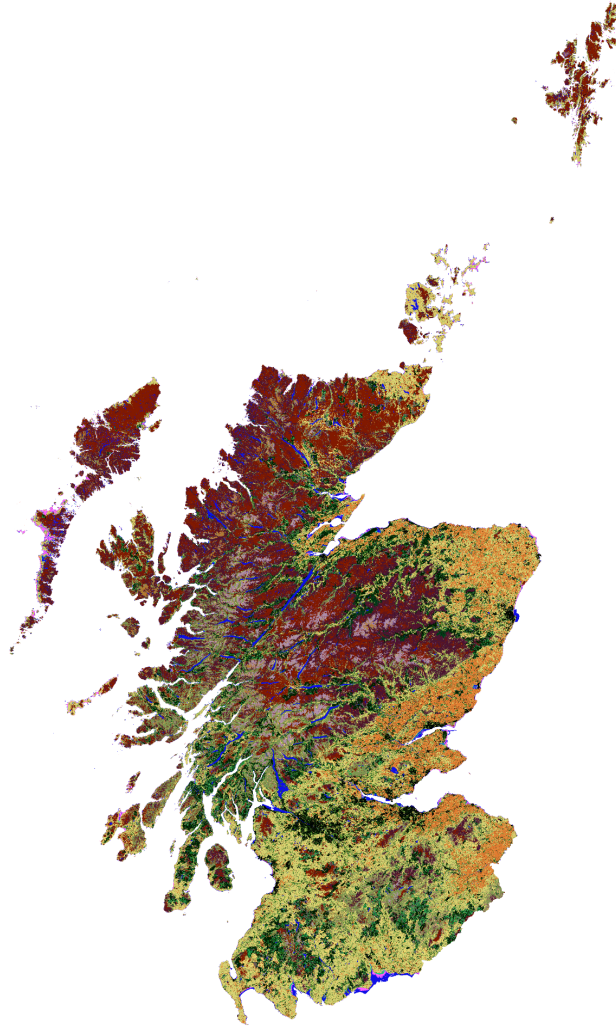# 2022 Scotland Land Cover Map - Report

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Report 1.0
14/07/2023

Executive Summary

Background - Space Intelligence was contracted to produce a land cover map of Scotland for 2022, in addition to those created for 2019 and 2020. In this report, we present the results of the 2022 corrected map after incorporating feedback from NatureScot on the 2022 draft map.

Approach - In order to produce wall-to-wall high-resolution maps of land cover, we used Space Intelligence's established HabitatMapper™ product. This is created using our tech stack which combines optical data from Landsat and Sentinel-2 satellites and Synthetic Aperture Radar (radar) data from the ALOS PALSAR and Sentinel-1 satellites. Final maps included some changes to incorporate feedback from NatureScot. The resulting map has a ground sampling distance of 20 m. Following discussions with NatureScot, final maps were created incorporating their feedback.

Key findings - We created an updated land cover map of Scotland for 2022, with a Level 1 and Level 2 overall accuracy of 92.02% and 79.81% respectively. We added 6 new classes which expanded on the country's forest, coastal and marine habitats. Overall we were able to produce a high accuracy classification of the landscape into 28 classes. We found that the most abundant class was raised and blanket bogs (D1), covering more than 16.51% of the country (around 1.32 Mha).

Table 0. Total area of each land cover type for Scotland in 2022

Land cover type	Area (ha)
C: Water	265,245.1
D1: Raised and blanket bogs	1,328,261.8
D2: Valley mires, poor fens and transition mires	18,834.6
D4: Base-rich fens and calcareous spring mires	0.8
E1: Dry grasslands	832,195.3
E2: Mesic grasslands	1,124,053.7
E3: Seasonally wet and wet grasslands	565,846.9
E4: Alpine and subalpine grasslands	142,516.0
E5: Woodland fringes and clearings and tall forb stands	92,900.1
F2: Arctic, alpine and subalpine scrub	41,950.9
F3: Temperate and mediterranean-montane scrub	24,222.1
F4: Temperate shrub heathland	1,161,467.5
F9: Riverine and fen scrubs	860.3
G1: Broadleaved deciduous woodland	484,294.8
G3.4: Scots pine woodland	20,668.4
G3.F: Highly artificial coniferous plantations	576,103.9

