrix

Number of 10kmgrids	Ground thruth	Art 17 – Annex I	
EUNIS habitat classification	H4080 Presence	Absence	Grand Total
F2.3 presence	1578	4051	5629
F2.3 absence	879	41459	42338
Grand Total	**2457**	**45510**	**47967**

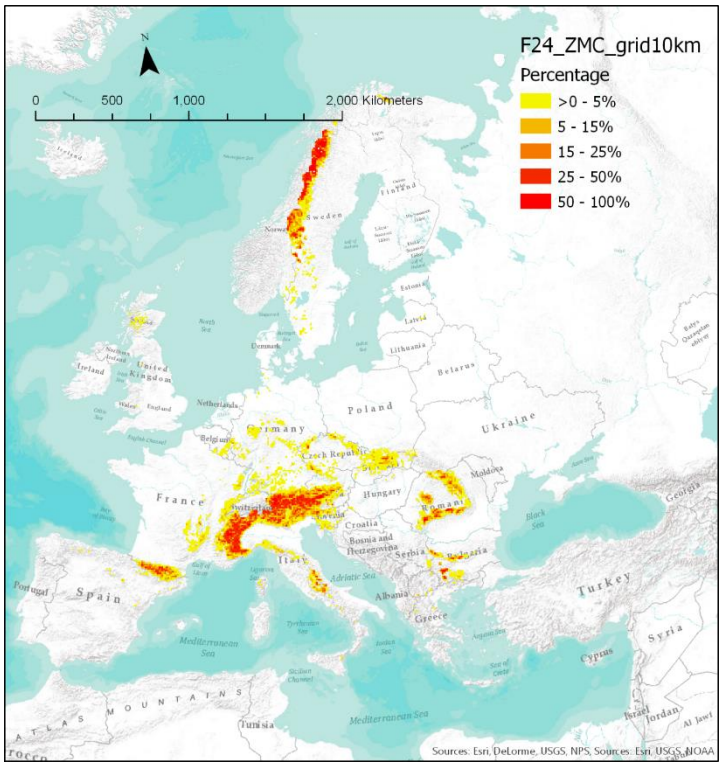
User's accuracy	28.0%
Producer's accuracy	64.2%
Overall accuracy	89.7%



Original EUNIS habitat probability map F2.4 Subalpine Pinus mugo scrub



Article 17 database with the related Annex I habitat type(s). H4070 Bushes with Pinus mugo and Rhododendron hirsutum (Mugo-Rhododendretum hirsuti)

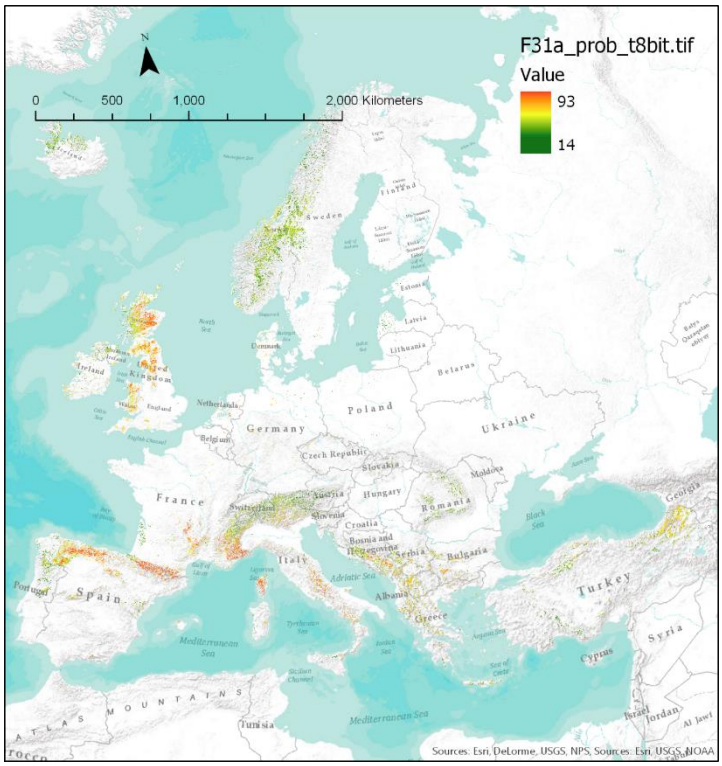


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

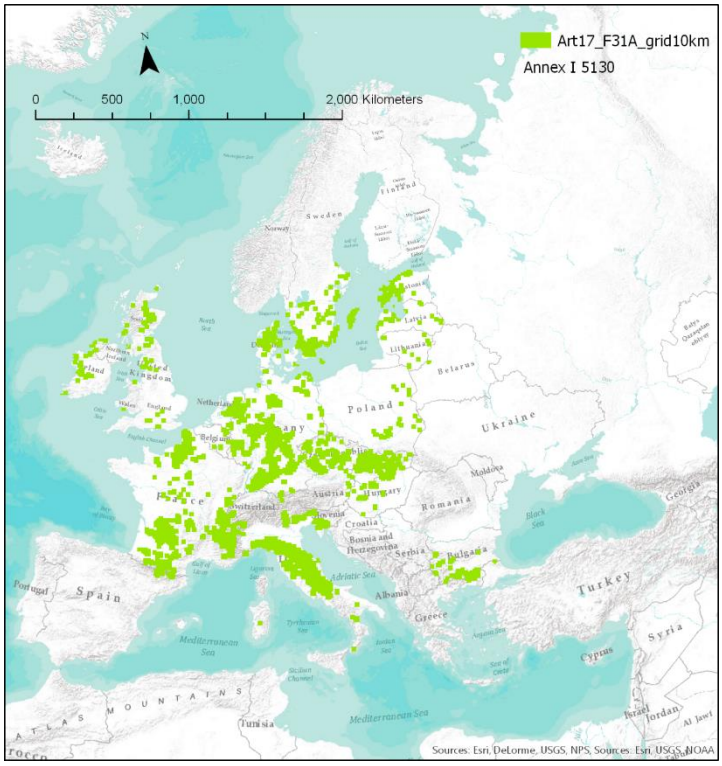
Comparison of the above two figures in an error matrix

Count of 10km grids cells	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H4070 presence	absence	Grand Total
F2.4 presence	**1406**	3340	4746
F2.4 absence	203	**43018**	43221
Grand Total	1609	46358	**47967**

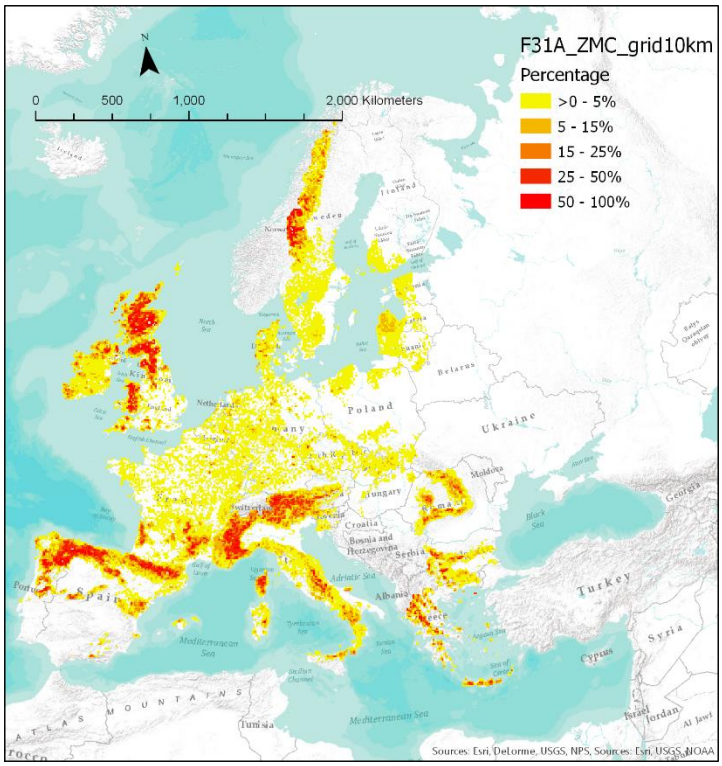
User's accuracy	29.6%
Producer's accuracy	87.4%
Overall accuracy	92.6%



Original EUNIS habitat probability map F3.1ª Lowland to montane temperate and submediterranean Juniperus scrub



Article 17 database with the related Annex I habitat type(s). H5130 Juniperus communis formations on heaths or calcareous grasslands

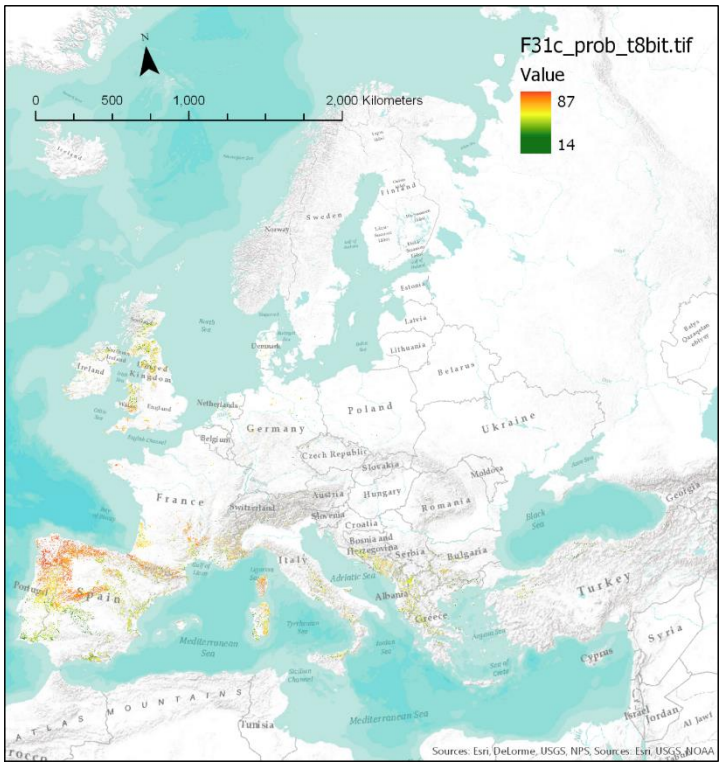


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

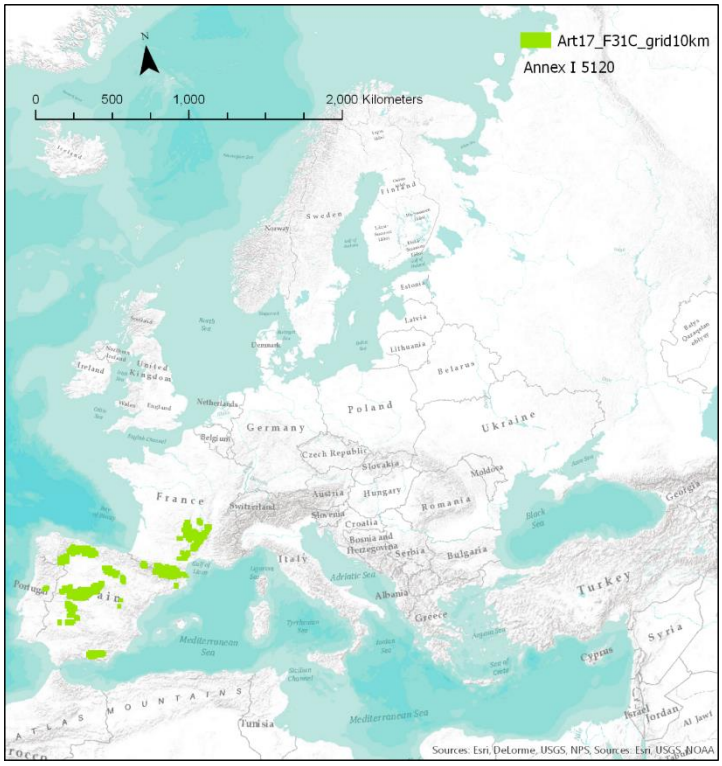
Comparison of the above two figures in an error matrix

Count of 10 km grids	Ground thruth	Art 17 - Annex I	
EUNIS habitat classification	H5130 presence	absence	Grand Total
F3.1A presence	**4775**	14426	19201
F3.1A absence	2967	**25799**	28766
Grand Total	7742	40225	**47967**

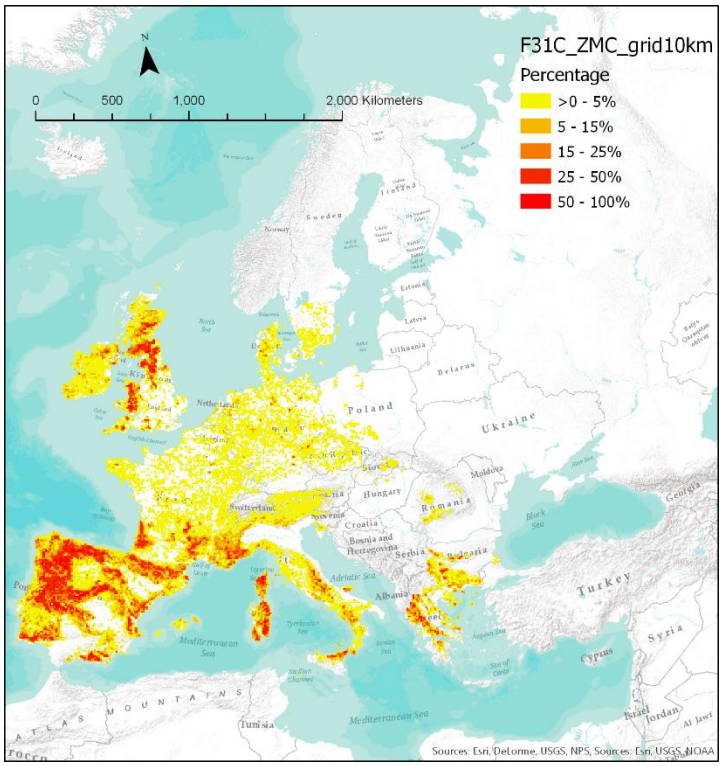
User's accuracy	24.9%
Producer's accuracy	61.7%
Overall accuracy	63.7%



Original EUNIS habitat probability map F3.1c Lowland to montane temperate and submediterranean genistoid scrub



Article 17 database with the related Annex I habitat type(s). H5120 'Mountain Cytisus purgans formations

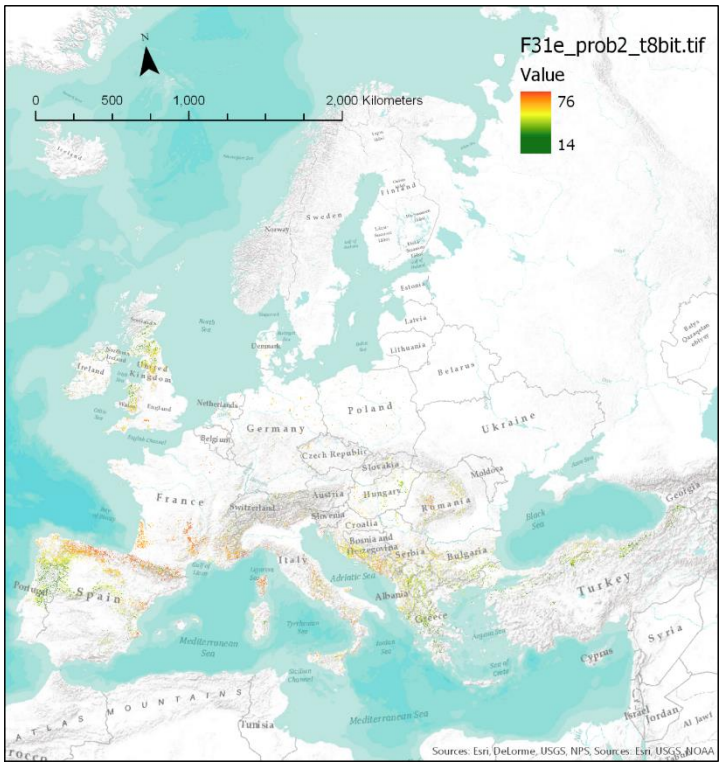


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

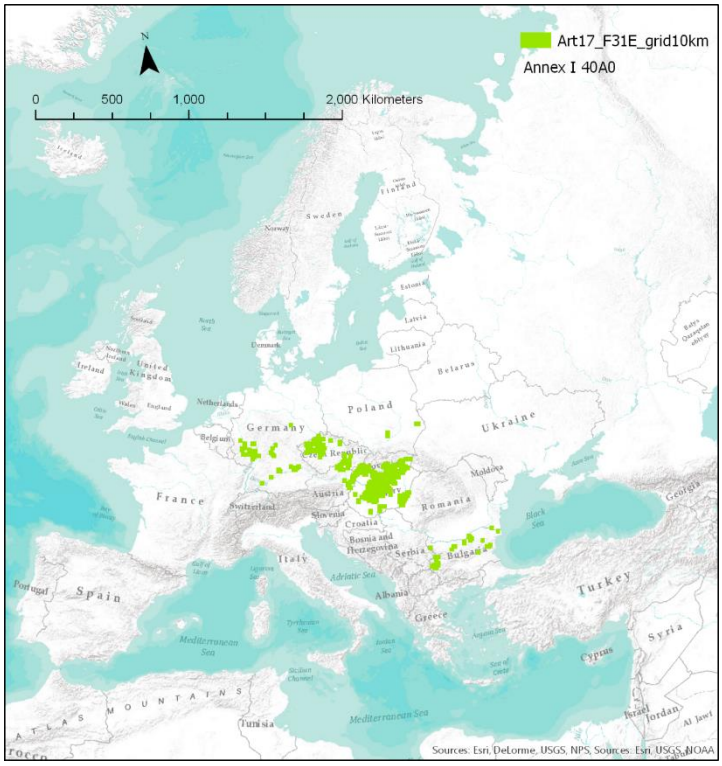
Comparison of the above two figures in an error matrix

Count of 10Km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H5120 presence	absence	Grand Total
F3.1C presence	**1181**	16167	17348
F3.1 C absence	37	**30582**	30619
Grand Total	1218	46749	**47967**

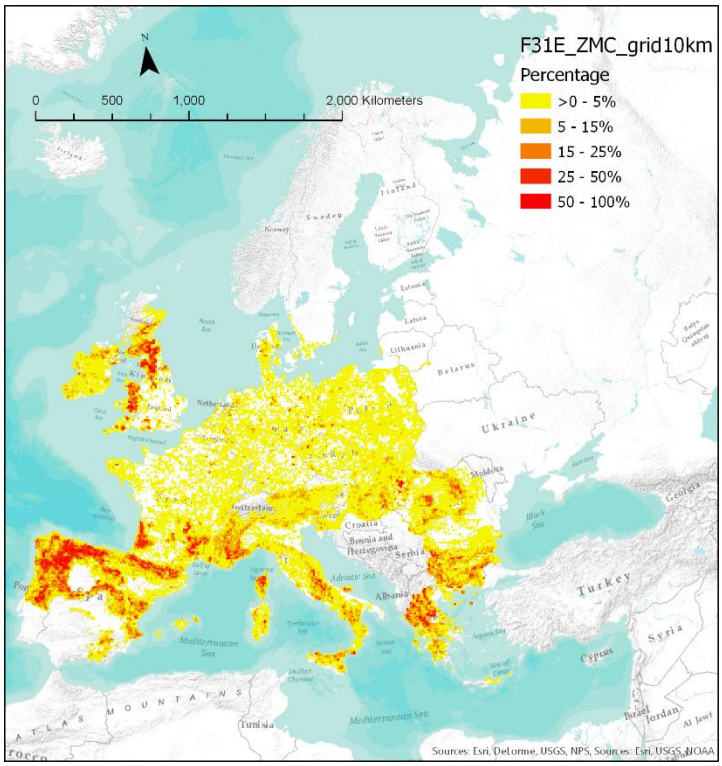
User's accuracy	6.8%
Producer's accuracy	97.0%
Overall accuracy	66.2%



