Living England: Satellite-based habitat classification

Technical User Guide

First published March 2022

Natural England Research Report NERR108

www.gov.uk/natural-england

Living England: Satellite-based habitat classification. Technical User Guide

Alex Kilcoyne, Miles Clement, Chris Moore, Guy Picton Phillipps, Rob Keane, Amy Woodget, Sophie Potter, Anne Stefaniak & Becky Trippier

March 2022

ISBN: 978-1-78354-921-4

Project details

This report should be cited as:

KILCOYNE, A.M., CLEMENT, M., MOORE, C., PICTON PHILLIPPS, G.P., KEANE, R., WOODGET, A., POTTER, S., STEFANIAK, A. & TRIPPIER, B. (2022). Living England: Technical User Guide. NERR108. Natural England.

Natural England contact

For any queries or further technical detail, please contact the Living England team at earth.observation@naturalengland.org.uk.

Authors

Alex Kilcoyne, Miles Clement, Chris Moore, Guy Picton Phillipps, Rob Keane, Amy Woodget, Sophie Potter, Anne Stefaniak & Becky Trippier

Keywords

Satellite imagery, remote sensing, habitat mapping, classification, machine learning.

Acknowledgements

We would like to thank our colleagues at Natural England for their support and input into the project. In particular: Chris Green, Nicholas Croft, David Allinton and Esther Pawley from the Desktop Validation Group; Andy Webb for working on the first iteration of the Living England Esri Collector App; and the Natural England Field Unit (NEFU) and Natural Capital and Ecosystem Assessment (NCEA) field staff for their time spent collecting training data and providing invaluable feedback. We also extend our thanks to JNCC for managing the AWS and in particular Paula Lightfoot for her feedback and suggested improvements. Finally, we would like to thank the wide range of internal and external habitat specialists for their significant contributions to the training data sources.

Further information

This report can be downloaded from the Natural England Access to Evidence Catalogue: http://publications.naturalengland.org.uk/. For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Executive summary

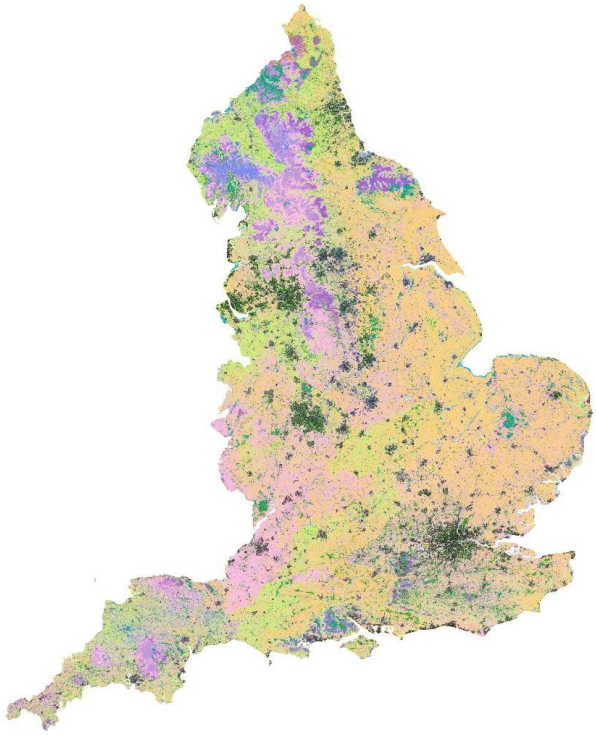

Figure 1: Living England Phase IV Habitat Probability Map. © Natural England 2022.

The Living England project, led by Natural England, is a multi-year programme delivering a satellite-derived national habitat layer in support of the Environmental Land Management (ELM) System and the Natural Capital and Ecosystem Assessment (NCEA) Pilot. The project uses a machine learning approach to image classification, developed under the Defra Living Maps project (SD1705 – Kilcoyne et al., 2017). The method first clusters homogeneous areas of habitat into segments using satellite imagery, then assigns each segment to a defined list of habitat classes using Random Forest machine learning algorithm. Phase I of the Living England project established the methodology for the analysis, Phase II achieved an average probability of 78%, and was improved in Phase III with an average probability of 84%. In Phase IV, further improvements to the classification and training data has resulted in an average habitat probability of 88%. The habitat probability reported by Living England represents the degree of agreement between the classification map and field collected data. The probability is output on a per segment basis and will vary between habitats and biogeographic zones.