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Land cover type	Area (ha)
G4: Mixed deciduous and coniferous woodland	48,654.3
G5: Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice	172,605.8
H2: Screes	16,628.2
H3: Inland cliffs, rock pavements and outcrops	69,491.0
I1: Arable land and market gardens	572,071.7
J: Built up	219,003.4
O: Bare Land	126,036.7
OW: Windthrow	27,094.1
A2: Littoral sediment	16,152.8
B1: Coastal dunes and sandy shores	50,118.7
B2: Coastal shingle	2,759.3
B3: Rock cliffs, ledges and shores	46,097.0

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1.   Introduction

This report accompanies the 2022 land cover map of Scotland. The 2022 map has been corrected after incorporating feedback from NatureScot on the 2022 draft map. This 2022 map is an update from the land cover maps Space Intelligence created for 2019 and 2020 for NatureScot. In this report we highlight the methods and data used to produce these maps, and discuss their results, accuracies, and limitations. Through the introduction of 6 new classes, this map ensures to improve on the detail of two of Scotland's most important habitats; Scotland's forests and coastline.

2.   Methods and datasets

We created cloud-free satellite data mosaics over the AOI for 2022 using optical data from Sentinel-2, Synthetic Aperture Radar (SAR) data from Sentinel-1 and data from ALOS-2/PALSAR-2 (for ALOS-2 we used data from 2021 as the 2022 data had not been released as of the time of making this map). We also calculated a vegetation index (NDVI) and spectral indices from Sentinel-2.

For the mapping exercise and validation, we used high and medium-resolution data:

High resolution data
High-resolution data was only used for reference data and validation.

Medium-resolution mosaics
Training data was based on high-resolution images where available, but these are typically only available for a single time period for each location. Therefore, we have created 10/30 m resolution mosaics to assess whether land use change occurred before/after the high-resolution imagery was captured (Table 1 and Figure 2). This can then be used to determine the time period for which a polygon derived from <5m data can be used.

Table 1. Medium resolution Imagery used

Satellite (spatial resolution)	Sentinel-2 (10 m)	Sentinel-2 spectral indices (20 m)	Sentinel-1 (20 m)	ALOS Palsar (20 m)
Time period	Spring : 01/03/2022 - 31/05/2022 Summer: 01/06/2022 - 31/08/2022 Autumn : 01/09/2022 - 31/12/2022	Spring : 01/03/2022 - 31/05/2022 Summer : 01/06/2022 - 31/08/2022 Autumn : 01/09/2022 - 31/12/2022	01/01/2022 - 31/12/2022	01/01/2021 - 31/12/2021

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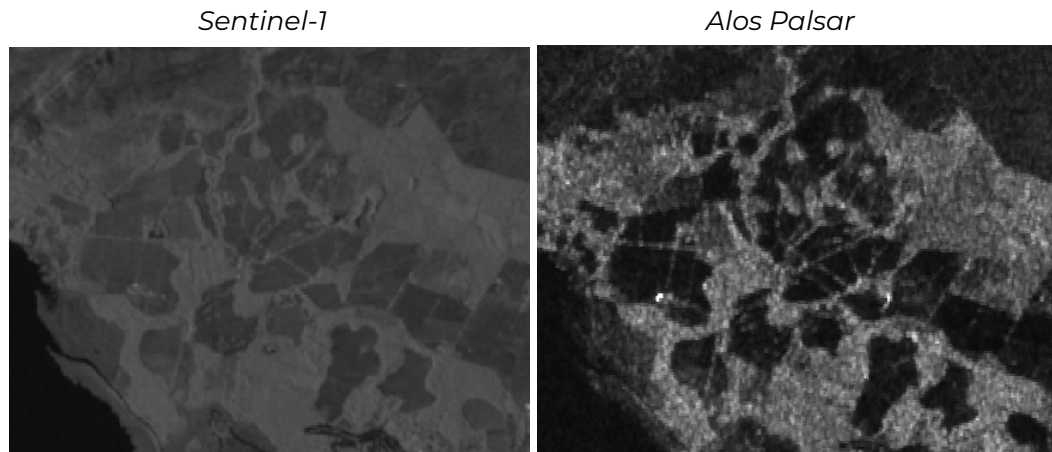
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Sentinel-1   Alos Palsar

Figure 1. Examples of Remote sensing data used in the land cover mapping of Scotland for 2022

In response to the feedback from NatureScot, we collected additional training data for many of the classes, including brand new samples for the new marine class, littoral sediment (A2). Furthermore, to target the overprediction of classes such as built-up (J), bare land (O), and arable land (I1), we created additional model layers and performed post-processing on the output maps to improve the accuracy of these classes.