Original EUNIS habitat probability map F3.1e Temperate and submediterranean thorn scrub



Article 17 database with the related Annex I habitat type(s). H40A0 Subcontinental peri-Pannonic scrub

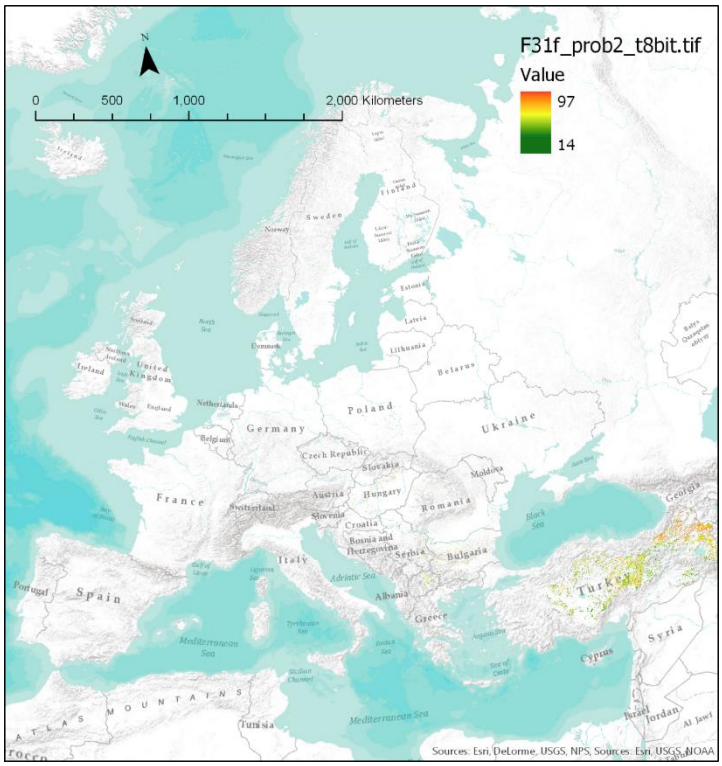


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

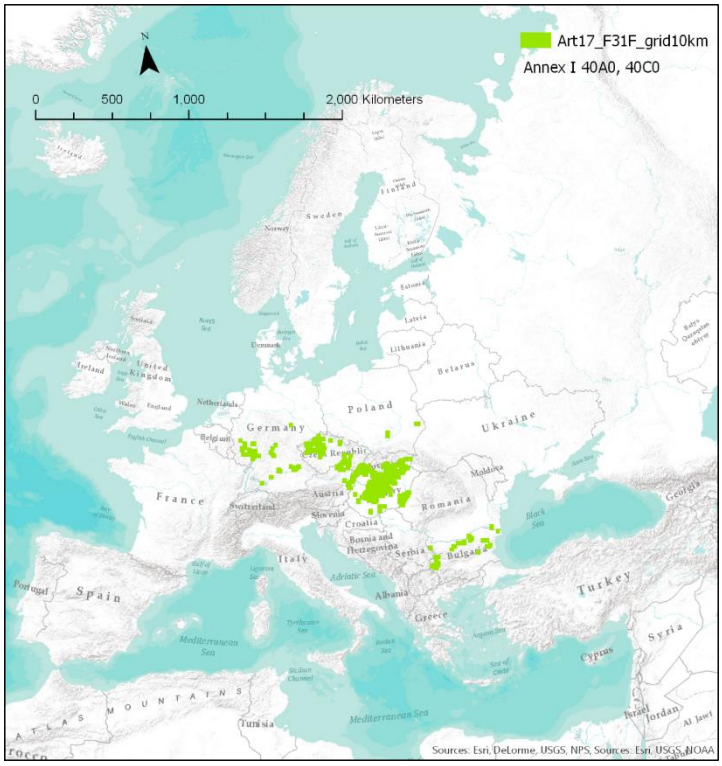
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H40A0 presence	absence	Grand Total
F3.1E presence	**1176**	21824	23000
F3.1E absence	294	**24673**	24967
Grand Total	1470	46497	**47967**

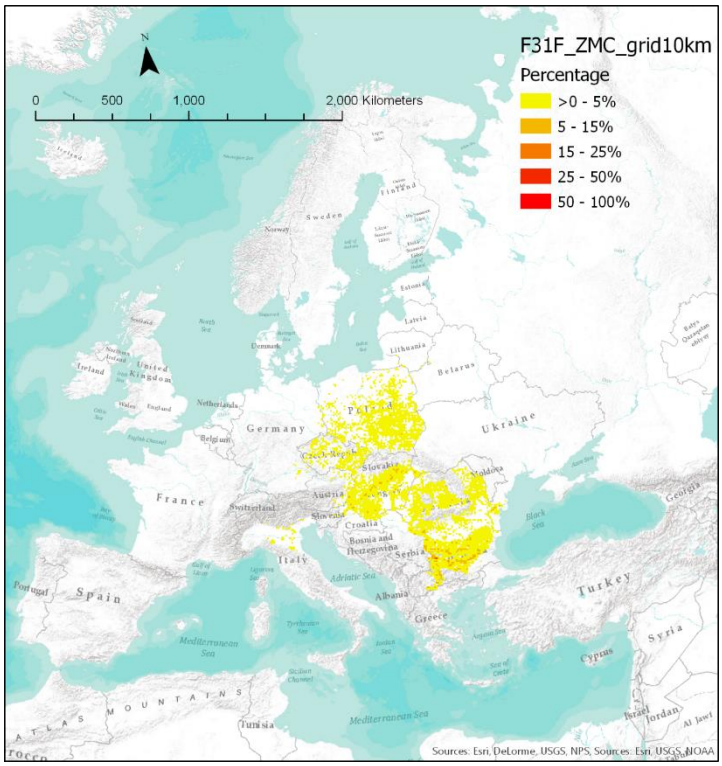
User's accuracy	5.1%
Producer's accuracy	80.0%
Overall accuracy	53.9%



Original EUNIS habitat probability map F3.1f Low steppic scrub



Article 17 database with the related Annex I habitat type(s). H40A0 Subcontinental peri-Pannonic scrub and 40C0 Ponto-Sarmatic deciduous thickets

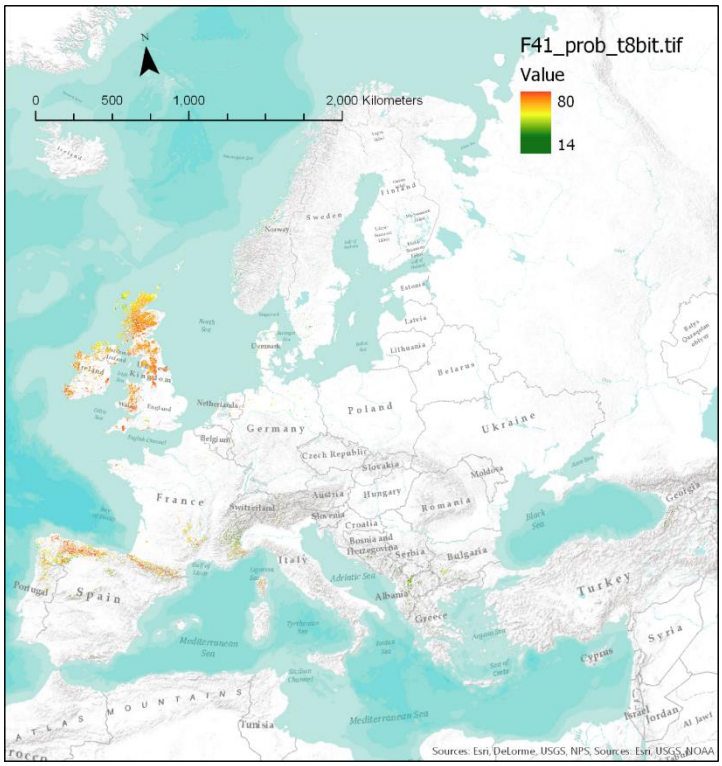


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

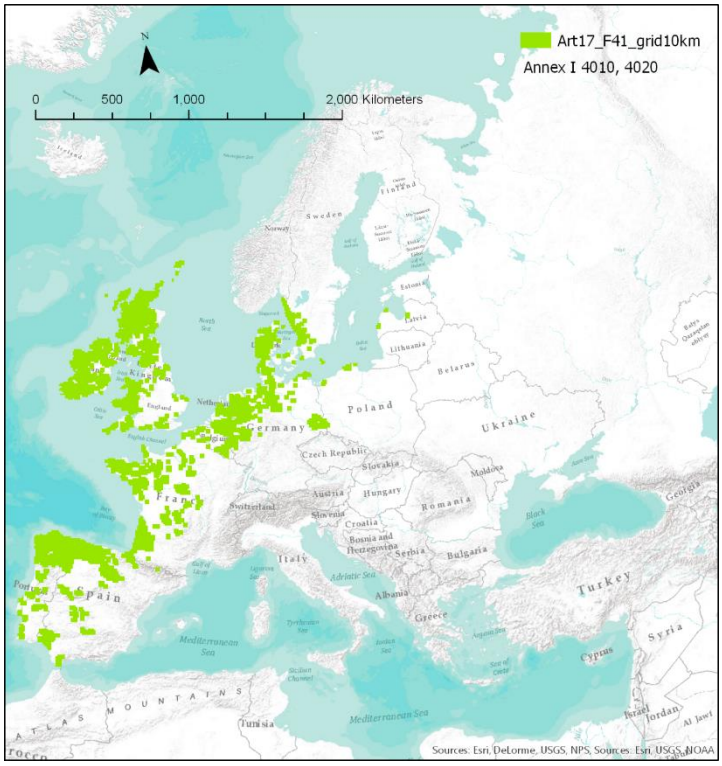
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H40A0 or H40C0 presence	absence	Grand Total
F3.1F presence	**792**	3629	4421
F3.1F absence	701	**42845**	43546
Grand Total	1493	46474	**47967**

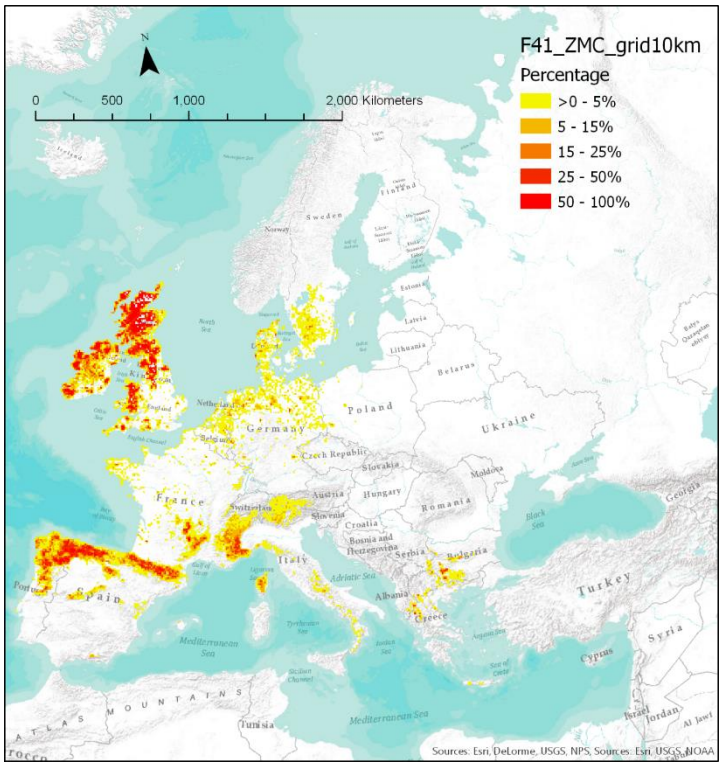
User's accuracy	17.9%
Producer's accuracy	53.0%
Overall accuracy	91.0%



Original EUNIS habitat probability map F4.1 Wet heath



Article 17 database with the related Annex I habitat type(s). H4010 Northern Atlantic wet heaths with Erica tetralix and H4020 Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix

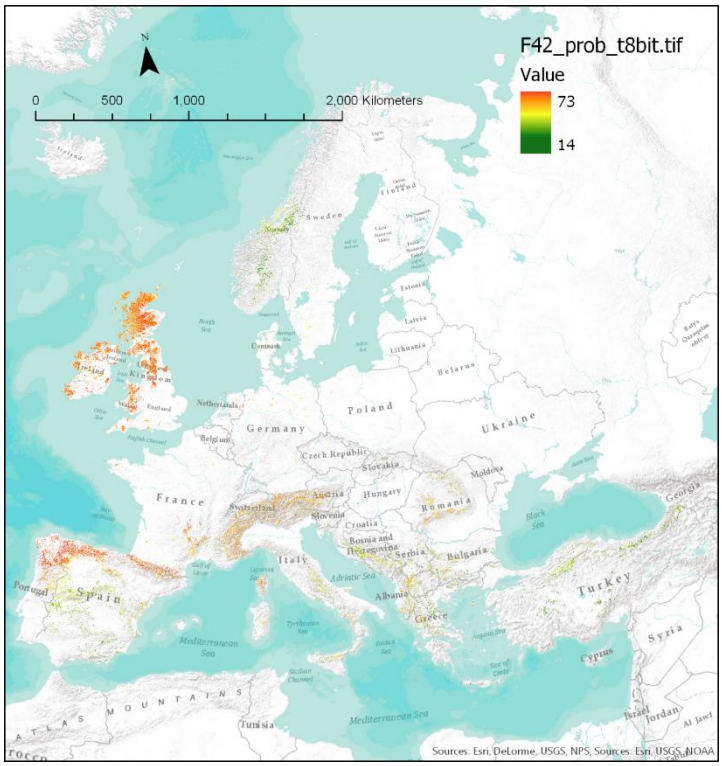


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

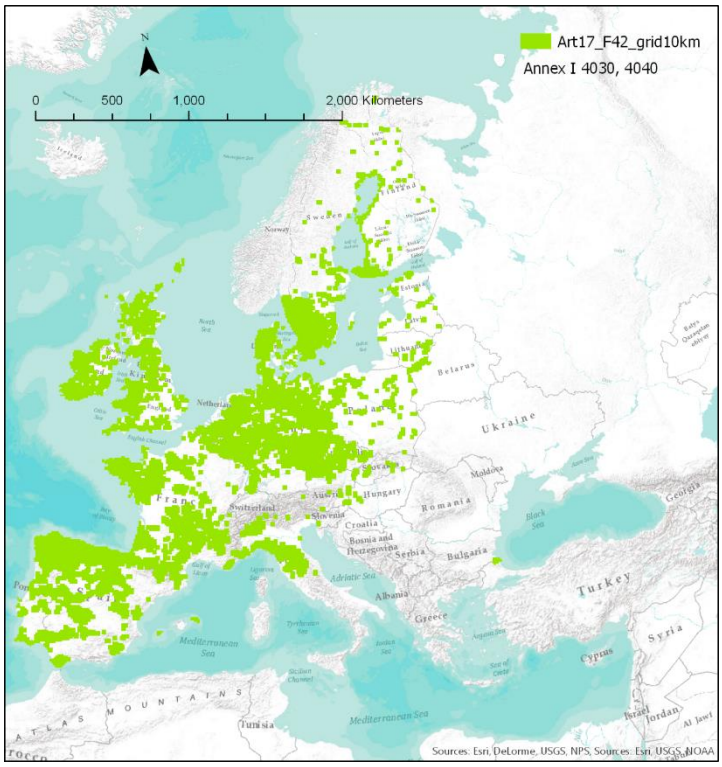
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H4010 or H4020 presence	absence	Grand Total
F4.1 presence	**4106**	3608	7714
F4.1 absence	3536	**36717**	40253
Grand Total	7642	40325	**47967**

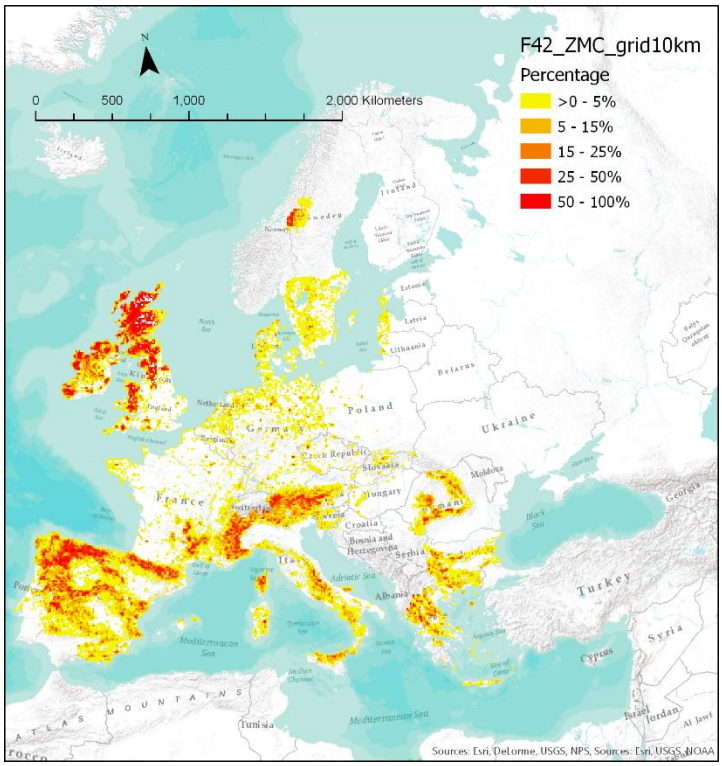
User's accuracy	53.2%
Producer's accuracy	53.7%
Overall accuracy	85.1%



Original EUNIS habitat probability map F4.2 Dry heath



Article 17 database with the related Annex I habitat type(s). H4030 European dry heaths and H4040 Dry Atlantic coastal heaths with Erica vagans