This technical user guide summarises the data and methodologies used to create the Living England habitat map, shown in Figure 1, produced in Phase IV of the project. This guide is to accompany the release of the Phase IV data under an Open Government Licence (OGL) providing users with information on how these modelled predictions were generated and how to interpret the results.

Contents

Executive summary 4
1. Introduction 6
1.1 Project History 7
2. Classification Framework 8
3. Methodology 10
3.1 Data Acquisition 11
3.2 Data Cleaning and Preparation 14
3.3 Segmentation 16
3.4 Vector Classification 17
3.5 Model-Based Classification 20
3.6 Model Validation 20
3.7 Data Outputs 21
4. Phase IV Results 21
4.1 Known Issues and limitations 23
5. Data Access and Format 24
5.1 Download and Data Format 24
5.2 Geographical Extent 24
5.3 Product Spatial Resolution 24
5.4 Data Attributes 24
6. Contact 25
Glossary 26
References 27
Appendix 1: Model training datasets 29
Appendix 2: Data Licensing 32

1. Introduction

The Living England project is a multi-year project which produces a national habitat map of England using satellite imagery, field collected data and machine learning. The project is funded by the Department for Environment, Food and Rural Affairs (Defra) through the Natural Capital and Ecosystem Assessment (NCEA) and the Environmental Land Management Scheme (ELMS). The evidence this provides is designed to help inform environmental policy decision making and national habitat extent and connectivity assessments for targeting nature recovery.

This approach predicts broad habitat classes for parcels of land known as ‘segments’, using an object-based machine learning algorithm. This is assessed through combining up-to-date, openly licensed satellite imagery, topographic and climatic data, and field habitat survey records. Through this project, Natural England have developed innovative and robust processing workflows to optimise classifying habitat types across England’s varying spatial landscape, using ecological knowledge and field surveys to help inform and validate the model.

This document pertains to 2021-22 (Phase IV) Living England product, and provides a brief overview of the data inputs, modelling approach, map of output probabilities, data formats and licensing information.

The Living England Phase IV habitat map provides an up-to-date prediction of habitat distribution and extent on a national scale for 2021/22. This can provide a valuable tool for assessing natural capital assets, ecosystem service modelling, as well updating the evidence base for key policy areas such as Environmental Land Management. Living England is an ongoing project and will develop and optimise the methodology further during 2022/23. Subject to the outcomes of the next phase of work, we aim to publish a new version of the 2021/22 habitat map in 2023/24 that uses this new, standardised methodology; therefore, this should be considered when utilising the Phase IV data in further analyses.

1.1 Project History

In 2016, Natural England proposed a satellite-based habitat mapping project through the Defra Earth Observation Centre of Excellence (EOCoE) known as Living Maps (Kilcoyne et al., 2017). The project built on the lessons learnt in the 'Making Earth Observation Work for UK Biodiversity' (MEOW) programme (Medcalf et al., 2014), utilising the European Space Agency's Copernicus Sentinel-1 and Sentinel-2 satellite data alongside open-source software. It aimed to improve efficiency of earlier habitat mapping approaches, whilst also reducing the financial costs. This project and resulting methodology were funded by the EOCoE and the Space for Smarter Government Programme (SSGP). Living Maps was successful in making a significant cost saving and attracting international praise and attention.

In 2017, Natural England's Earth Observation (EO) Service started trialling cloud-based image processing for Living Maps. This brought about a huge transformation in the amount of data that could be processed, paving the way for the analysis of national-scale datasets, under a newly named project: Living England. Phase I of the Living England project established the methodology for the analysis, using data acquired in 2018-19. Phase II implemented this methodology on data from 2019-20, achieving an average probability of 78% of correctly classified habitat types. Phase III used data from 2020-21 and improved this average probability to 84%. This report details the methodology applied in Phase IV (2021-22) of the Living England project, which further improved the average probability of correctly classifying habitats to an average probability of 88%.