3.   Class definitions and Reference data

To create the reference data for the classification, we used expert interpretation of high-resolution satellite data, feedback from local experts and a literature review of the region. We also followed NCAI and EUNIS classifications, and the classes used in the previously created 2019 and 2020 maps of Scotland.

The characteristics of the classes for the land cover maps are shown in Table 2. We have provided a Level 1 land cover map with 5 classes, and a Level 2 land cover map with 28 classes. The Level 2 2022 map includes 6 new classes: Coniferous woodland (G3) was split up into Scots pine woodland (G3.4) and highly artificial coniferous plantations (G3.F). Three new coastal ecosystem classes were added including sand (B1), shingle (B2) and coastal rock (B3). A marine class, littoral sediment (A2), was added using predominantly A2.5 (saltmarsh) training samples. Furthermore, a new windblown trees (OW) class was added depicting areas where forest has experienced damage from strong winds.

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Table 2: Showing a summary of the Level 1 and Level 2 classes used in the 2022 Scotland Land Cover Map

SUMMARY Classes	
LEVEL 1	**LEVEL 2**
G: Woodland, forest and other wooded land	G1: Broadleaved deciduous woodland G3.4: Scots pine woodland G3.F: Highly artificial coniferous plantations G4: Mixed deciduous and coniferous woodland G5: Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice
E: Grasslands and lands dominated by forbs, mosses or lichens	E1: Dry grasslands E2: Mesic grasslands E3: Seasonally wet and wet grasslands E4: Alpine and subalpine grasslands E5: Woodland fringes and clearings and tall forb stands
F: Heathland, scrub and tundra	F2: Arctic, alpine and subalpine scrub F3: Temperate and mediterranean-montane scrub F4: Temperate shrub heathland F9: Riverine and fen scrubs
D: Raised and blanket bogs	D1: Raised and blanket bogs D2: Valley mires, poor fens and transition mires D4: Base-rich fens and calcareous spring mires
H: Inland unvegetated or sparsely vegetated habitats	H2: Screes H3: Inland cliffs, rock pavements and outcrops
I: Regularly or recently cultivated agricultural, horticultural and domestic habitats	I1: Arable land and market gardens
O: Bare Land: Areas of bare land	O: Bare Land OW: Windthrow
J: Built up: Constructed, industrial and other artificial habitats	J: Built up
C: Water	C: Water
B: Coastal habitats	B1: Coastal dunes and sandy shores B2: Coastal shingle B3: Rock cliffs, ledges and shores
A: Marine habitats	A2: Littoral sediment

The total number / number of sampled pixels for each land cover class is listed in Table 3, and its distribution shown in Figure 2. 70% of the data were used for training, and 30% for validation.

Table 3: Training data (number of spatial units)

LEVEL 1	Number of samples	Number of pixels	LEVEL 2	Number of samples	Number of pixels
G: Woodland, forest and other wooded land	4395	302,816	G1	1489	88,584
			G3.4	144	15,744
			G3.F	1573	161,450
			G4	682	16,084
			G5	508	18,748
E: Grasslands and lands dominated by forbs, mosses or lichens	4751	172,280	E1	1003	21,588
			E2	1613	112,113
			E3	1005	16,873
			E4	364	16,039
			E5	766	5667
I: Regularly or recently cultivated agricultural, horticultural and domestic habitats	859	215,243	I1	859	215,243
F: Heathland, scrub and tundra	2023	98,406	F2	341	7477
			F3	675	4683
			F4	865	85,350
			F9	140	889
D: Raised and blanket bogs	1823	119,996	D1	953	115,458
			D2	643	3999
			D4	227	539
H: Inland unvegetated or sparsely vegetated habitats	882	11,696	H2	511	3155
			H3	371	8541
O: Bare Land: Areas of bare land	444	38,597	O	320	31,865
			OW	124	6732
J: Built up: Constructed, industrial and other artificial habitats.	1243	77,684	J	1243	77,684
B: Coastal habitats	813	17,945	B1	423	14,935
			B2	131	935
			B3	248	2075
C: Water	1259	390,990	C	1259	390,990
A: Marine habitats	144	3666	A2	144	3666
Total	18,492	1,445,653		18,480	1,443,440