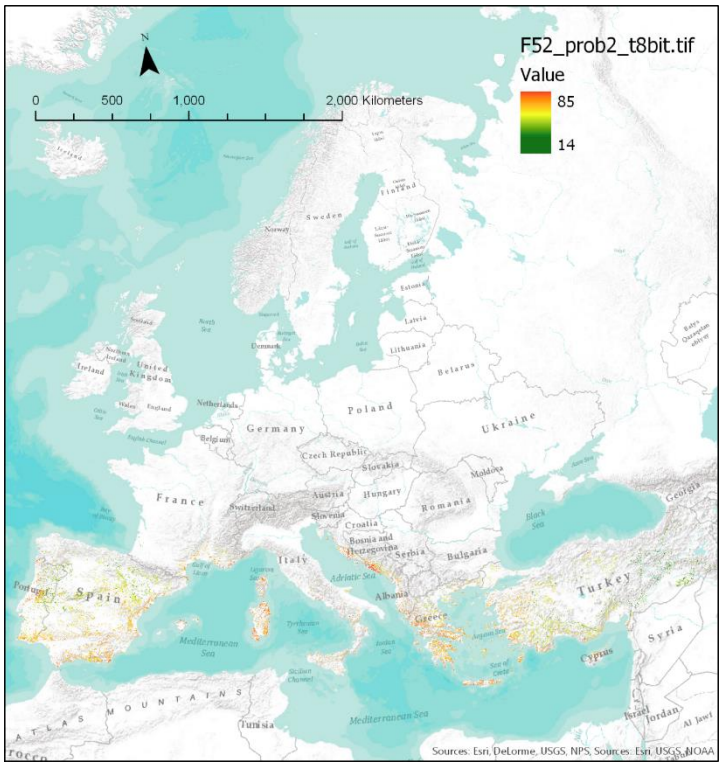


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

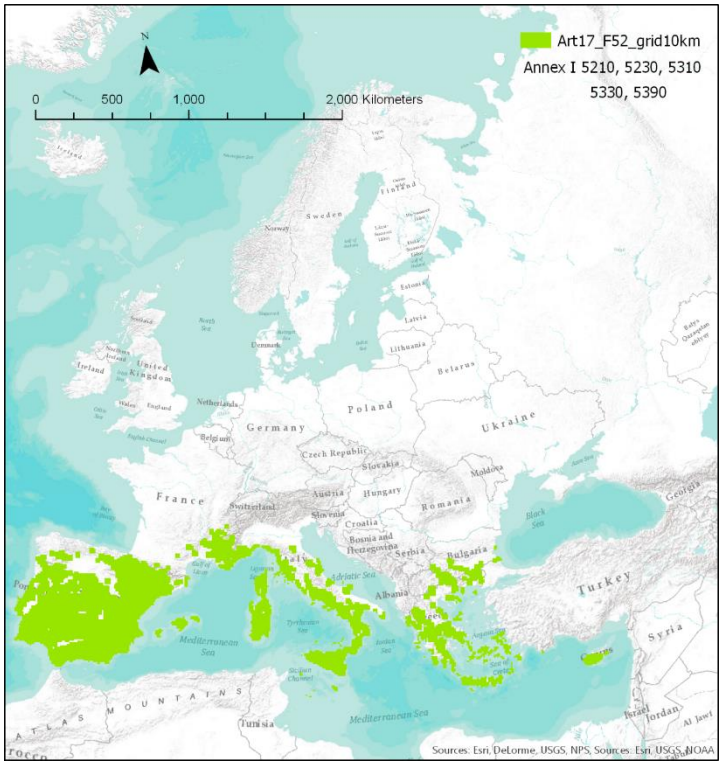
Comparison of the above two figures in an error matrix

Count of 10km grids	Ground truth	Art 17 Annex I	
EUNIS habitat classification	H4030 or H4040 presence	absence	Grand Total
F4.2 presence	**8133**	7431	15564
F4.2 absence	10145	**22258**	32403
Grand Total	18278	29689	**47967**

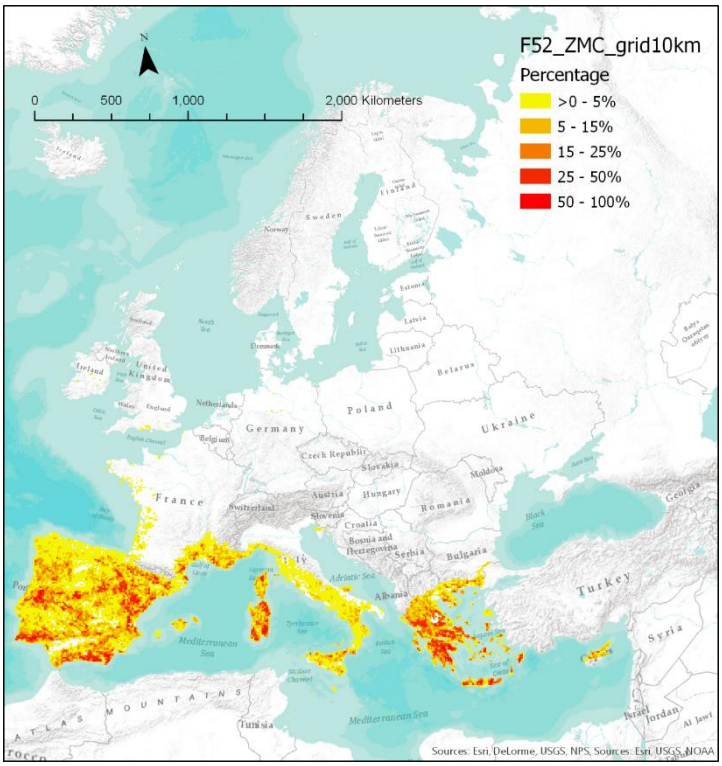
User's accuracy	52.3%
Producer's accuracy	44.5%
Overall accuracy	63.4%



Original EUNIS habitat probability map F5.2 Arborescent matorral and maquis



Article 17 database with the related Annex I habitat type(s). H5210 Arborescent matorral with Juniperus spp , H5230 Arborescent matorral with Laurus nobilis, H5310 Laurus nobilis thickets, H5330 Thermo-Mediterranean and pre-desert scrub

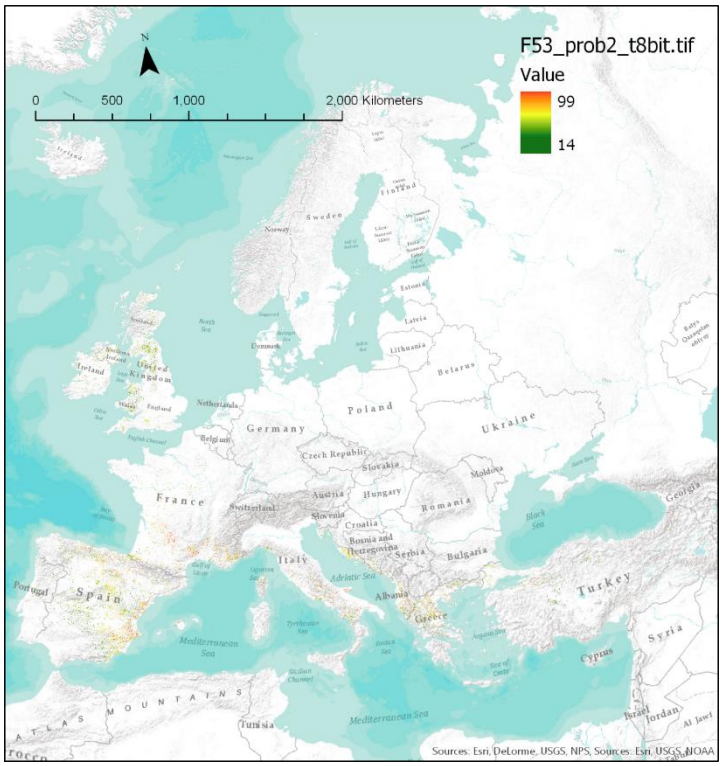


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

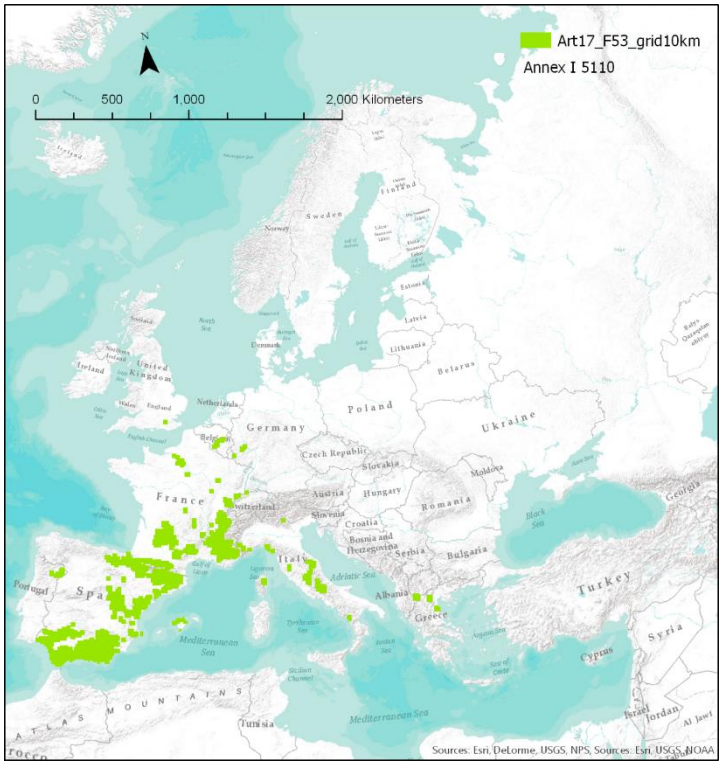
Comparison of the above two figures in an error matrix

Count of 10 km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H5210, H5230, H5310, H5330, H5390 presence	Absence	Grand Total
F5.2 presence	**7256**	2509	9765
F5.2 absence	1562	**36640**	38202
Grand Total	8818	39149	**47967**

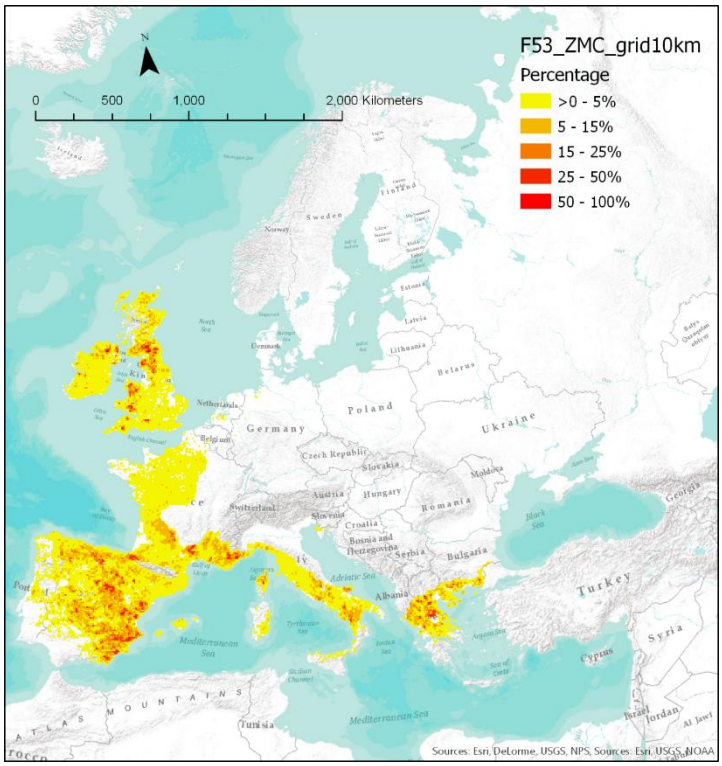
User's accuracy	74.3%
Producer's accuracy	82.3%
Overall accuracy	91.5%



Original EUNIS habitat probability map F5.3 Stable xerothermophilous formations with Buxus sempervirens on rock slopes



Article 17 database with the related Annex I habitat type(s). H5110 Stable xerothermophilous formations with Buxus sempervirens on rock slopes

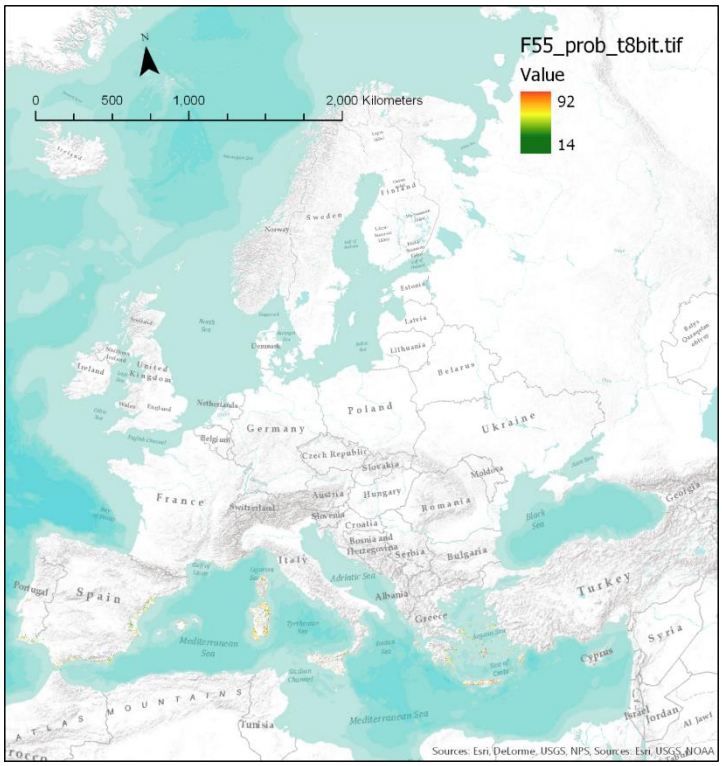


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

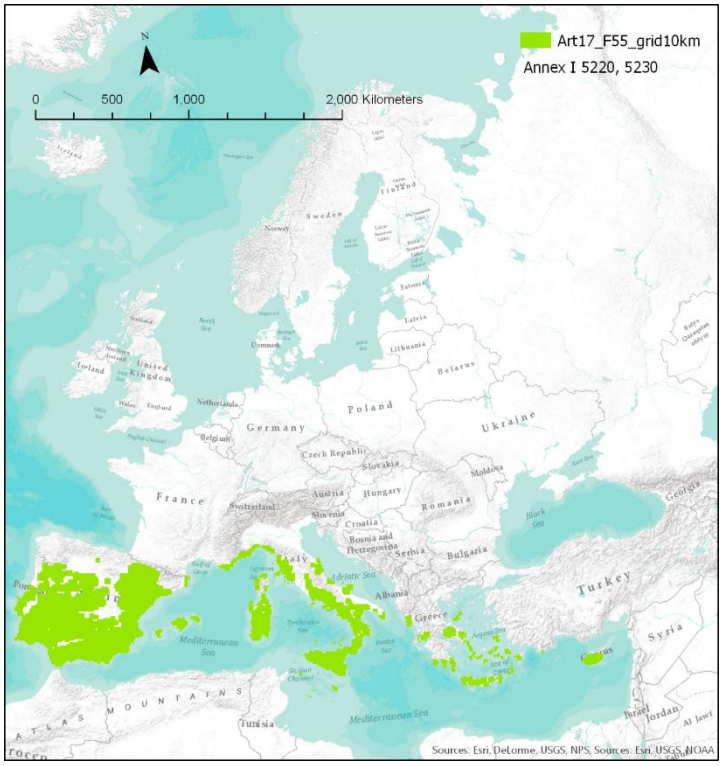
Comparison of the above two figures in an error matrix

Count of 10 km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H5110 presence	absence	Grand Total
F5.3 presence	**2243**	10039	12282
F5.3 absence	1049	**34636**	35685
Grand Total	3292	44675	**47967**

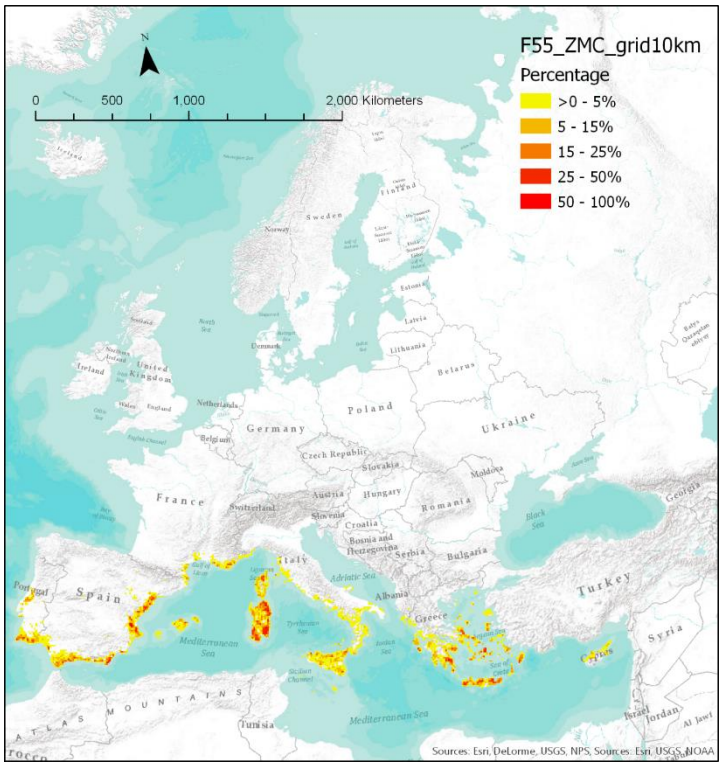
User's accuracy	18.3%
Producer's accuracy	68.1%
Overall accuracy	76.9%



Original EUNIS habitat probability map. F5.5 Thermo-Mediterranean scrub



Article 17 database with the related Annex I habitat type(s). H5220 Arborescent matorral with Zyziphus. H5330 Thermo-Mediterranean and pre-desert scrub

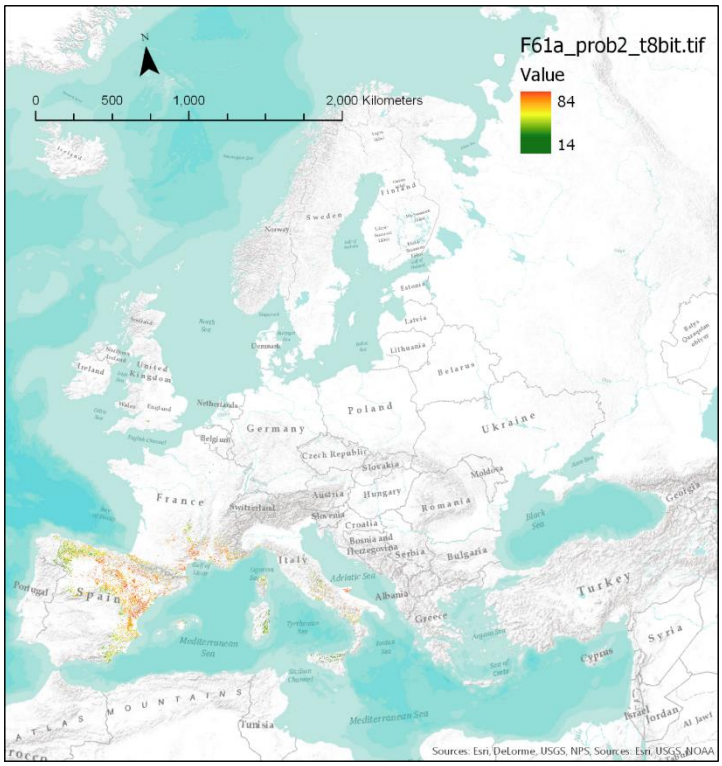


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

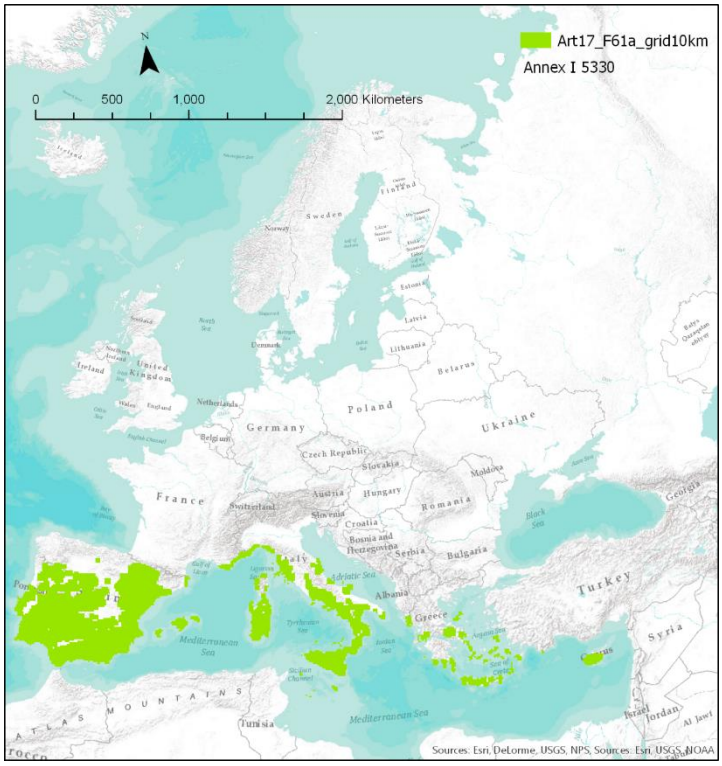
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H5220 or H5330 presence	absence	Grand Total
F5.5 presence	**1903**	621	2524
F5.5 absence	4524	**40919**	45443
Grand Total	6427	41540	**47967**