The project is funded by the Department for Environment, Food and Rural Affairs (Defra) through the Natural Capital and Ecosystem Assessment (NCEA) and the Environmental Land Management Scheme (ELMS). Currently in a pilot phase, NCEA is a transformative programme to understand the extent, condition and change over time of environmental assets across England's land and water environments (freshwater and marine), supporting the government's ambition to improve the environment within a generation. On land it is a pioneering partnership between Defra, Natural England, Environment Agency, Forest Research, and the Joint Nature Conservation Committee. NCEA aligns with the work of Natural England's Science, Evidence and Evaluation Strategy, Shift 4.

2. Classification Framework

The habitat classification framework adopted by Living England is the UK Biodiversity Action Plan (UKBAP) classification framework, as shown in Table 1 (JNCC 2011). The UKBAP Habitat Classification is an established framework for classifying habitats under an Open Government Licence. Figure 2 provides an example of the Living England classification and symbology.

Segments labelled as 'Unclassified', typically indicate locations where cloud-free satellite imagery was not available, or highly reflective urban areas that show similar characteristics to cloud in the satellite imagery and have been misclassified in the cloud-masking algorithm.

Table 1: Living England habitat classes (UKBAP).

Detailed Habitat	Broad Habitat
Acid, Calcareous, Neutral Grassland	Grassland
Arable and Horticultural	Cropland
Bare Ground	Bare Ground
Bare Sand	Bare Ground
Bog	Wetland
Bracken	Grassland
Broadleaved, Mixed and Yew Woodland	Woodland
Built-up Areas and Gardens	Urban
Coastal Saltmarsh	Coastal
Coastal Sand Dunes	Coastal
Coniferous Woodland	Woodland
Dwarf Shrub Heath	Heath
Fen, Marsh and Swamp	Wetland
Improved Grassland	Grassland
Scrub	Woodland
Water	Freshwater
Unclassified	Unclassified