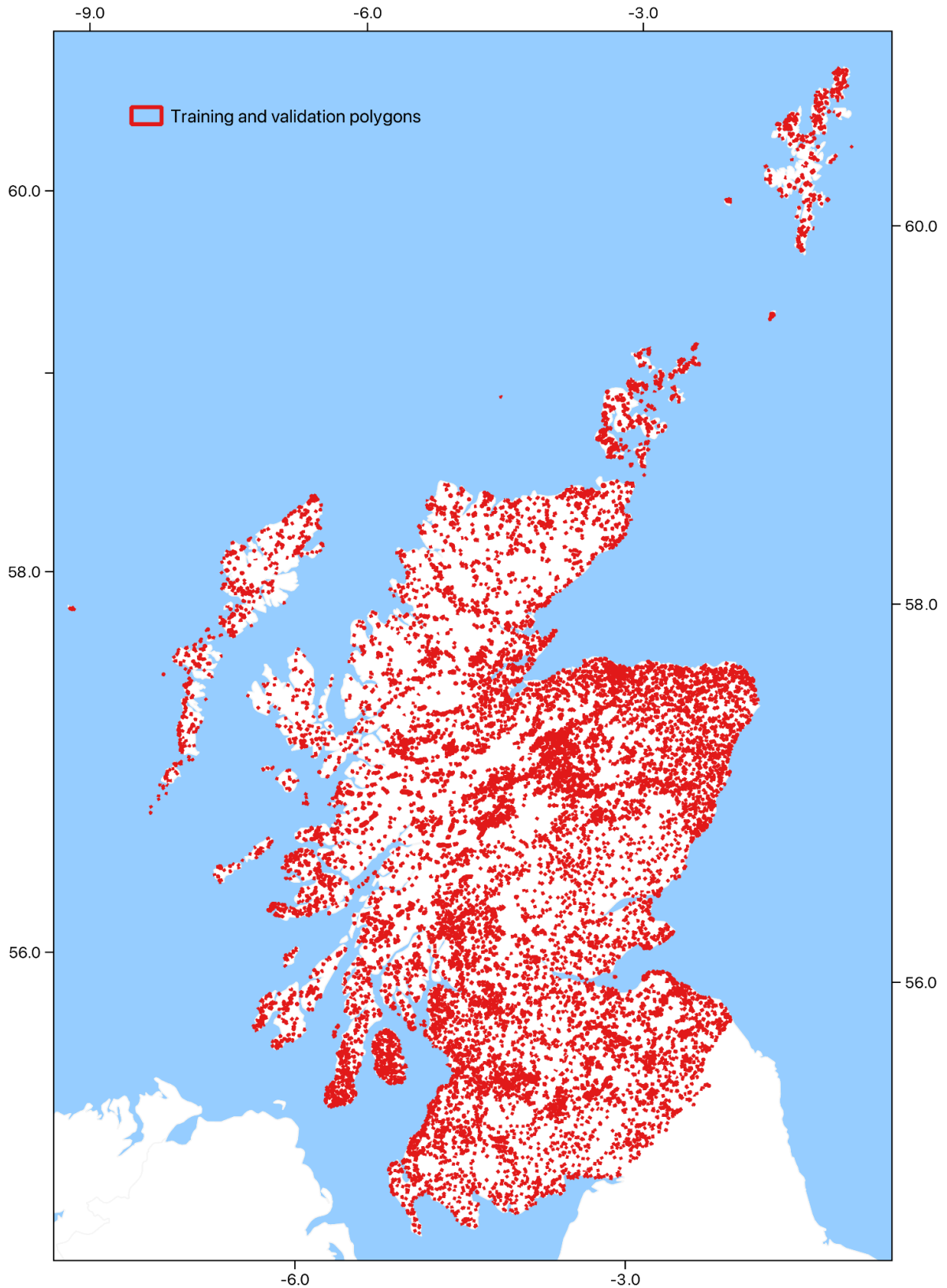*Figure 2. Location of the training and validation polygons used for land cover mapping of Scotland for 2022*