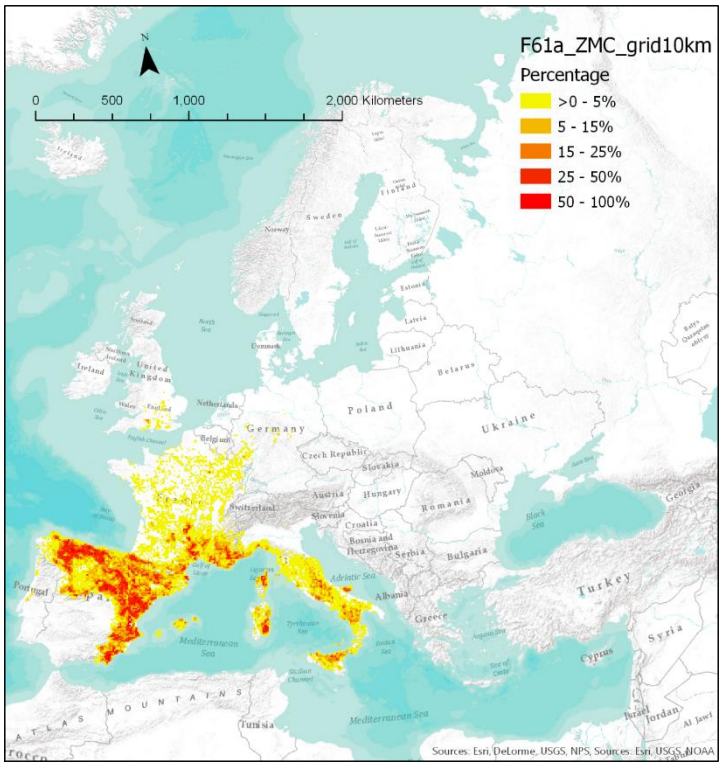
User's accuracy	75.4%
Producer's accuracy	29.6%
Overall accuracy	89.3%



Original EUNIS habitat probability map F6.1a Western basiphilous garrigue



Article 17 database with the related Annex I habitat type(s). H5330 Thermo-Mediterranean and pre-desert scrub

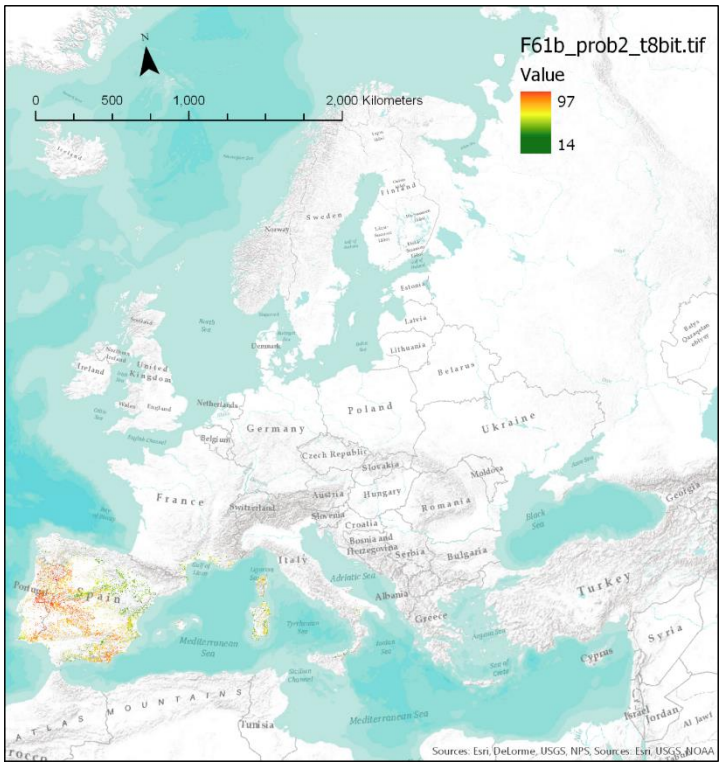


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

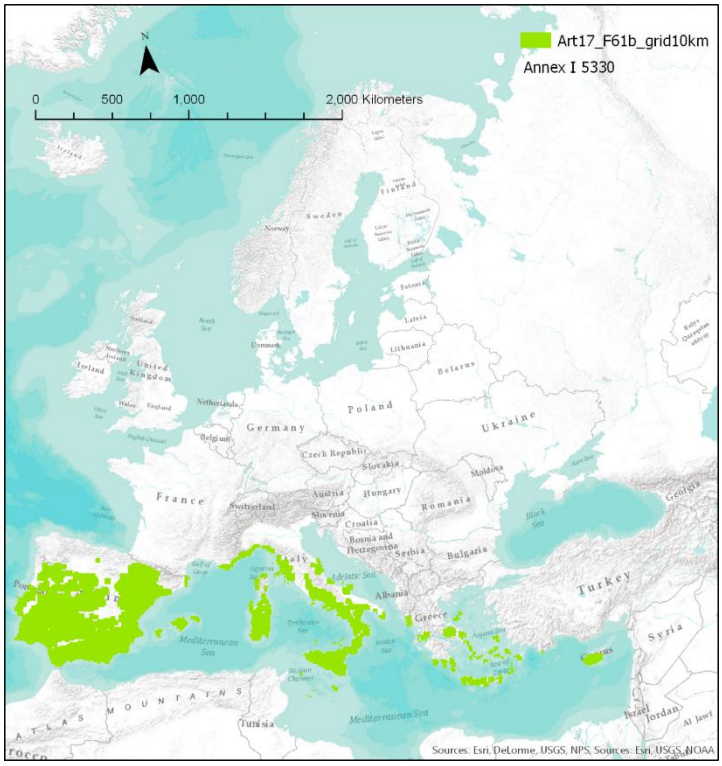
Comparison of the above two figures in an error matrix

Count of 10km grids	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H5330 or H5140 presence	absence	Grand Total
F6.1a presence	**2816**	4760	7576
F6.1a absence	3611	**36780**	40391
Grand Total	6427	41540	**47967**

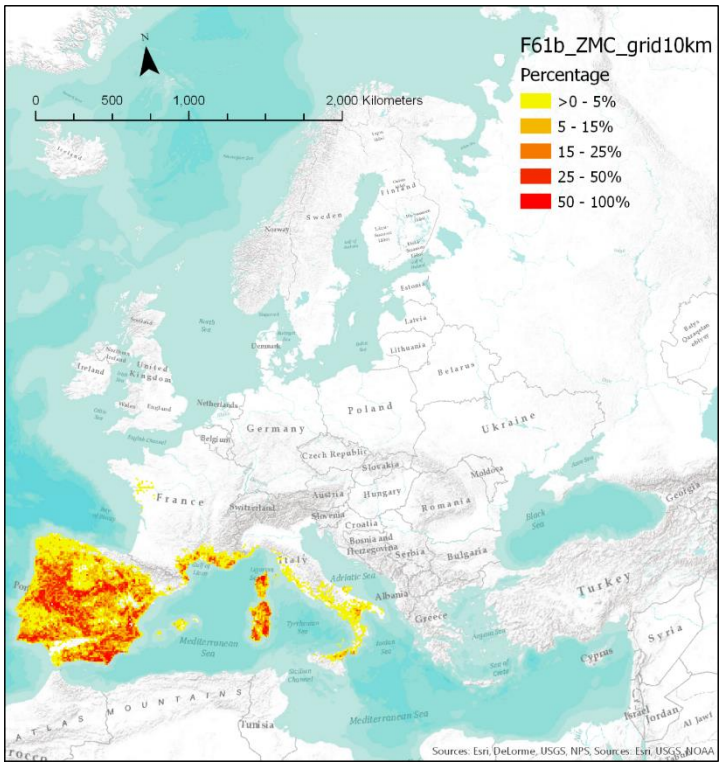
User's accuracy	37.2%
Producer's accuracy	43.8%
Overall accuracy	82.5%



Original EUNIS habitat probability map F6.1b Western acidophilous garrigue



Article 17 database with the related Annex I habitat type(s). H5330 'Thermo-Mediterranean and pre-desert scrub

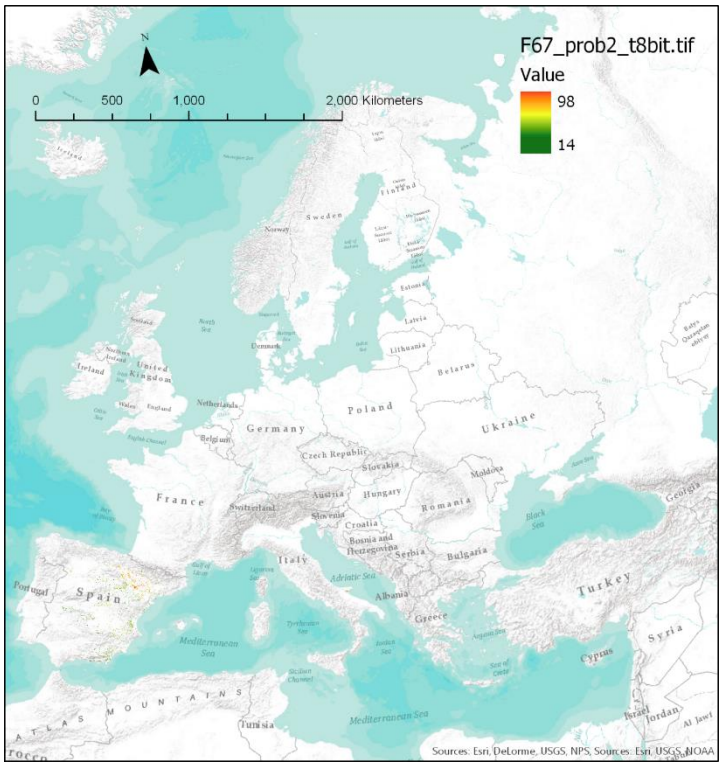


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

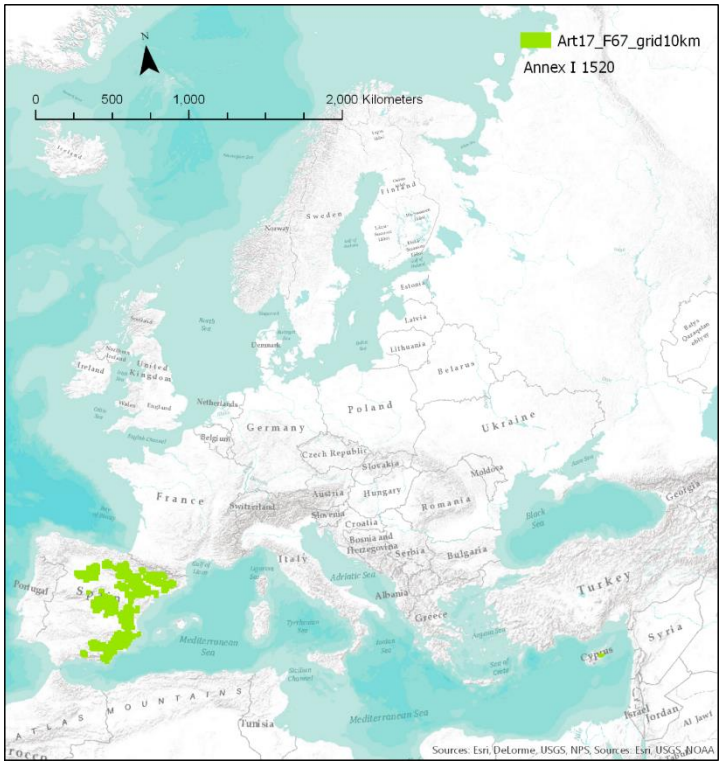
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H5330 presence	absence	Grand Total
F6.1b presence	**4600**	2010	6610
F6.1b absence	1827	**39530**	41357
Grand Total	6427	41540	**47967**

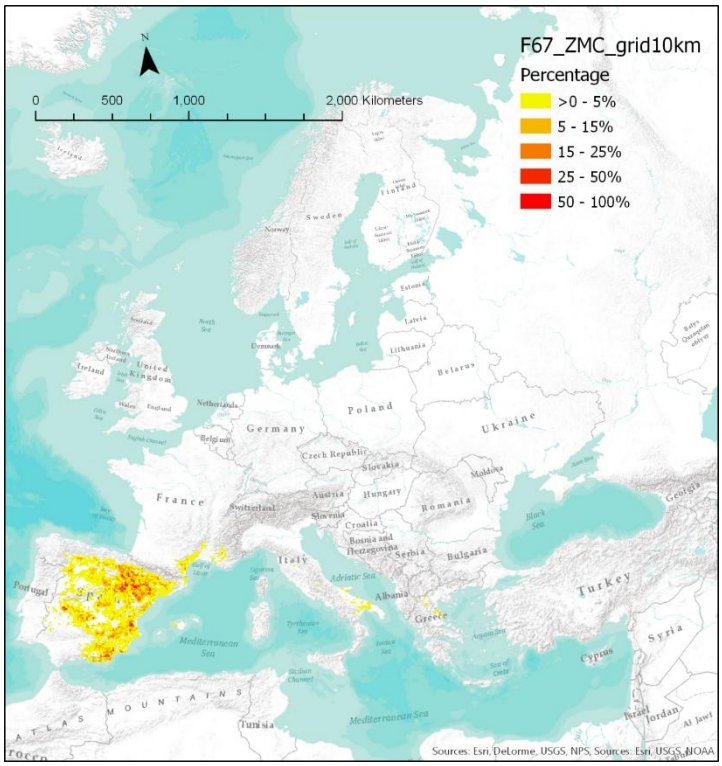
User's accuracy	69.6%
Producer's accuracy	71.6%
Overall accuracy	92.0%



Original EUNIS habitat probability map F6.7 Mediterranean gypsum scrub



Article 17 database with the related Annex I habitat type(s). H1520 'Iberian gypsum vegetation (Gypsophiletalia)

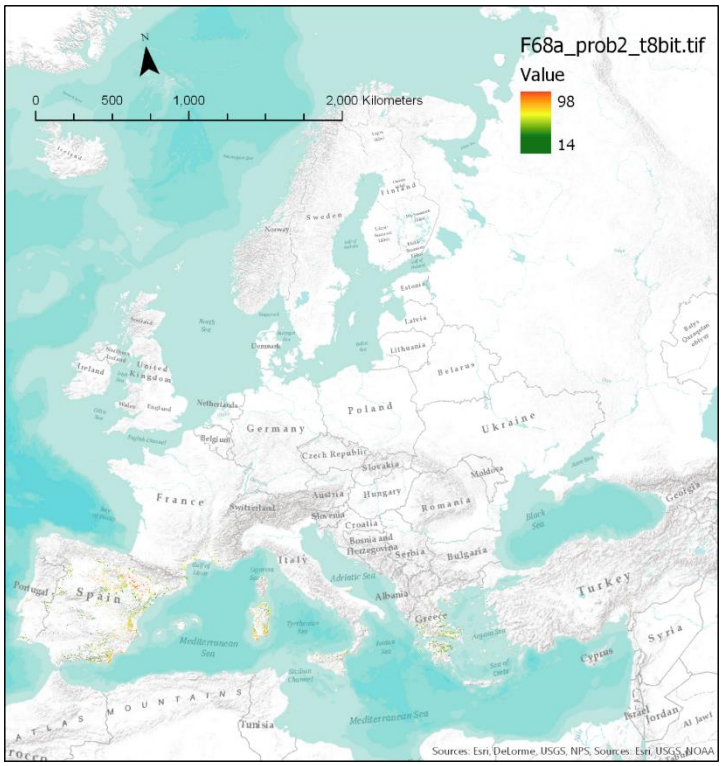


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

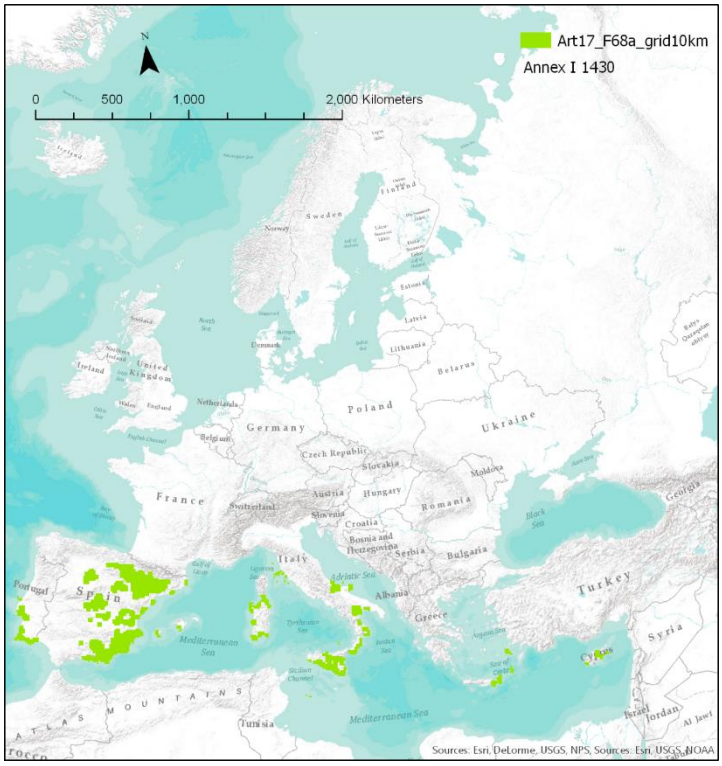
Comparison of the above two figures in an error matrix