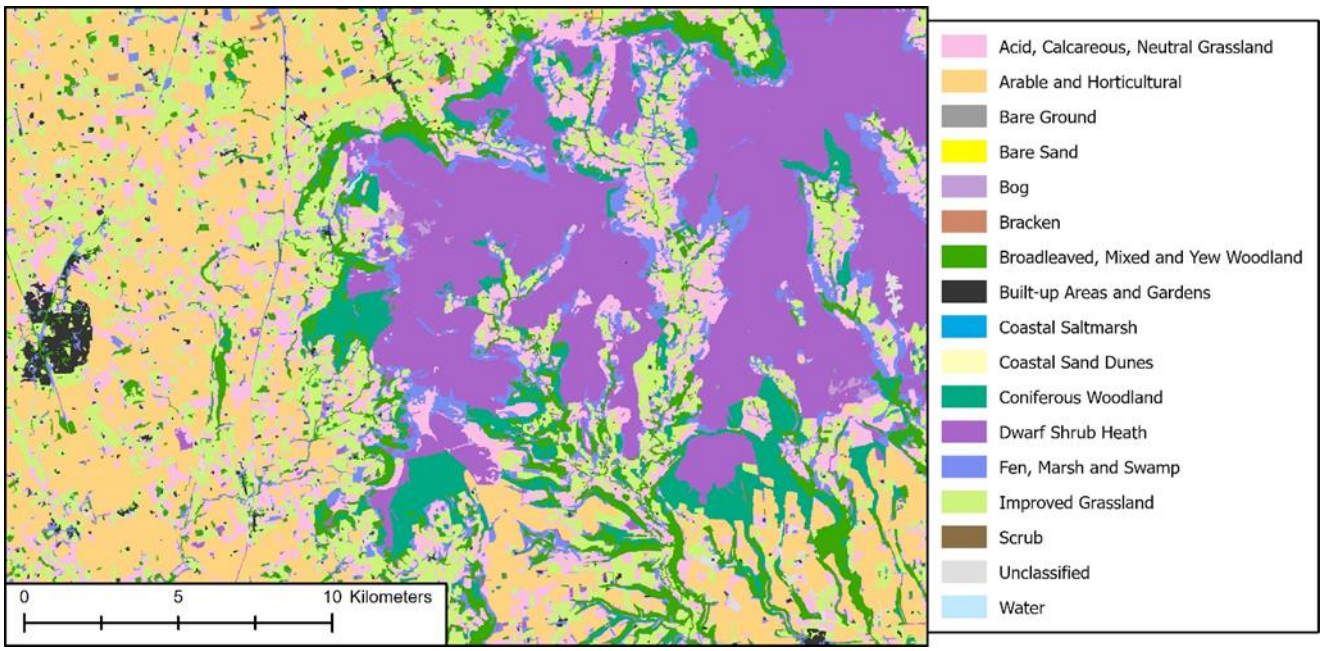

Figure 2: Example Living England Habitat Probability classification (Phase 4) and symbology, showing the North York Moors and Northallerton. © Natural England 2022.

3. Methodology

The main processing steps used to create the Living England habitat probability map are outlined in Figure 3 with detailed summaries of these described in Section 3.1.