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4. Results

4.1. Land Cover Classification

We have completed maps of Scotland for 2022 at 20 m resolution with 5 classes (Figure 4), and 28 classes (Figure 3). This involved mapping almost 7.5 million hectares, or almost 200 million pixels. Raised and blanket bogs (D1) was the most abundant land class in 2022, covering around 1,328,261.8 ha of the country. This was followed closely by temperate shrub heathlands (F4) and mesic grasslands (E2) which had areas of 1,161,467.5 ha and 1,124,053.7 ha respectively. Highly artificial coniferous plantations (G3.F) and Broadleaved deciduous woodland (G1) were the most common forest classes with 576,103.9 ha and 484,294.8 ha respectively. Figure 3 shows the 28 class Level 2 land cover map for 2022 and Figure 4 shows the 5 class Level 1 land cover map for 2022.

Table 4. Land cover areas for 2022 at level 1

LEVEL 1 class	Area (ha)	% of total area
C: Water	261,406.2	3.3
D, F: Raised and blanket bogs / heathland, scrub and tundra	2,611,844.2	32.5
E, I: Grasslands / cultivated agricultural, horticultural and domestic habitats	3,289,739.7	40.9
G: Woodland, forest and other wooded land	1,310,159.7	16.3
B, H, J, O: Coastal habitats / unvegetated habitats / built-up areas / bare land	572,985.5	7.1

Table 5. Land cover areas for 2022 at level 2

LEVEL 2 class	Area (ha)	% of total area
C: Water	265,245.1	3.30
D1: Raised and blanket bogs	1,328,261.8	16.51
D2: Valley mires, poor fens and transition mires	18,834.6	0.23
D4: Base-rich fens and calcareous spring mires	0.8	0.00
E1: Dry grasslands	832,195.3	10.34
E2: Mesic grasslands	1,124,053.7	13.97
E3: Seasonally wet and wet grasslands	565,846.9	7.03
E4: Alpine and subalpine grasslands	142,516.0	1.77
E5: Woodland fringes and clearings and tall forb stands	92,900.1	1.15
F2: Arctic, alpine and subalpine scrub	41,950.9	0.52
F3: Temperate and mediterranean-montane scrub	24,222.1	0.30
F4: Temperate shrub heathland	1,161,467.5	14.44
F9: Riverine and fen scrubs	860.3	0.01
G1: Broadleaved deciduous woodland	484,294.8	6.02
G3.4: Scots pine woodland	20,668.4	0.26
G3.F: Highly artificial coniferous plantations	576,103.9	7.16
G4: Mixed deciduous and coniferous woodland	48,654.3	0.60
G5: Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice	172,605.8	2.15
H2: Screes	16,628.2	0.21
H3: Inland cliffs, rock pavements and outcrops	69,491.0	0.86
I1: Arable land and market gardens	572,071.7	7.11
J: Built up	219,003.40	2.72
O: Bare Land	126,036.7	1.57
OW: Windthrow	27,094.1	0.34
A2: Littoral sediments	16,152.8	0.20
B1: Coastal dunes and sandy shores	50,118.7	0.62
B2: Coastal shingle	2,759.3	0.03
B3: Rock cliffs, ledges and shores	46,097.0	0.57
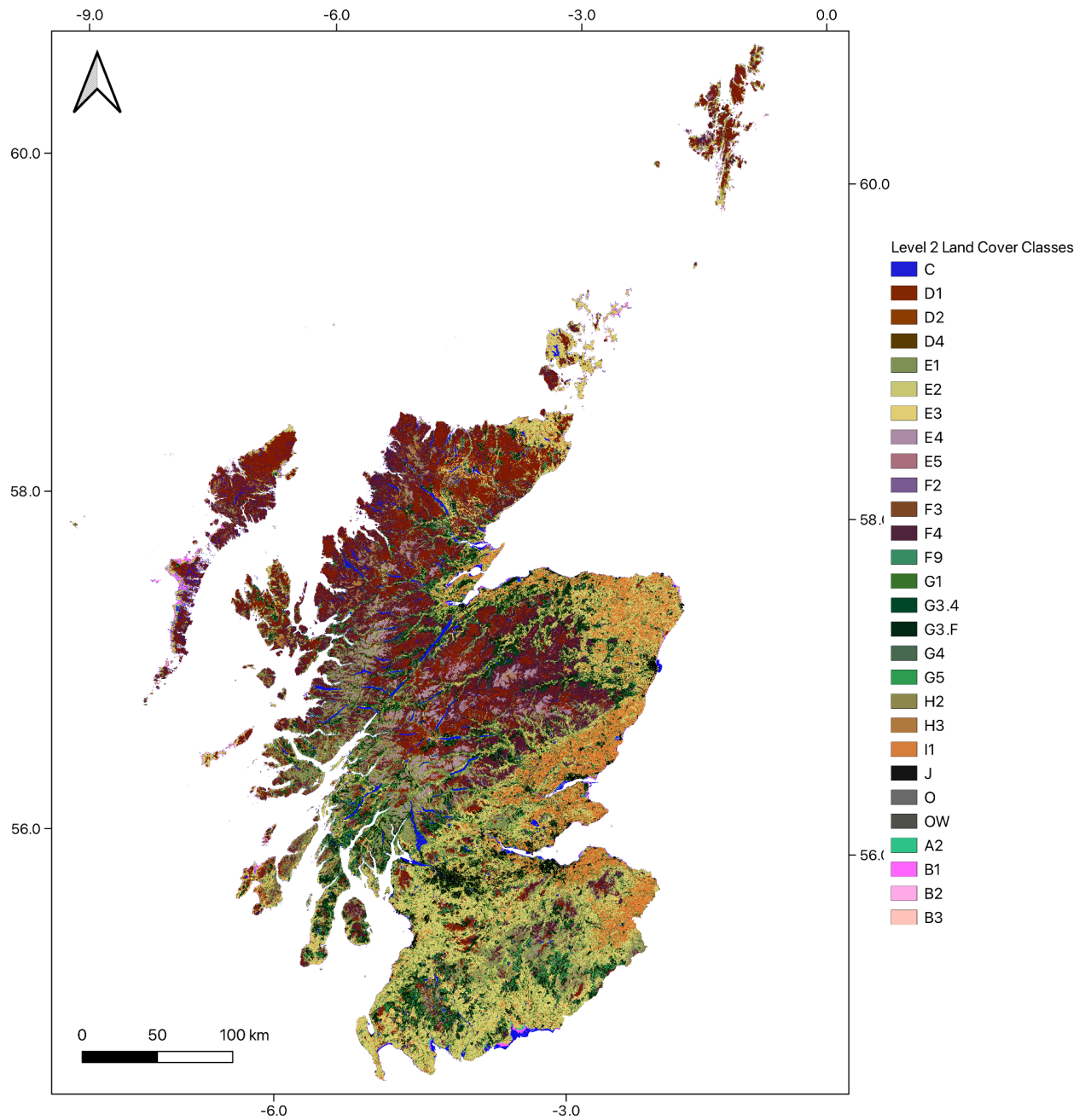
Figure 3. Level 2 land cover map of Scotland for 2022