Count of 10km grids	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H1520 presence	absence	Grand Total
F6.7 presence	**1264**	1338	2602
F6.7 absence	292	**45073**	45365
Grand Total	1556	46411	**47967**

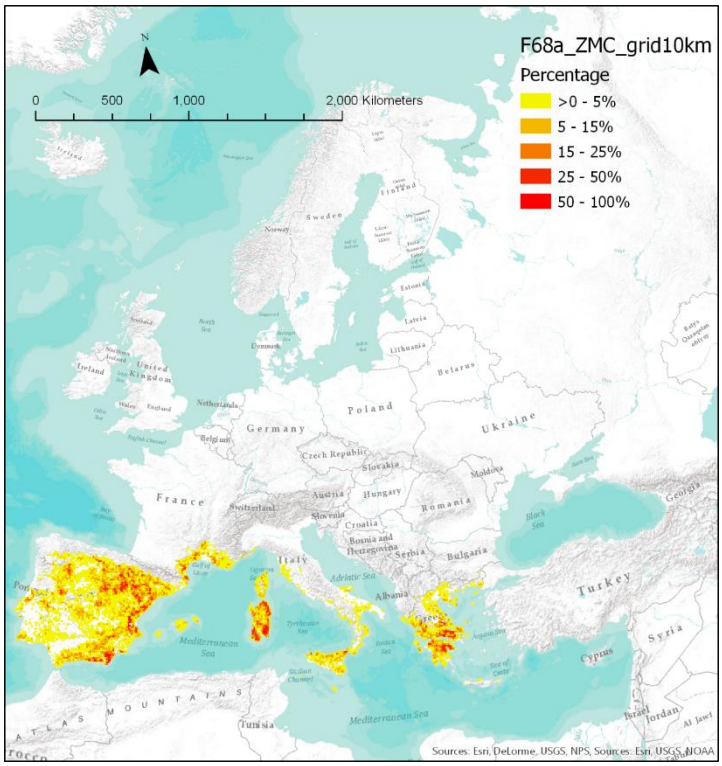
User's accuracy	48.6%
Producer's accuracy	81.2%
Overall accuracy	96.6%



Original EUNIS habitat probability map F6.8a Mediterranean halo-nitrophilous scrub



Article 17 database with the related Annex I habitat type(s). H1430 Halo-nitrophilous scrubs (Pegano-Salsoletea)

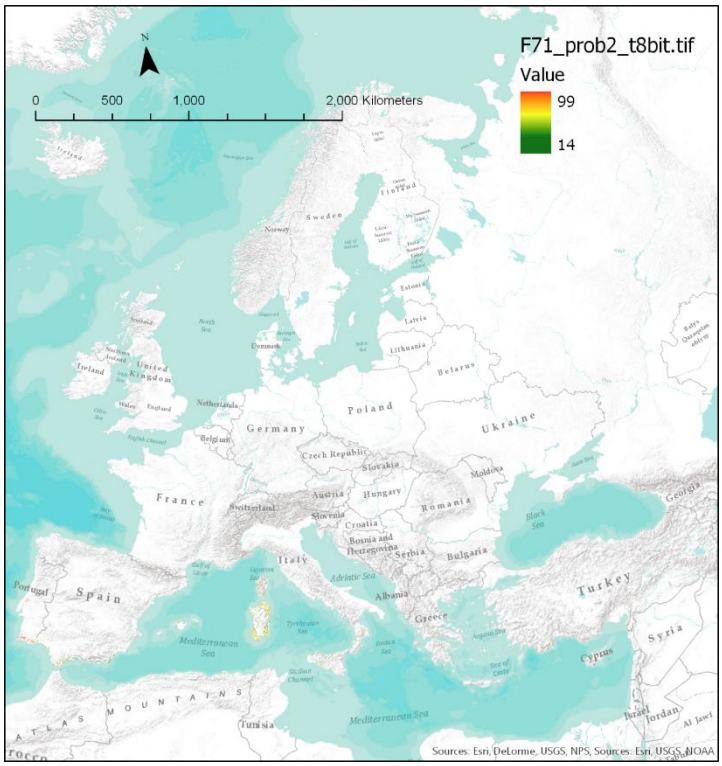


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

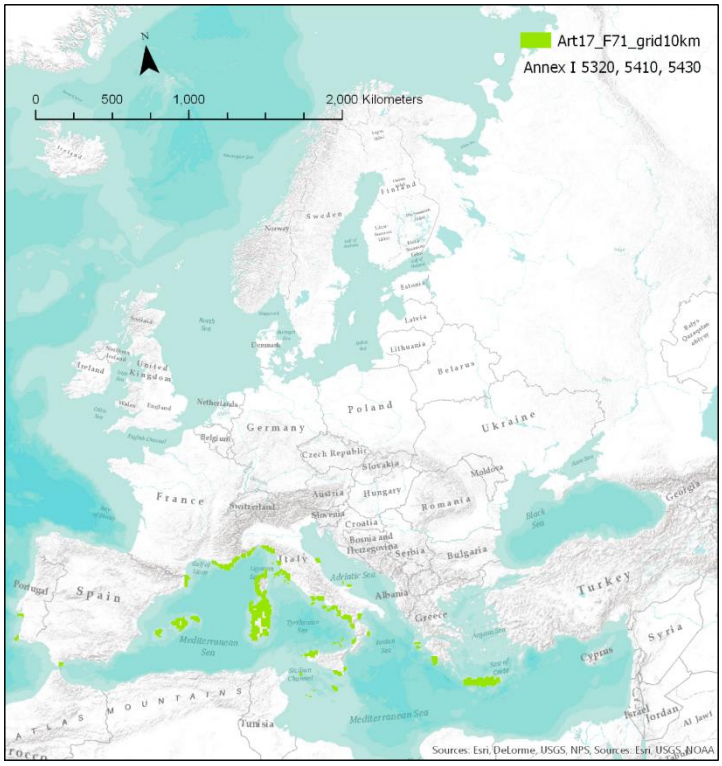
Comparison of the above two figures in an error matrix

Count of 10km grids	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H1430 presence	absence	Grand Total
F6.8a presence	**1534**	4250	5784
F6.8a absence	547	**41636**	42183
Grand Total	2081	45886	**47967**

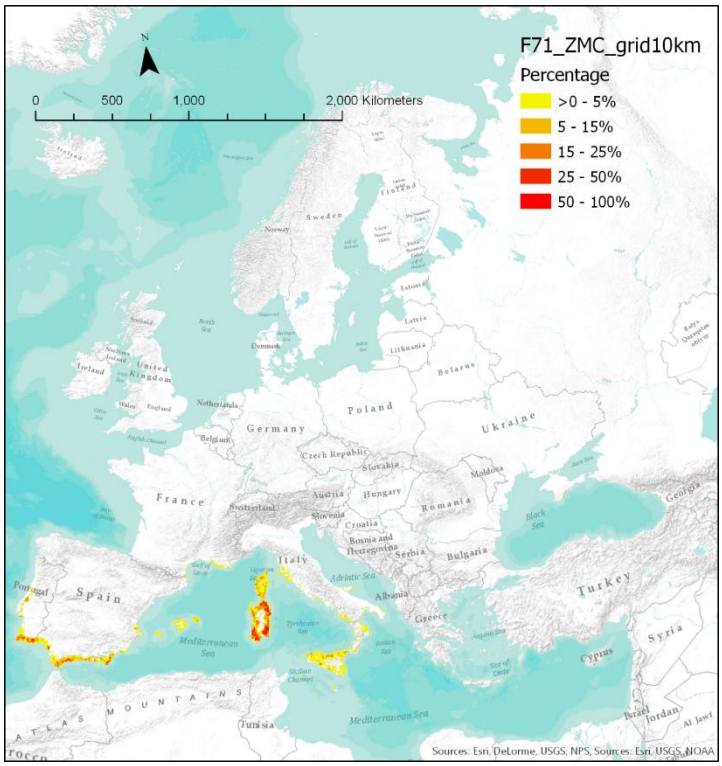
User's accuracy	26.5%
Producer's accuracy	73.7%
Overall accuracy	90.0%



Original EUNIS habitat probability map F7.1 Western Mediterranean coastal garrigue



Article 17 database with the related Annex I habitat type(s). H5320 Low formations of Euphorbia close to cliffs, H5410 West Mediterranean clifftop phryganas (Astragalo-Plantaginetum subulatae), H5430 Endemic phryganas of the Euphorbio-Verbascion

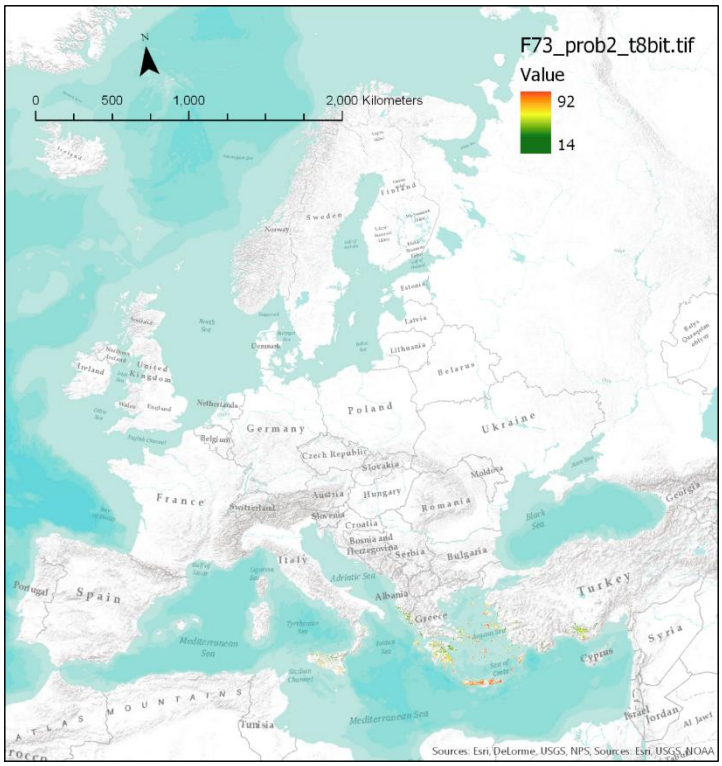


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

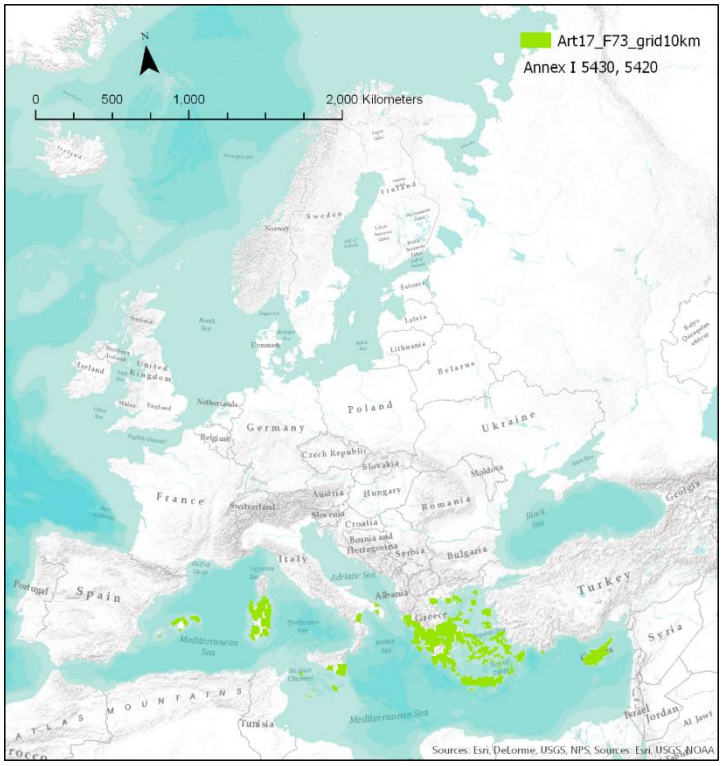
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H5320, H5410, H5430 presence	absence	Grand Total
F7.1 presence	**428**	591	1019
F7.1 absence	557	**46391**	46948
Grand Total	985	46982	**47967**

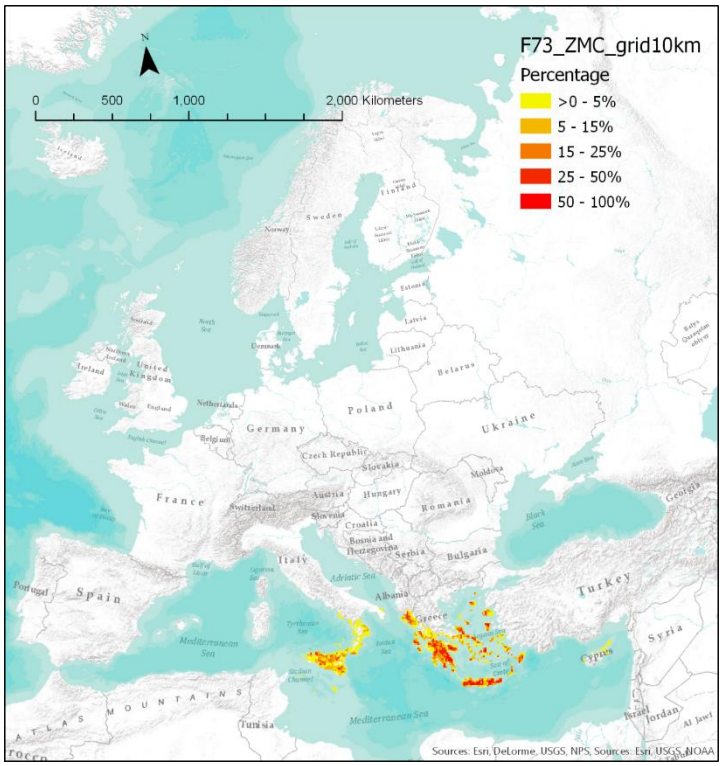
User's accuracy	42.0%
Producer's accuracy	43.5%
Overall accuracy	97.6%



Original EUNIS habitat probability map F7.3 Eastern Mediterranean spiny heath (phrygana)



Article 17 database with the related Annex I habitat type(s). H5430 Endemic phryganas of the Euphorbio-Verbascion and H5420 Sarcopoterium spinosum phryganas

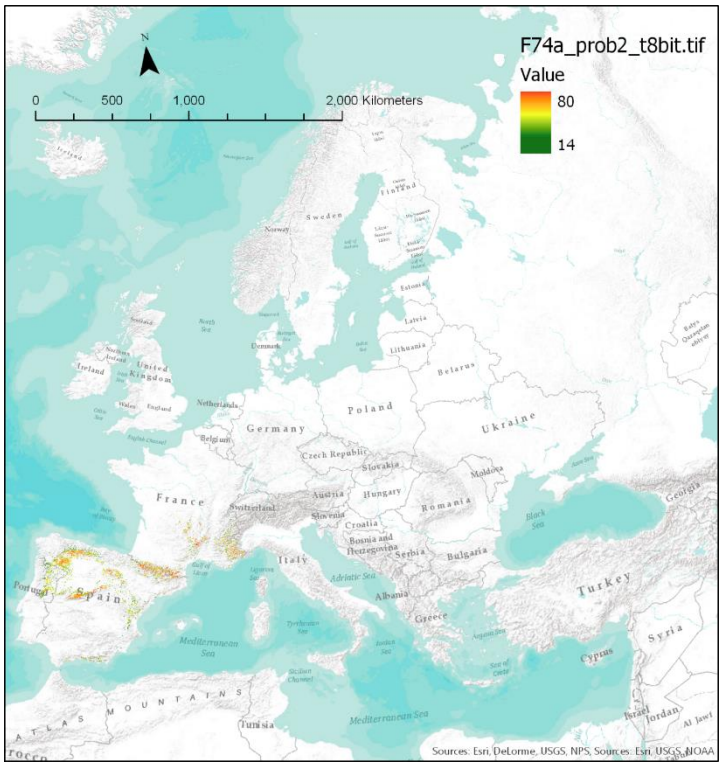


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

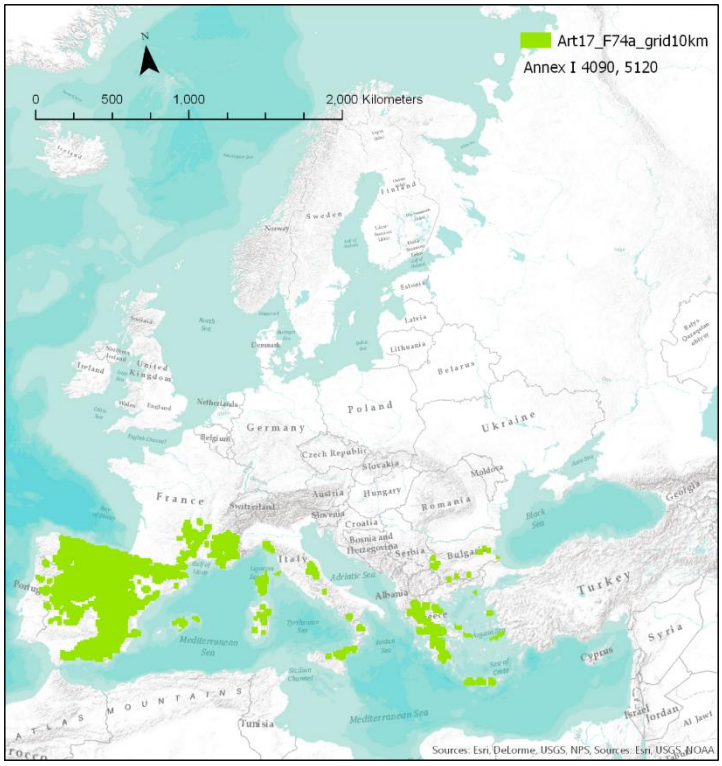
Comparison of the above two figures in an error matrix

Count of 10 km grid cells	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H5430 or H5420 presence	absence	Grand Total
F7.3 presence	**792**	492	1284
F7.3 absence	906	**45777**	46683
Grand Total	1698	46269	**47967**

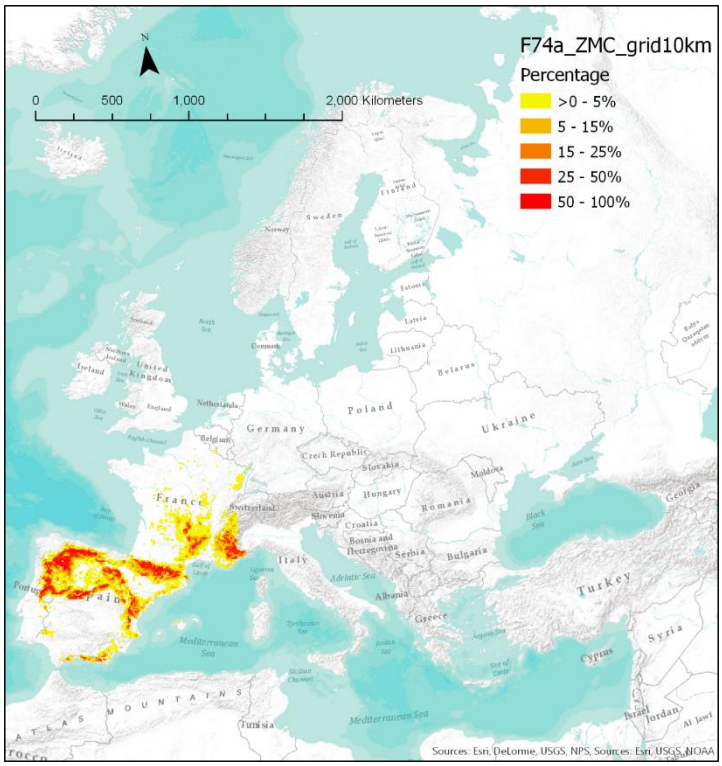
User's accuracy	61.7%
Producer's accuracy	46.6%
Overall accuracy	97.1%