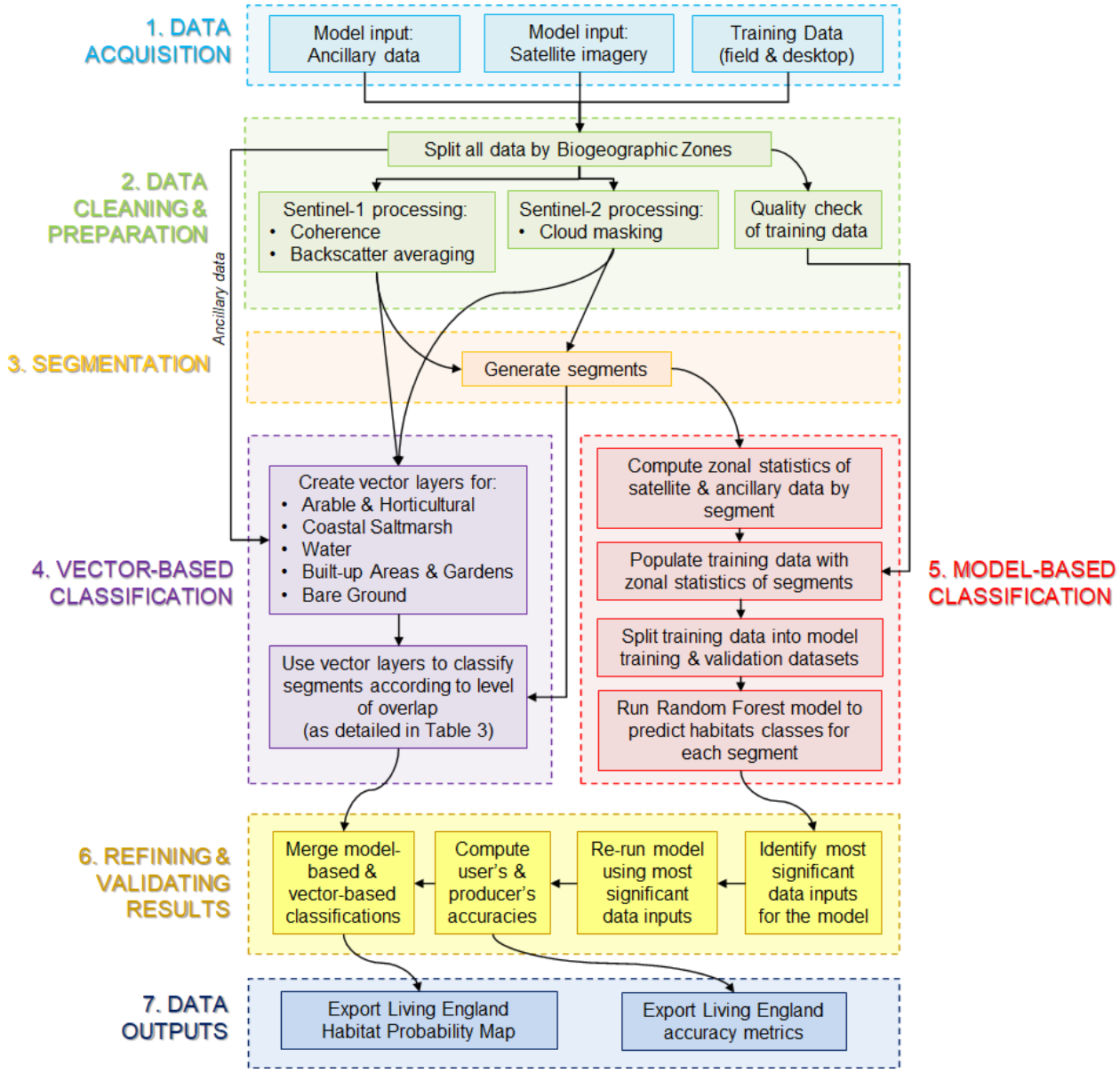

Figure 3. Overview of the Living England classification process.

3.1 Data Acquisition

Living England uses a range of data to model habitat probability. These datasets are acquired for two key purposes:

- As **model input data** – model variables used for classifying segments and within the Random Forest model to predict habitat type.
- As **training points** – training points for the model and for calibrating and validating the habitat prediction model, derived from existing habitat inventories, partner surveys and the bespoke Living England Collector App.

The model input datasets used in the modelling and classification processes are listed in Table 2.

The training points are a collection of habitat records which have been identified, collated and processed for use in Living England through engagement with internal and external habitat and monitoring specialists. These are listed in Appendix 1. The training datasets have been selected to ensure they provide an accurate representation of the habitat type within the assigned segment. These data have undergone a quality checking and translation process to ensure classifications align to the UKBAP habitat framework. Further details on the licensing of these datasets can be found in Appendix 2.

To support data collection and targeting, a bespoke Esri ArcGIS Collector data collection application was developed for internal use by NE surveyors using ArcGIS Pro and ArcGIS Online (AGOL). This allowed for easy and consistent recording of new training data points. A map interface allows surveyors to accurately relate their ground observations to the segment boundaries used as a framework for creating the Living England map, assisted by high-resolution Esri World Imagery (Esri 2021). Users can then select from a pre-determined list of habitats to record Living England detailed habitat classes and an estimate of the percentage cover of that habitat type within a given segment. By hosting the data points in AGOL, Natural England field surveyors have been able to target under-recorded habitat classes, helping to significantly improve the consistency of the overall training point dataset.

Table 2: The model input datasets used to produce the Phase IV habitat probability map.
* ESA (European Space Agency), EA (Environment Agency), BGS (British Geological Survey), OS (Ordnance Survey), RPA (Rural Payments Agency)

Dataset	Licensing Body	Web Location	Spatial Resolution	Temporal Resolution	Update Frequency	Notes
Sentinel-2 Multispectral Imagery	ESA	Google Earth Engine	10 m pixels	Sept 2019 – April 2021	5-day revisit period	Cloud-masked multitemporal (1 month) mosaics produced by NE.
Sentinel-1 Backscatter Imagery	ESA	Google Earth Engine	10 m pixels	Sept 2019 – April 2021	6-day revisit period	Multi-temporally filtered @1 month. Current revisit time of 12 days due to failure of the Sentinel 1B system
Sentinel-1 Single Look Complex (SLC) Imagery	ESA	SciHub	20 m pixels	June 2021 – July 2021	6-day revisit period	Processed to calculate an average coherence map covering 24 days.
Integrated Height Model	EA	Bluesky International Ltd/Getmapping PLC. 2021.	2 m, resampled to 10 m	2016 - 2019	Annual update	Product not openly available for download. Used to derive slope, aspect and Height Above Nearest Drainage.