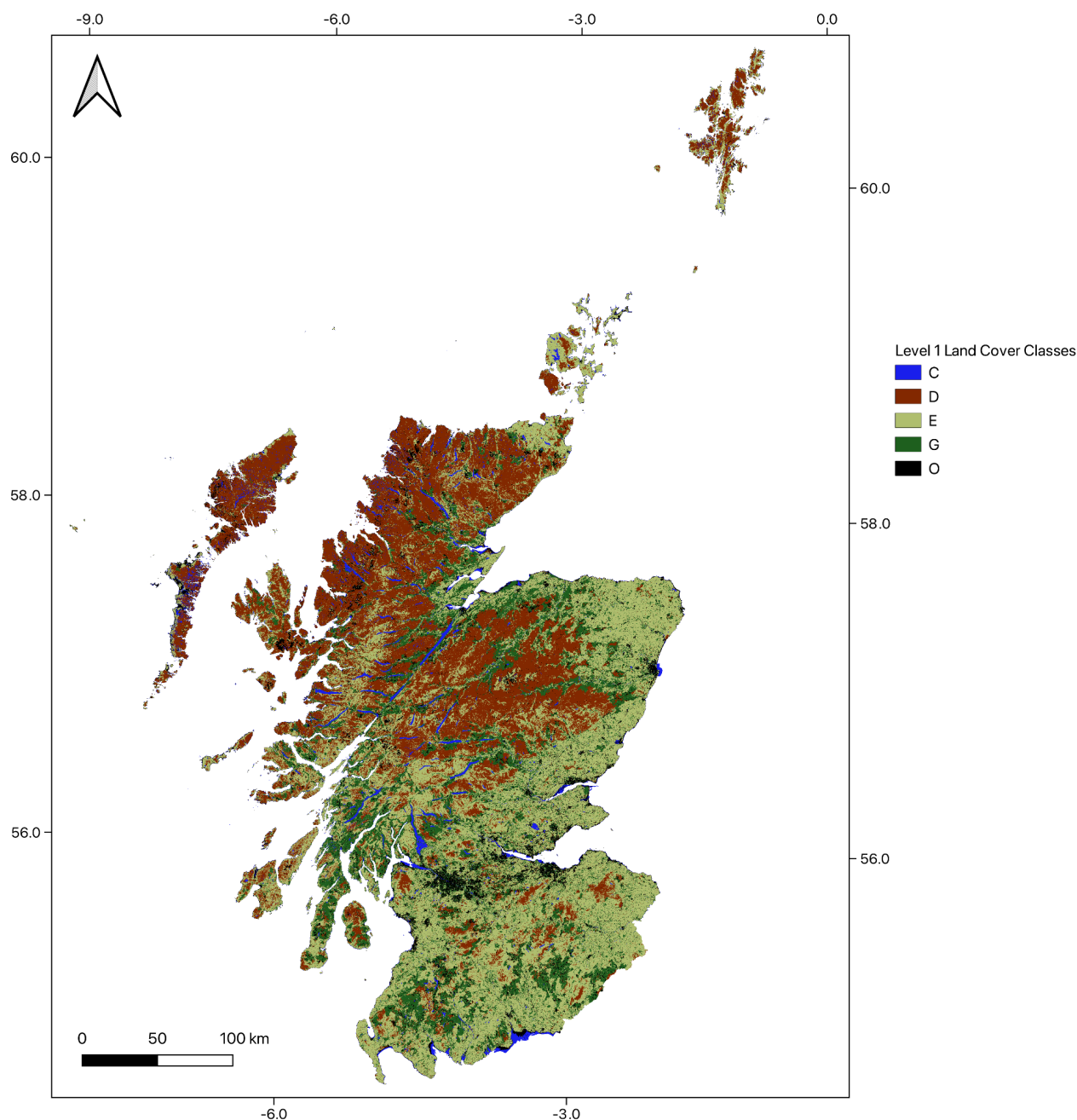Scotland Land Cover Map 2022 Report. Version 1.0. 14/07/2023