Original EUNIS habitat probability map F7.4a Western Mediterranean mountain hedgehog-heath



Article 17 database with the related Annex I habitat type(s). H4090 Endemic oro-Mediterranean heaths with gorse and H5120 Mountain Cytisus purgans formations

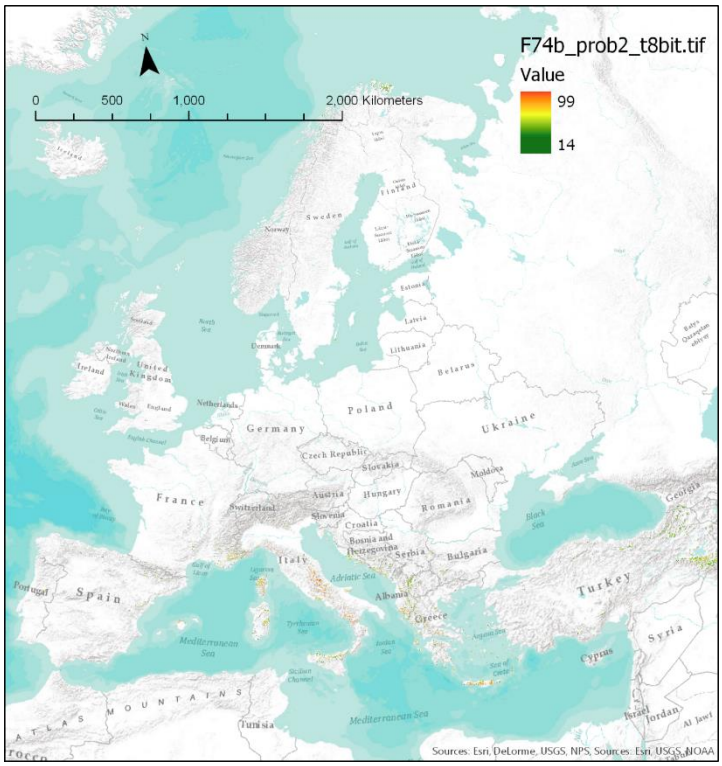


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

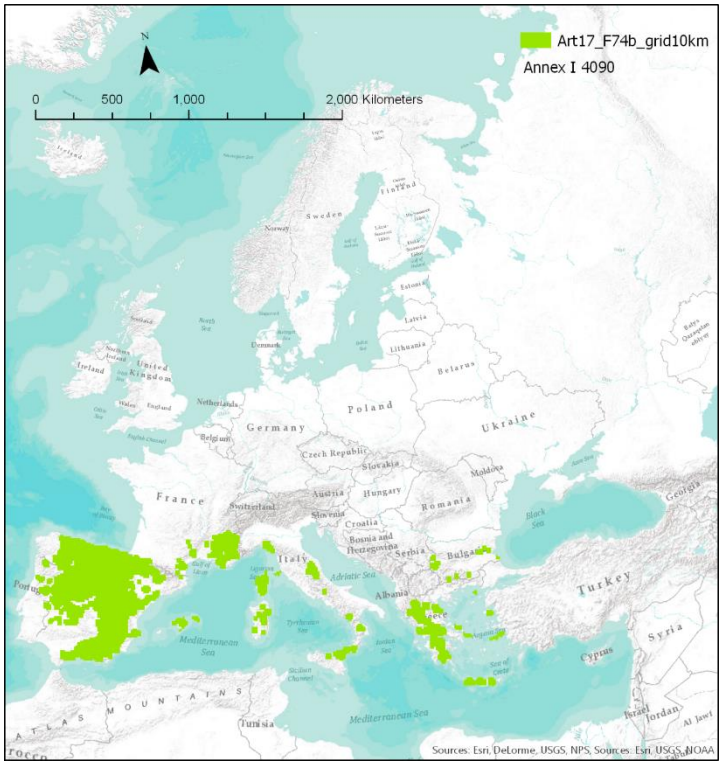
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H4090 or H5120 presence	absence	Grand Total
F7.4a presence	**2585**	971	3556
F7.4a absence	3328	**41083**	44411
Grand Total	5913	42054	**47967**

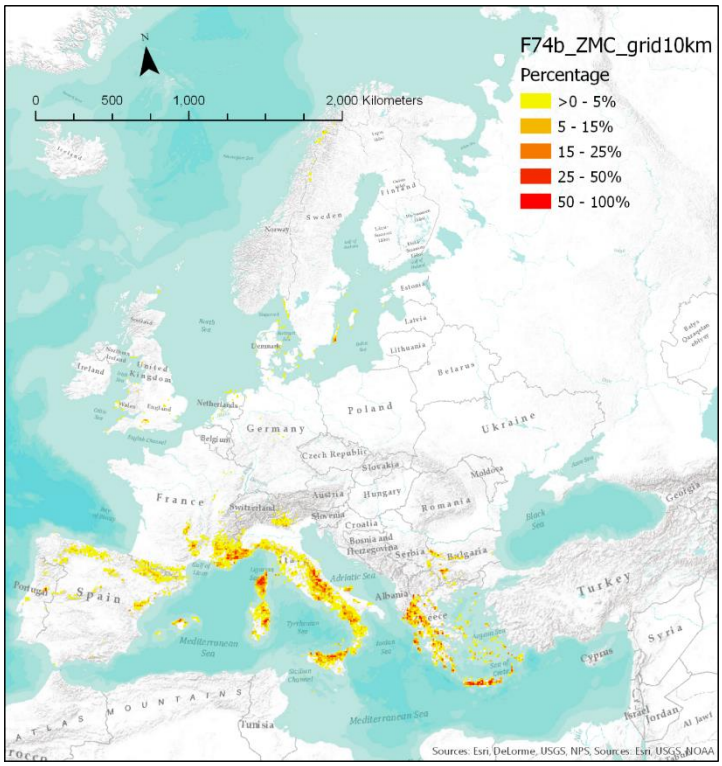
User's accuracy	72.7%
Producer's accuracy	43.7%
Overall accuracy	91.0%



Original EUNIS habitat probability map F7.4b Central Mediterranean mountain hedgehog-heath



Article 17 database with the related Annex I habitat type(s). H4090 Endemic oro-Mediterranean heaths with gorse

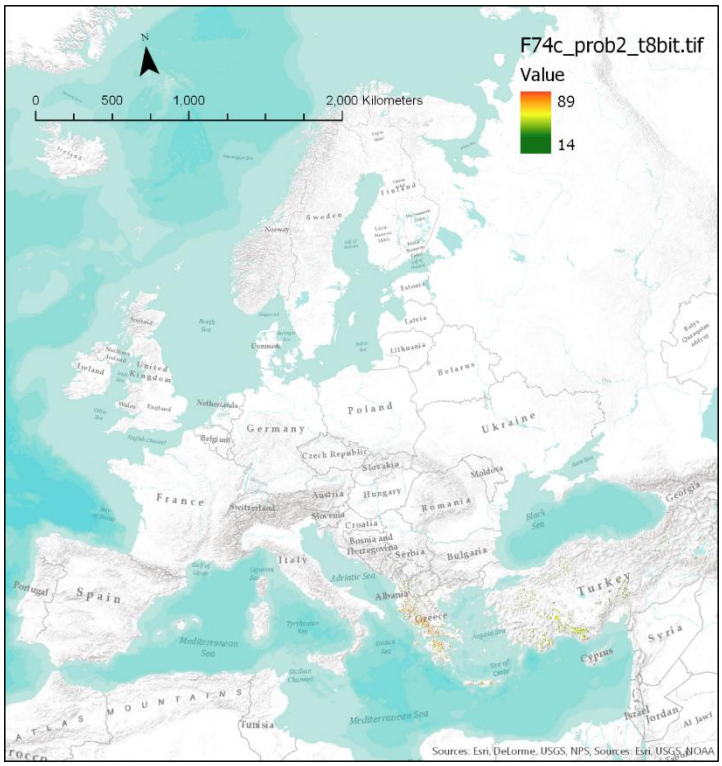


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

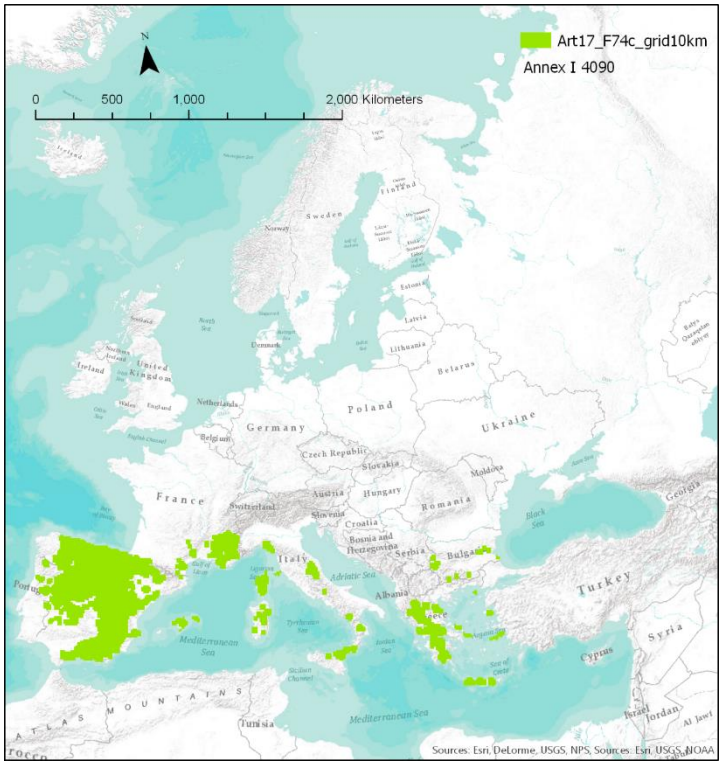
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H4090 presence	absence	Grand Total
F7.4b presence	**1437**	1714	3151
F7.4b absence	4073	**40743**	44816
Grand Total	5510	42457	**47967**

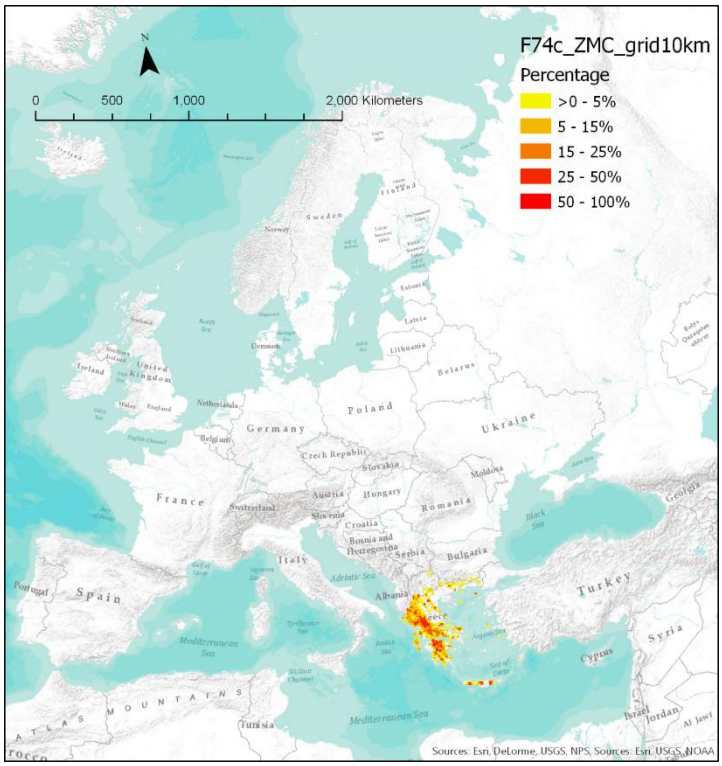
User's accuracy	45.6%
Producer's accuracy	26.1%
Overall accuracy	87.9%



Original EUNIS habitat probability map F7.4c Eastern Mediterranean mountain hedgehog-heath



Article 17 database with the related Annex I habitat type(s). H4090 Endemic oro-Mediterranean heaths with gorse

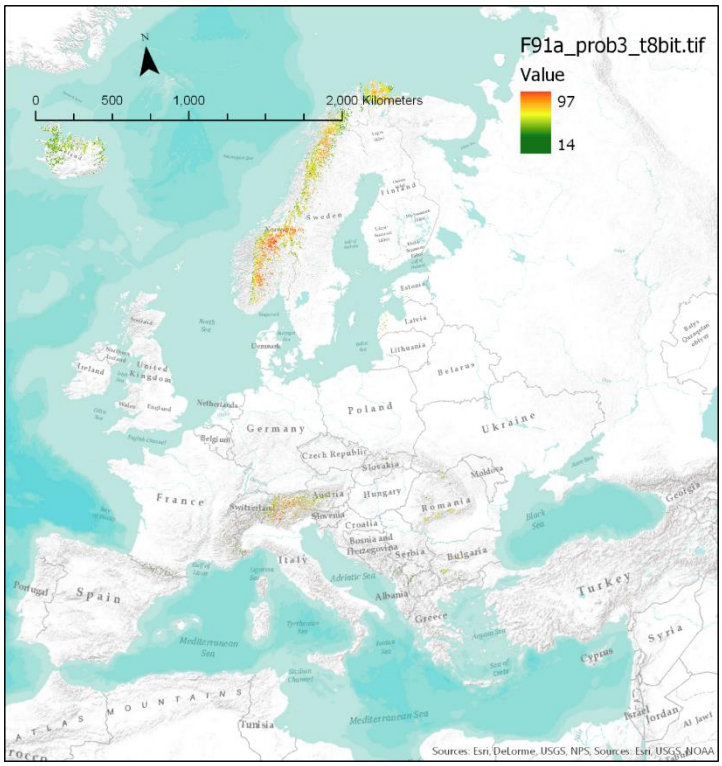


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

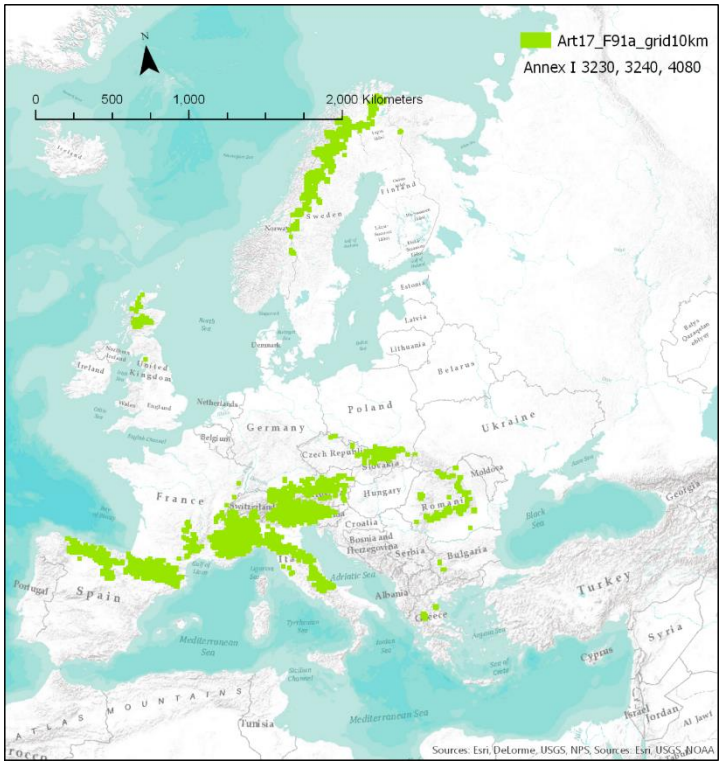
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H4090 presence	H4090 absence	Grand Total
F7.4c presence	**430**	312	742
F7.4c absence	5080	**42145**	47225
Grand Total	5510	42457	**47967**

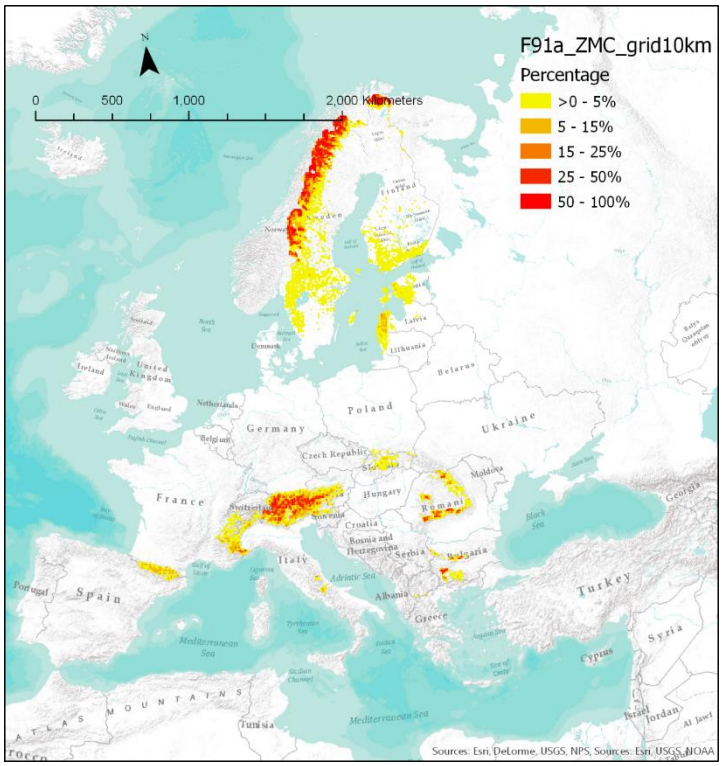
User's accuracy	58.0%
Producer's accuracy	7.8%
Overall accuracy	88.8%



Original EUNIS habitat probability map F9.1a Arctic, boreal and alpine riparian scrub



Article 17 database with the related Annex I habitat type(s). H3230 Alpine rivers and their ligneous vegetation with Myricaria germanica, H3240 Alpine rivers and their ligneous vegetation with Salix elaeagnos, H4080 Sub-Arctic Salix spp scrub