Geology	BGS	BGS Geology 50k	1:50,000	N/A	N/A	Product not openly available for download.
Vectormap District	OS	OS OpenData Hub	1:15000 to 1:30,000	2010 - 2018	Six monthly	
Saltmarsh Extent and Zonation	EA	data.gov	20 cm aerial imagery	2006 - 2019	Annual update	
Crop Map of England (CROME)	RPA	data.gov	0.41 ha hexagonal grid	2019	Annual update	2019 version used due to the higher reported accuracy compared to the 2020 version.
BioClim Climatic Variables	Worldclim	WorldClim	1 km	1970-2000	N/A	Variables used: max temperature, min temperature, annual rainfall

Training points have also been digitised through a desktop validation process. This process was developed to assess previous iterations of the Living England habitat probability maps and validate predicted classifications through comparisons with Esri (2021) World Imagery and Sentinel-2 imagery. For less complex habitat classes, such as bracken and bare sand, which can be easily distinguished from the imagery, manual points are digitised and included in the training dataset.

3.2 Data Cleaning and Preparation

3.2.1 Biogeographic Zones

For the processing stages, England has been split into 14 Biogeographic Zones (BGZs), pictured in Figure 4. This was to accommodate the phenological and habitat variation across England and to facilitate the acquisition of cloud-free image mosaics. The BGZs are based on merging the National Character Areas, which are distinctive areas each with a unique 'sense of place' (Natural England, 2021). BGZ boundaries extend 3 km beyond the Mean Height Water Springs (MHWS) limit for data processing and classification purposes.

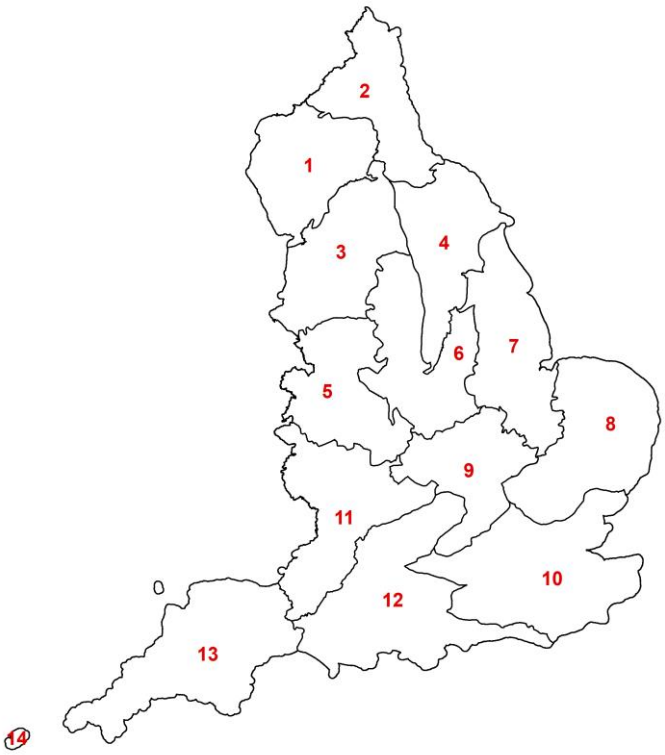

Figure 4: Living England Biogeographic Zones

3.2.2 Sentinel-2 Cloud-Mask

A “Swiss Cheese” method of producing cloud-free Sentinel-2 mosaics was developed by the Living England team and applied to each BGZ using Google Earth Engine (GEE). Multi-temporal image collections over 4-week periods in Spring and Autumn were first obtained for each biogeographic zone. These were then masked using an automated cloud and cloud shadow masking algorithm. The cloud masking was applied in GEE using the Sentinel Hub’s cloud probability algorithm (Batic, 2018), applied at 10 m spatial resolution. Cloud shadow was calculated using a Near-InfraRed (NIR) dark pixel threshold, a distance from the cloud and Mean Solar Azimuth Angle, acquired from image metadata. Once masked, these were arranged sequentially for mosaicking according to the amount of cloud identified in each image, or the imagery date. As such, masked areas within an image are then filled with clear imagery from subsequent images. Imagery between September 2019 and April 2021 was used to achieve mosaics which were as cloud-free as possible.