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Figure 4. Level 1 land cover map of Scotland for 2022

In addition to the land cover maps, we have included a second most likely Level 2 land cover map (Appendix 1, Figure 8). This map has been created by assigning each pixel the second most probable land cover class if that pixel has a confidence of ≤75%. This threshold of ≤75% was chosen to avoid changing pixels predicted with high confidence, for example urban areas and water over lochs and seas.

4.2.　　　Map accuracy

To test the accuracy of the output map, we performed a 5-fold cross validation, wherein 20% of our training data was held back (the exact proportion varied slightly per class), allowing a comparison of model prediction against independent sample data. Producer's accuracy is the proportion of test pixels of a particular class that were classified as that class in the end map. By contrast, the User's accuracy is the proportion of pixels of a specific class in the final map that test data show are, in fact, that class.

The overall accuracy of the map against these data is 92.02% for Level 1 and 79.81% for Level 2 land cover classes (Table 7 and Table 8). The accuracy in Level 2 land cover varies according to class. Water (C), mesic grasslands (E2), highly artificial conifer plantations (G3.F), arable land and market gardens (I1), and sand (B1) were some of the classes predicted with the highest accuracy (over 80% in both User's and Producer's accuracy). Valley mires, poor fens and transition mires (D2) and riverine and fen scrubs (F9) were some of the classes predicted with the lowest accuracy (a Producer's accuracy of 0.12% and 0.05% respectively). Dry grasslands (E1) and wet grasslands (E3) also had low accuracy, most likely rooted in confusion between these two classes.