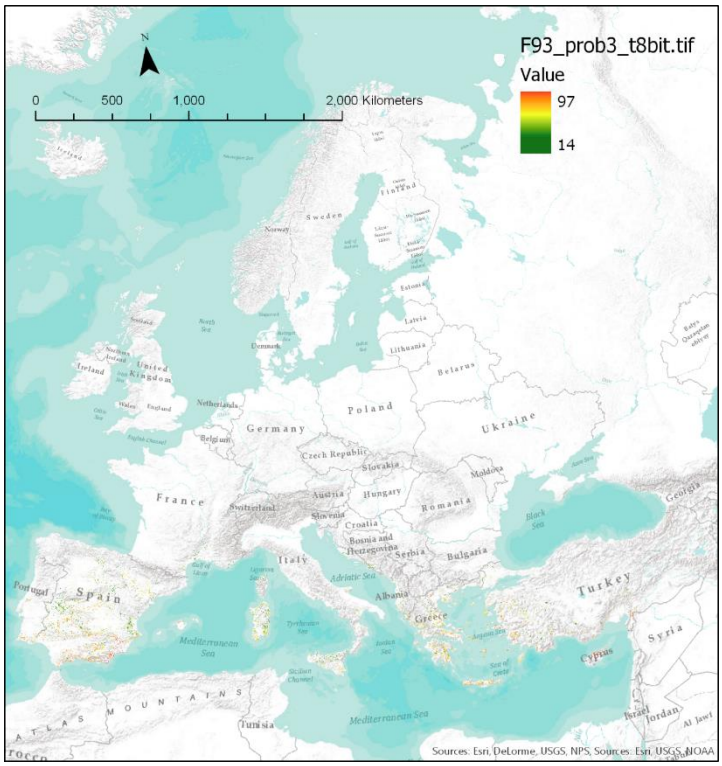


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

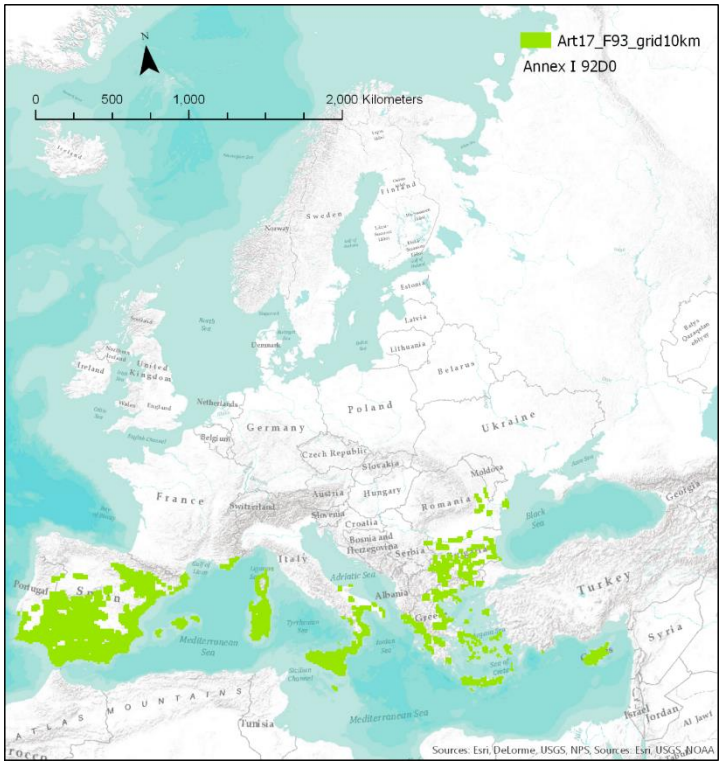
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H3230, H3240, H4080 presence	absence	Grand Total
F9.1a presence	**2176**	2577	4753
F9.1a absence	3568	**39646**	43214
Grand Total	5744	42223	**47967**

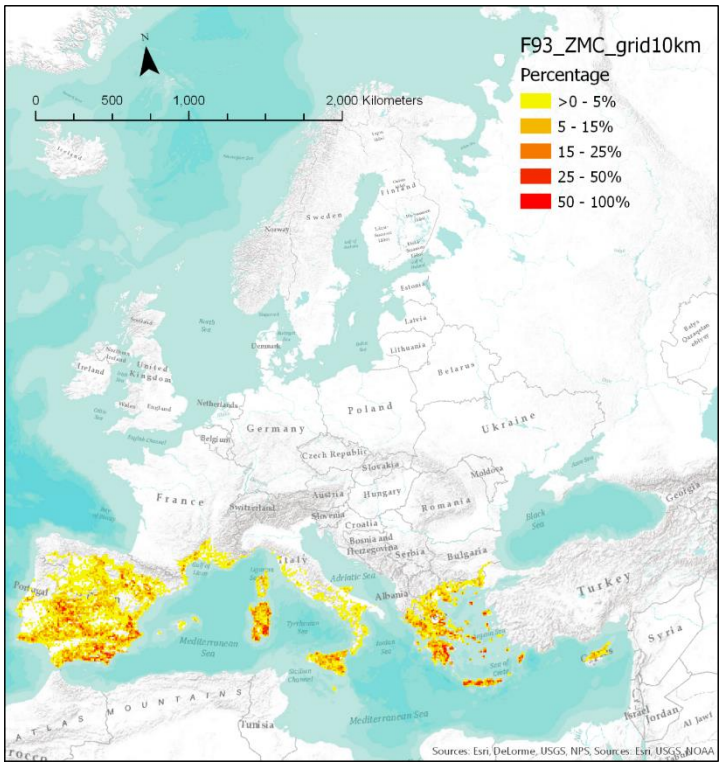
User's accuracy	45.8%
Producer's accuracy	37.9%
Overall accuracy	87.2%



Original EUNIS habitat probability map F9.3 Mediterranean riparian scrub



Article 17 database with the related Annex I habitat type(s). H92D0 Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)

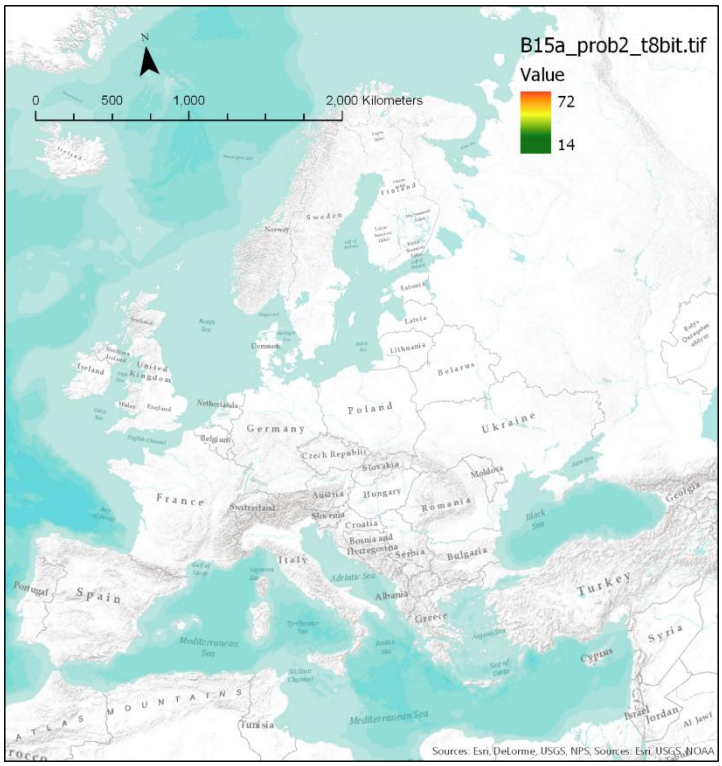


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

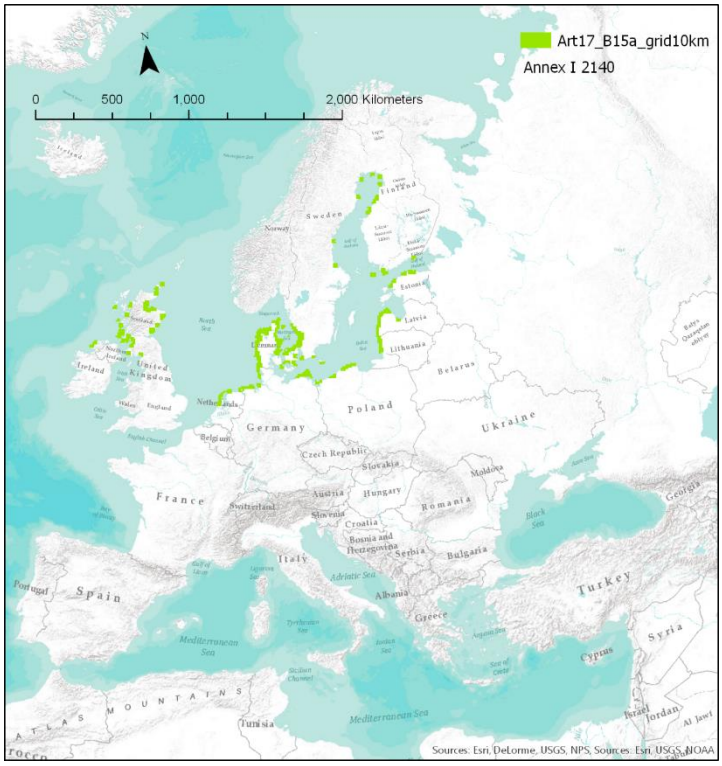
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	92D0 presence	absence	Grand Total
F9.3 presence	**3736**	2210	5946
F9.3 absence	2275	**39746**	42021
Grand Total	6011	41956	**47967**

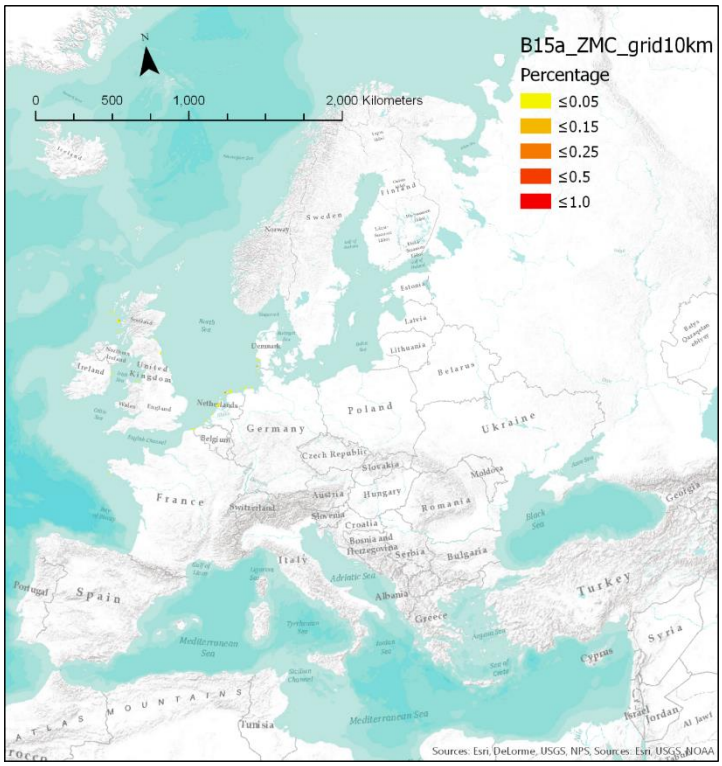
User's accuracy	62.8%
Producer's accuracy	62.2%
Overall accuracy	90.6%



Original EUNIS habitat probability map B1.5a Atlantic and Baltic coastal Empetrum heaths



Article 17 database with the related Annex I habitat type(s). H2140 Decalcified fixed dunes with Empetrum nigrum

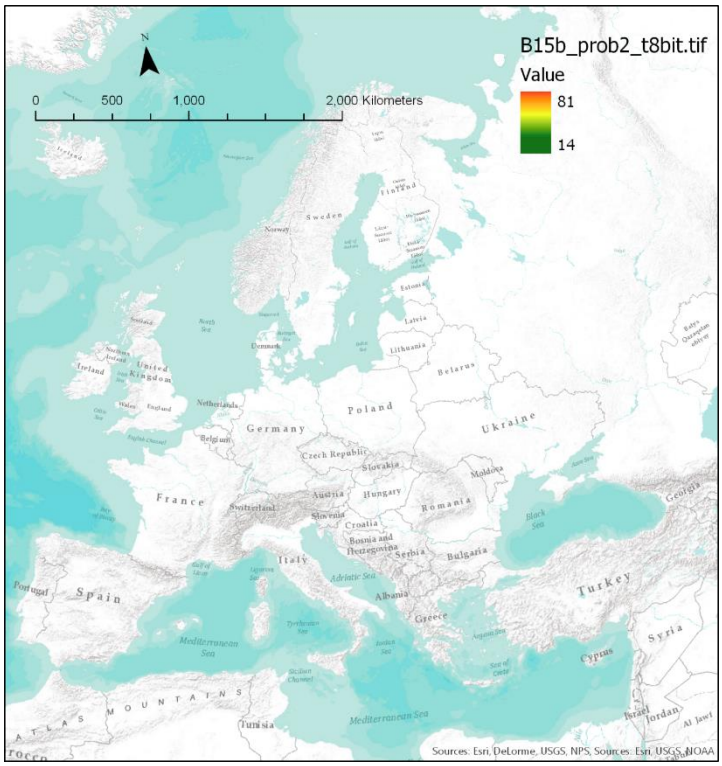


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

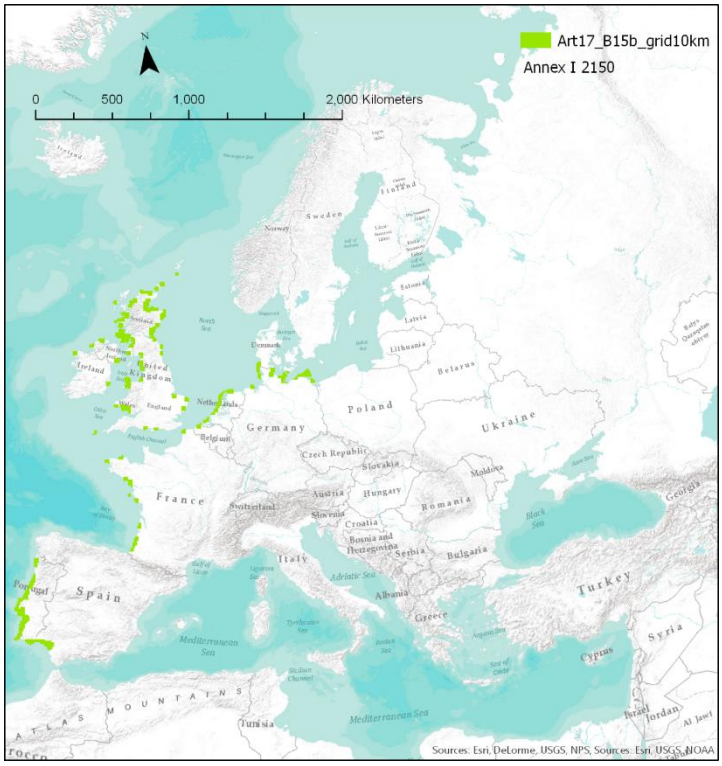
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H2140 presence	absence	Grand Total
B1.5a presence	**24**	12	36
B1.5b absence	987	**46944**	47931
Grand Total	1011	46956	**47967**

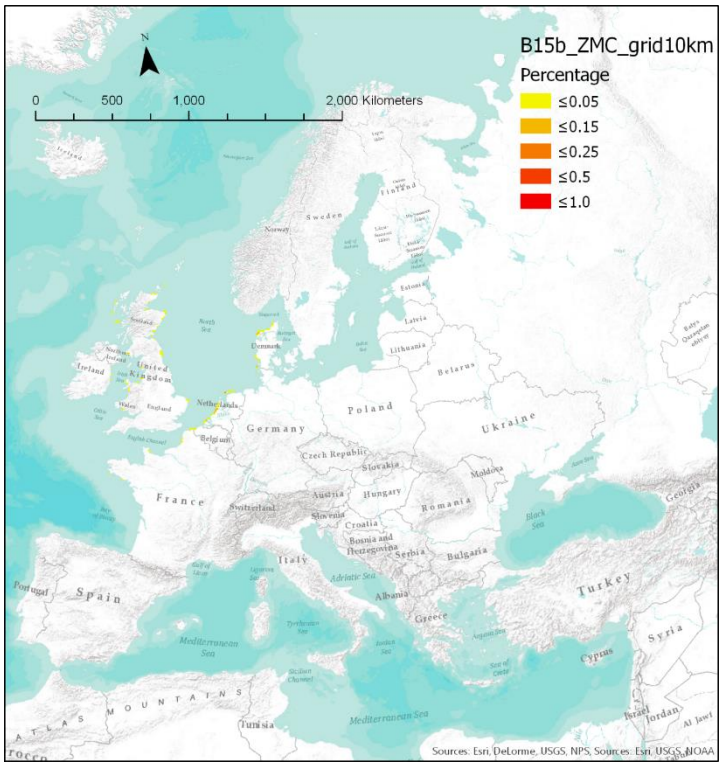
User's accuracy	66.7%
Producer's accuracy	2.4%
Overall accuracy	97.9%



Original EUNIS habitat probability map B1.5b Atlantic coastal Calluna and Ulex heaths



Article 17 database with the related Annex I habitat type(s). H2150 Atlantic decalcified fixed dunes (Calluno-Ulicetea)

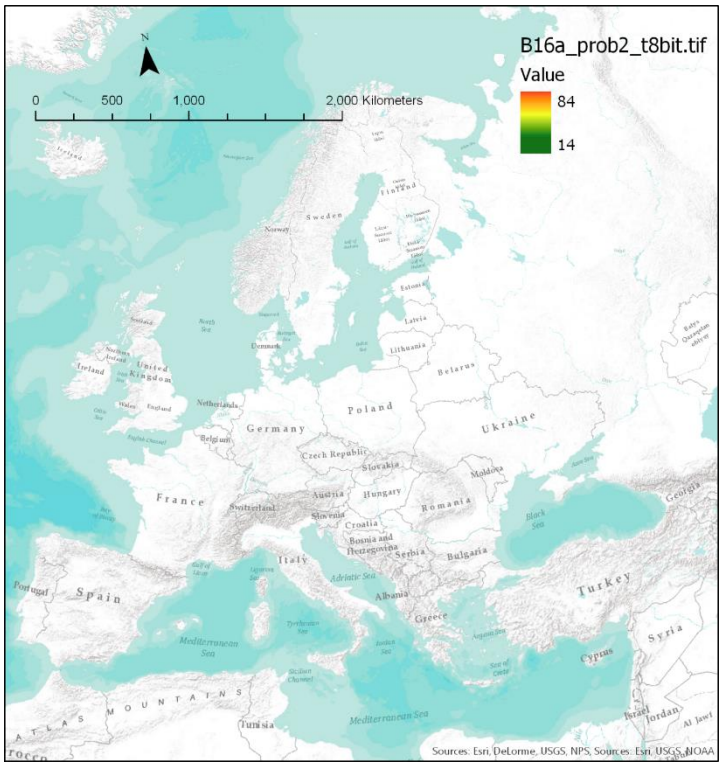


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

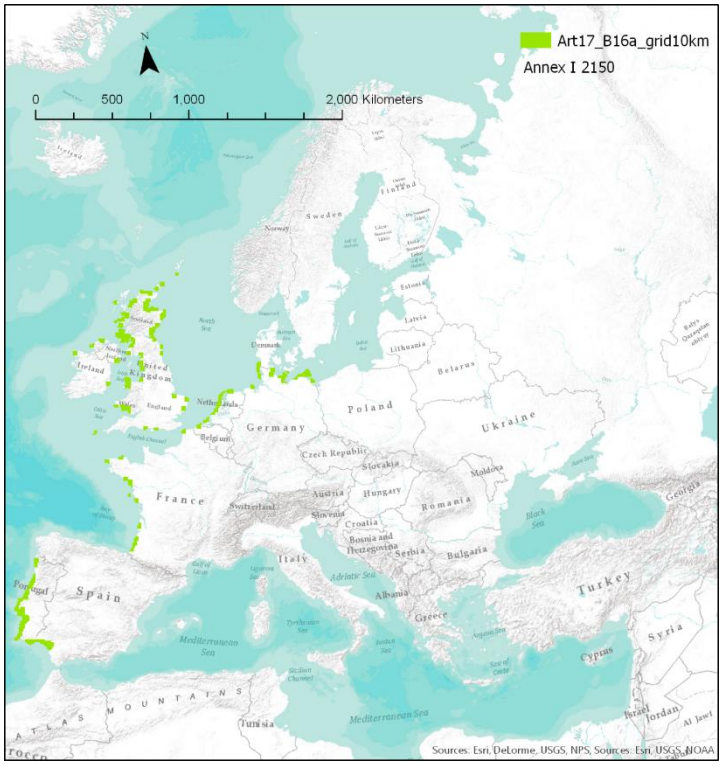
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H2150 presence	absence	Grand Total
B1.5b presence	**69**	45	114
B1.5b absence	968	**46885**	47853
Grand Total	1037	46930	**47967**