The thresholds used in the process demonstrated good masking of most types of cloud, however, some thin cloud remained undetected. Further, there are significant false positives in urban areas detected by the cloud probability layer threshold required to detect the majority of cloud.

This process achieved 99.7% cloud free imagery for the Random Forest classification across all BGZs.

3.2.3 Sentinel-1 Backscatter

Sentinel-1 mosaics were temporally filtered over the same time periods as the Sentinel-2 data using Google Earth Engine (GEE). The median pixel value was extracted from 4-week collections to reduce radar speckle. Both vertical-vertical (VV) and vertical-horizontal (VH) polarisations were extracted from the Ascending and Descending acquisition modes to produce temporally averaged Sentinel-1 backscatter layers with reduced image speckle.

3.2.4 Sentinel-1 Coherence

A processing chain to produce average coherence maps was developed in Python (version 3.7 (2018)) using the ESA Sentinel Applications Platform (SNAP) software (version 8.0 (2020)). For each BGZ, 10 Sentinel-1 Level-1 Single Look Complex (SLC) images covering a period of 24 days in June and July 2021 were processed and paired to calculate coherence over a range of temporal baselines. Summer-time acquisition dates

were chosen to coincide with likely cloud-free Sentinel-2 imagery. Both Ascending and Descending orbit directions and VV and VH polarisations were used. Coherence image pairs were then geo-coded, and the mean average taken, such that each temporal baseline (6-day, 12-day, 18-day, 24-day) was equally weighted.

3.2.5 Training Data Validation

The training dataset was validated to ensure the quality of the training points used to inform the Random Forest model.

This included two main steps:

- Data Reduction - to ensure only one training point per segment was selected to train the model. Points are prioritised based on year of survey and survey coverage of the habitat types.
- Statistical validation – boxplots were used to assess the training points against the reflectance of each image band in the satellite imagery, comparing across habitat types and BGZs. A training point was flagged as a potential outlier if it fell outside of the upper and lower quartile range for any of the image bands. The number of flagged bands required for a training point to be removed from the training dataset is tested and optimised in the Random Forest model for each BGZ.

Post-validation, a total of 61,375 training points remained and were used in the model-based classification.

3.3 Segmentation

Living England uses an object-based classification. Objects are discrete spatial areas, also known as segments, which create the framework used to classify and map different habitat types. Segments are created using a ‘multiresolution segmentation’, which uses Sentinel-2 imagery to identify and group pixels into areas of similar spectral reflectance characteristics.

The segmentation process was conducted using Trimble’s eCognition software (Trimble Geospatial, Version 9.2). During the process, some segments are created that are smaller than the defined Minimum Mapping Unit (MMU) of 3 pixels (300 m^2). The Living England MMU has been chosen to ensure there are sufficient pixels available in each segment to calculate meaningful zonal statistics (mean, minimum, maximum, standard deviation – used within the Random Forest model) for each data layer. Any segment found to be below the MMU is subsequently merged with a neighbouring segment with which they

share the longest boundary. The Phase IV Living England product contains approximately 6.9 million segments.

3.4 Vector Classification

The processing steps were undertaken in R (version 4.1.1 (2021)) and RStudio (version 2021.09.0 (2021)), with the exception of the Bare Ground thematic layer creation which was undertaken in Python (version 3.7 (2018)) using the ArcPy interface with ArcGIS Pro (version 2.9 (2021)).

3.4.1 Thematic Layer Creation

The Living England team has developed several algorithms for producing thematic layers to assist in the accurate classification of specific broad habitats. These are later classified outside of the Random Forest model, detailed in 3.4.2 Vector-Based Classification. These habitat classes include water, bare ground and built-up areas and gardens.