Table 6. Level 1 Producer's and User's Accuracy per class, based on independent data

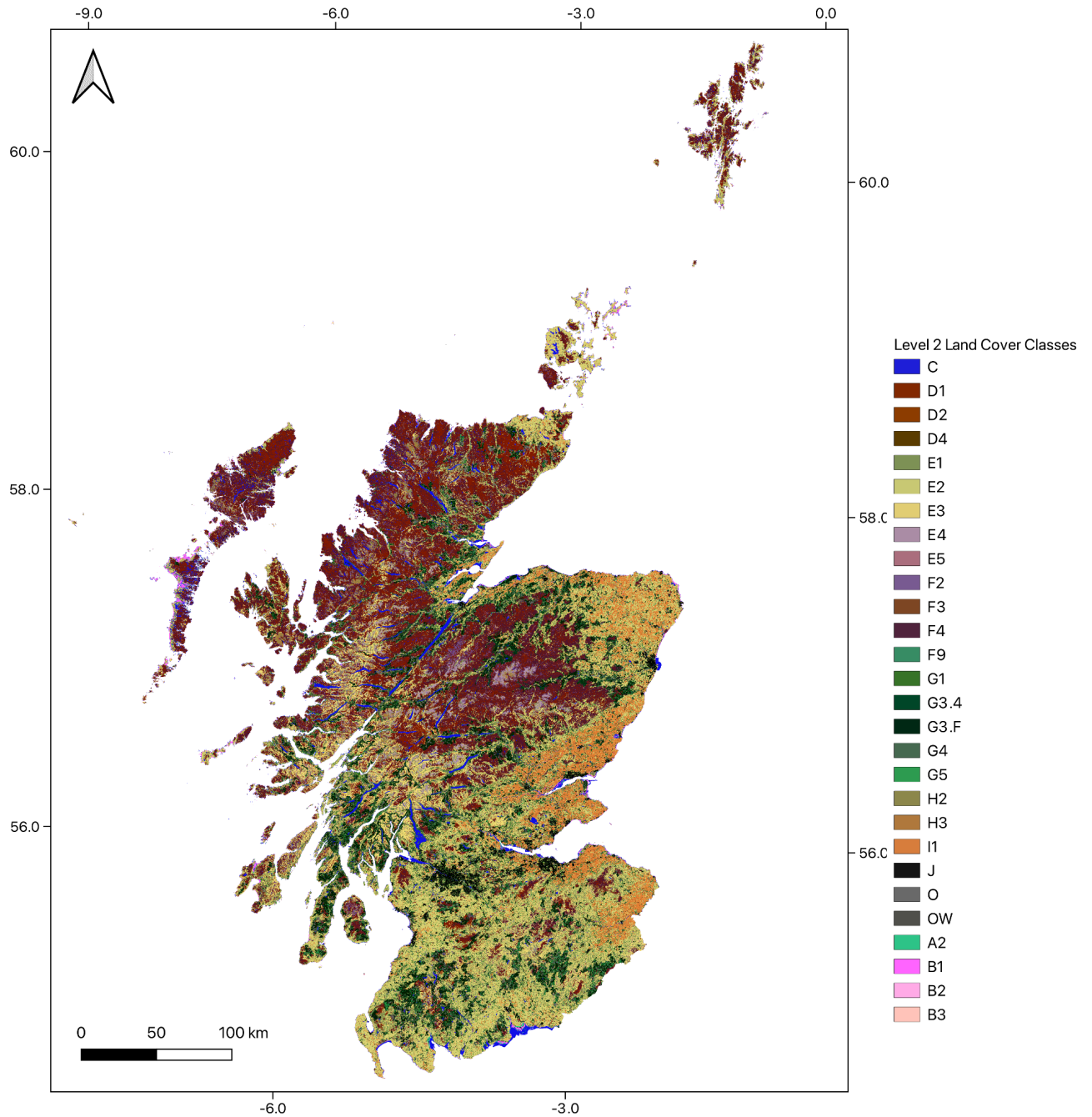| Level 1 Land cover type	User's accuracy	Producer's accuracy
C	0.99 ± 0.00	0.98 ± 0.00
D	0.89 ± 0.01	0.83 ± 0.02
E	0.89 ± 0.01	0.93 ± 0.01
G	0.95 ± 0.01	0.97 ± 0.01
O	0.92 ± 0.02	0.91 ± 0.02
Overall Accuracy		92.02 ± 0.60

Appendix 1

Figure 8. Second most likely class Level 2 land cover map of Scotland for 2022

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