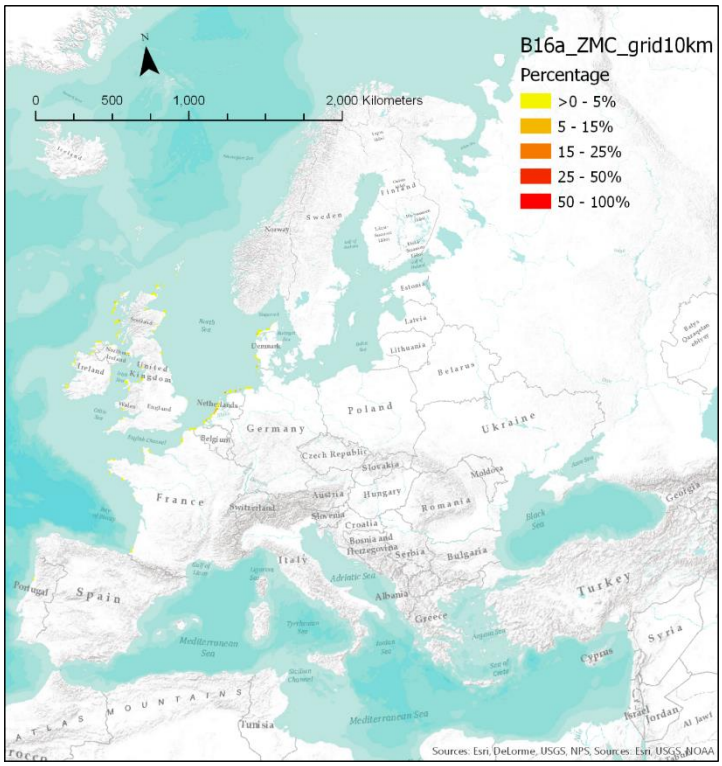
User's accuracy	60.5%
Producer's accuracy	6.7%
Overall accuracy	97.9%



Original EUNIS habitat probability map B1.6a Atlantic and Baltic coastal dune scrub



Article 17 database with the related Annex I habitat type(s). H2150 Atlantic decalcified fixed dunes (Calluno-Ulicetea)

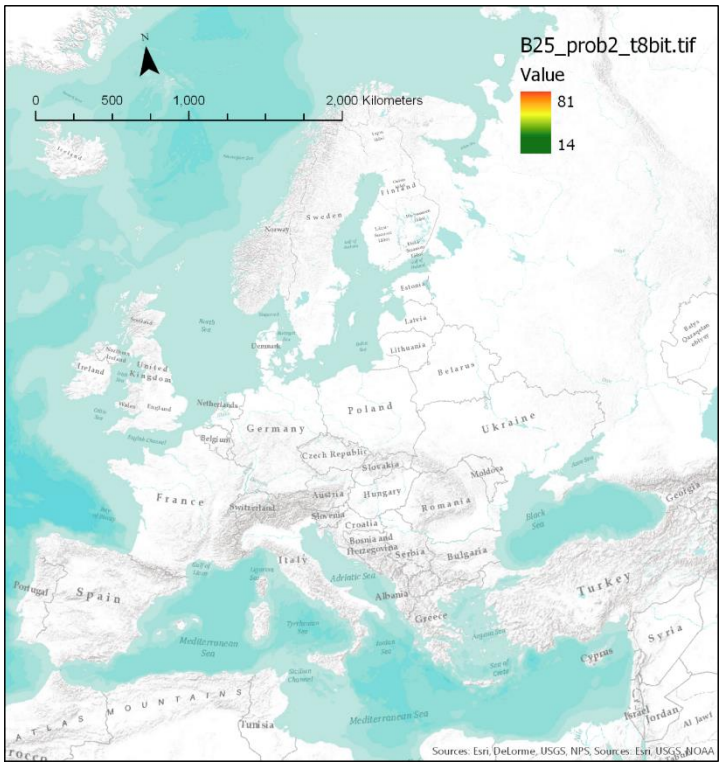


The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

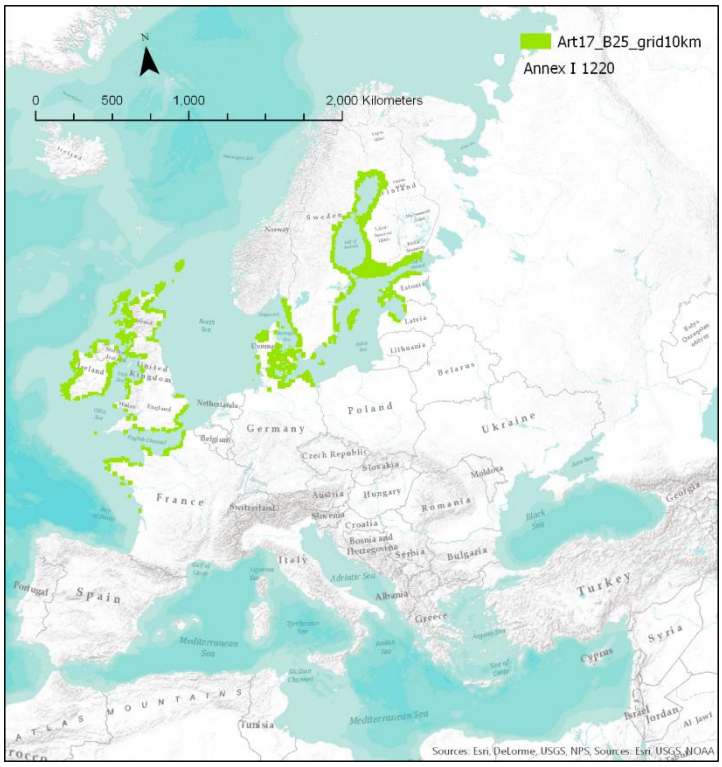
Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 – Annex I	
EUNIS habitat classification	H2150 presence	absence	Grand Total
B1.6a presence	**78**	84	162
B1.6a absence	959	**46846**	47805
Grand Total	1037	46930	**47967**

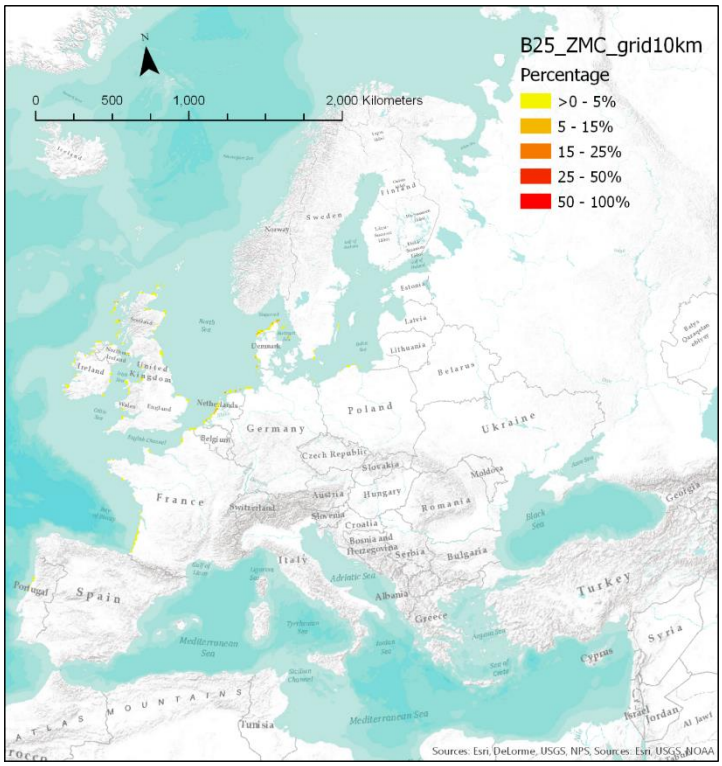
User's accuracy	48.1%
Producer's accuracy	7.5%
Overall accuracy	97.8%



Original EUNIS habitat probability map B2.5 Shingle and gravel beaches with scrub



Article 17 database with the related Annex I habitat type(s). H1220 Perennial vegetation of stony banks



The EUNIS habitat probability map displayed as percentage coverage per 10 km gridcell

Comparison of the above two figures in an error matrix

Count of 10km grid cells	Ground truth	Art 17 - Annex I	
EUNIS habitat classification	H1220 presence	absence	Grand Total
B2.5 presence	**112**	116	228
B2.5 absence	3298	**44441**	47739
Grand Total	3410	44557	**47967**

User's accuracy	49.1%
Producer's accuracy	3.3%
Overall accuracy	92.9%

4 Conclusions and discussion

The main objective was the assessment of our produced EUNIS probability maps for the major EUNIS F category of heathland, scrub and tundra habitat on basis of the Article 17 database. The article 17 database based upon national reporting obligations of Member States on Annex I habitats is in this case considered to be the ground truth. Complication in this assessment is that the relationships between Annex I and EUNIS habitats is in many cases not straightforward (see Table 1.2) and that the spatial data reported under the Article 17 of the Habitats directive can be of variable accuracy from habitat distribution across the whole country to habitat distribution based largely or entirely on designated sites. Nevertheless, the Article 17 database is a very valuable database and is considered by us as the ground truth for this assessment.

Table 4.1 provides a summary of the error matrices for all 29 EUNIS heathland, scrub and tundra habitat types that have been assessed. If we look at the overall accuracy, and if we consider an overall accuracy of > 70 % as good, we can conclude that only four produced habitat probably maps are not good, namely:

1) F31a Lowland to montane temperate and submediterranean Juniperus scrub
2) F31c Lowland to montane temperate and submediterranean genistoid scrub
3) F31e Temperate and submediterranean thorn scrub
4) F42 Dry heath

Of these four EUNIS habitat maps, F31c 'Lowland to montane temperate and submediterranean genistoid scrub' and F31e still have a very good producer's accuracy of respectively 97% and 80%. This means that the related Habitats directive Annex I habitat types have almost entirely been identified. The weak point here is the low user's accuracy, which means that many areas have been identified as the concerning habitat type, while according to the Article 17 database the related habitat type(s) have not been reported. This means that our spatial rules were not strict enough. Another option is of course to exclude more locations with a very low habitat probability. In our cases all habitat probabilities > 0 were considered in this analysis.

Table 4.1 Overview of the error matrices for all 29 EUNIS habitat types based on the comparison with the Article 17 database. Ordered by overall accuracy

EUNIS habitat (L3)	**Overall accuracy**	User's accuracy	Producer's accuracy
B15a	**97.9%**	66.7%	2.4%
B15b	**97.9%**	60.5%	6.7%
B16a	**97.8%**	48.1%	7.5%
F71	**97.6%**	42.0%	43.5%
F73	**97.1%**	61.7%	46.6%
F67	**96.6%**	48.6%	81.2%
F21	**95.0%**	78.3%	43.2%
B25	**92.9%**	49.1%	3.3%
F24	**92.6%**	29.6%	87.4%
F61b	**92.0%**	69.6%	71.6%
F52	**91.5%**	74.3%	82.3%
F74a	**91.0%**	72.7%	43.7%
F31f	**91.0%**	17.9%	53.0%

F93	**90.6%**	62.8%	62.2%
F68a	**90.0%**	26.5%	73.7%
F22a	**89.8%**	68.6%	65.0%
F23	**89.7%**	28.0%	64.2%
F55	**89.3%**	75.4%	29.6%
F74c	**88.8%**	58.0%	7.8%
F74b	**87.9%**	45.6%	26.1%
F91a	**87.2%**	45.8%	37.9%
F22b	**86.0%**	55.5%	55.8%
F41	**85.1%**	53.2%	53.7%
F61a	**82.5%**	37.2%	43.8%
F53	**76.9%**	18.3%	68.1%
F31c	**66.2%**	6.8%	97.0%
F31a	**63.7%**	24.9%	61.7%
F42	**63.4%**	52.3%	44.5%
F31e	**53.9%**	5.1%	80.0%

Besides one can argue that the overall accuracy is not the best indicator for the quality of our produced EUNIS habitat probability maps since the overall accuracy also includes all grid cells were both databases agree about the absence of the specific habitat type. Therefore one could argue that the overall accuracy is overestimated in its value.

And at the same time one could argue that the user's accuracy is in this context not a very good indicator since the spatial data reported under the Article 17 of the Habitats directive can be of variable accuracy from habitat distribution across the whole country to habitat distribution based largely or entirely on designated sites. Some countries produce maps which accurately show the habitat distribution across the whole country (eg the Czech Republic) while others base the maps largely or entirely on the designated sites (eg Italy). Most of them provide good data for some habitats and poor (often based on very simple models) for others.

For that reason the producer's accuracy says much more since here we know indeed that the habitat type has been reported and exists. So the question here is how much of the reported habitat type(s) have been identified by our EUNIS habitat probability maps, and can be answered by the producers' accuracy.

And another reason that F3.1c and F3.1e have very low user accuracy might be the fact that there is a mismatch in the definitions and/or relationship between the EUNIS habitats and the Annex I habitats. F3.1e 'Temperate and submediterranean thorn scrub' is the related to the Annex I habitat type 40Ao 'Subcontinental peri-Pannonic scrub'. So this Annex I habitat type is more or less restricted to the Pannonic region, while F3.1e has a much broader range over the temperate and submediterranen region. So the definitions do not agree at all and therefore makes it more difficult to assess these specific habitat types.

Therefore next to the overall accuracy it is better to focus on the producer's accuracy, see Table 4.2 below. In this Table it becomes clear that all B types; B15a 'Atlantic and Baltic coastal Empetrum heaths', B15b 'Atlantic coastal Calluna and Ulex heaths', B16a 'Atlantic and Baltic coastal dune scrub', B25 'Shingle and gravel beaches with scrub', have a very low producer's accuracy. These B types are very difficult to identify with our methodology, and are therefore considered by us as not reliable. Their very high overall accuracy of > 90% is due to the fact that these habitat types have a very

restricted coverage. It means that for the majority of 10 km grid cells both the EUNIS habitat probability maps and the related Article17 habitat(s) agree that the habitat is not present.

However, one could state that absence is as important as presence in the assessment, and therefore the overall accuracy remains a valuable measurement tool. And else one should concentrate on the producer's accuracy.

Concerning the assessment by producer's accuracy, only twelve of the twenty-nine habitat probability maps have a producer's accuracy above 60% in Table 4.2. If one looks more closely at the seventeen habitat probability maps that have a producer's accuracy below 60%, the lower producer's accuracy is mainly caused by a mismatch in definition and /or relationship between the two habitat typologies, and is therefore not fair to judge as wrongly classified. But indeed in some cases, such as F2.1 'Subarctic and alpine dwarf Salix scrub' our spatial decision rules were not correct since Scotland should not be absent. In the original F2.1 suitability map Scotland is namely still present. According to Table 1 the F2.1 habitat probability maps has been limited to land cover types 3.3.2 bare rocks (31) and 3.3.3 sparsely vegetated areas (32) which seems to be correct, but probably something went wrong with the filter based on the biogeographic regions where F2.1 was limited to subarctic and subalpine. So in the case of F2.1 there is room for improvement in the decision rules that we used. But a problem is that biogeographic regions as subartic and subalpine are poorly defined, and are easily misinterpreted. But in general it is more the mismatch between the EUNIS and Annex I typologies, which hampers a good comparison.

Table 4.2 Overview of the error matrices for all 29 EUNIS habitat types based on the comparison with the Article 17 database. Ordered by producer's accuracy

EUNIS habitat (L3)	**Producer's accuracy**	User's accuracy	Overall accuracy
F31c	**97.0%**	6.8%	66.2%
F24	**87.4%**	29.6%	92.6%
F52	**82.3%**	74.3%	91.5%
F67	**81.2%**	48.6%	96.6%
F31e	**80.0%**	5.1%	53.9%
F68a	**73.7%**	26.5%	90.0%
F61b	**71.6%**	69.6%	92.0%
F53	**68.1%**	18.3%	76.9%
F22a	**65.0%**	68.6%	89.8%
F23	**64.2%**	28.0%	89.7%
F93	**62.2%**	62.8%	90.6%
F31a	**61.7%**	24.9%	63.7%
F22b	**55.8%**	55.5%	86.0%
F41	**53.7%**	53.2%	85.1%
F31f	**53.0%**	17.9%	91.0%

F73	**46.6%**	61.7%	97.1%
F42	**44.5%**	52.3%	63.4%
F61a	**43.8%**	37.2%	82.5%
F74a	**43.7%**	72.7%	91.0%
F71	**43.5%**	42.0%	97.6%
F21	**43.2%**	78.3%	95.0%
F91a	**37.9%**	45.8%	87.2%
F55	**29.6%**	75.4%	89.3%
F74b	**26.1%**	45.6%	87.9%
F74c	**7.8%**	58.0%	88.8%
B16a	**7.5%**	48.1%	97.8%
B15b	**6.7%**	60.5%	97.9%
B25	**3.3%**	49.1%	92.9%
B15a	**2.4%**	66.7%	97.9%

But overall we would like to conclude that except for the B types, our produced EUNIS habitat probability maps are of good to sufficient quality, especially if one looks at the overall accuracies. And that our methodology of starting with distributions maps (measured vegetation plots), followed by modelled suitability maps (reflecting potential distribution of the habitat) and finally towards habitat probability maps based on the actual situation as observed by satellite imagery, especially by incorporating actual land cover, is a good approach to identify the individual EUNIS habitat types across the European landscapes. Although we have to accept that our spatial decision rules could be improved, but needs more input from vegetation experts. And another issue is that the Copernicus High Resolution land cover maps are preferred as an input when available, since there 20 meter spatial resolution reflects more the actual situation of the often very fragmented habitats.

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Appendix 1 Corine Land Cover legend

Table 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 vegetation associations	3.2.1	natural grasslands	26
				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