The Water habitat class was identified as one of those that could benefit from being classified outside of the Random Forest model, due to early models occasionally failing to differentiate between water and the woodland classes. A bespoke water layer is generated using three components:

- *SumIR*, which is a measure calculated from the Sentinel-2 imagery bands of Near-Infrared (NIR) and Short-wave Infrared (SWIR), using the equation (Zhou et al. 2017):

$$SumIR = NIR + SWIR1 + SWIR2$$

- Height Above Nearest Drainage (HAND, Nobre et al. 2011), calculated from the EA Integrated Height Model (IHM) (Bluesky International Ltd. & Getmapping PLC. 2020).
- Proximity to surface water, calculated from OS Vectormap District (Ordnance Survey Vectormap District, 2021).

A threshold is then applied to each of the above datasets, and where a pixel meets the thresholds in all three datasets, it is then classified as water and forms part of the water mask. Kernel density plots are used to guide the threshold calculation for the *SumIR* layer. The pixel values for large water bodies and the surrounding land are extracted and plotted, creating a bimodal histogram that allows determination of a suitable land-water threshold for the *SumIR* layer. Thresholds for the HAND and water proximity layers are determined

subjectively to minimise misclassifications, achieved by iteratively quality checking mapped outputs from the full algorithm.

A classification for **Bare Ground** was developed due to an insufficient number of inland rock and bare soil/peat training data points and misclassification in previous model iterations of bare sand and vegetated upland slopes. Pixels close to “building features” derived from the OS Vectormap District dataset were first removed to avoid misclassification. Sentinel-1 and Sentinel-2 data were then overlaid to identify areas dominated by either inland rock or bare soil/peat, with thresholds selected to maximise the overlap with bare ground training points and minimise the overlap with all other training data. This was through assessing:

- Sentinel-1 VV+VH average coherence – used to identify areas with consistent surface reflection properties whilst reducing background noise in the imagery.
- Sentinel-2 Normalised Difference Vegetation Index (NDVI) – an index derived from the imagery used to indicate plant productivity (Rouse et al., 1974). Here, low NDVI values are used to identify areas with very sparse or no vegetation. This is calculated with the equation (IDB Project, 2021):

$$NDVI = (NIR – Red) / (NIR + Red)$$

The classification for **Built-up Areas and Gardens** is implemented using the building features found in the OS Vectormap District dataset. This is supplemented by an additional index layer calculated from Sentinel-2 imagery, the Normalised Difference Vegetation Index – Red Edge (*NDVIre*). This is calculated using the following equation (Osgouei et al., 2019):

$$NDVIre = (NIR – RedEdge) / (NIR + RedEdge)$$

A number of test locations were identified to help determine a suitable threshold for the *NDVIre* layer, which was iteratively determined using Esri ArcPro software by assessing the extraction of urban areas compared to Sentinel-2 imagery. The *NDVIre* layer was prone to extracting unwanted upland bare rock and man-made bare ground features (eg. quarries). These features typically have higher slope than found in an urban setting, with the classification of the *NDVIre* restricted to locations of slope less than 10° to remove any misclassifications. This threshold was chosen with the aim of maximising the positive classification of urban areas whilst removing falsely classified features. The slope layer was calculated from the Environment Agency’s Integrated Height Model (IHM).

3.4.2 Vector-Based Classification

Several habitats are classified outside of the model-based classification, based on the percentage overlap between a segment and a thematic layer representing that specific habitat. The reasons for this are two-fold:

1. To ensure consistency with other Defra mapping products.
2. To provide improved classification for habitats that showed sub-optimal results when determined using the model-based classification.

The vector classification of habitats is processed in a specific order based on the accuracy of the classifying dataset, and the potential for overlap with other habitats. Table 3 outlines the classification order, target habitat, classifying dataset and overlap requirements used in the vector-based classification process. These are classified sequentially in the order listed by assessing whether a segment overlaps by a specified percentage cover with the dataset. For example, where a segment is covered by at least 33% of the OS Vectormap buildings data it is classified as “Built-up Areas and Gardens”. Both the ‘Bare Ground’ and ‘Water’ classes are also classified through the model-based classification, with the aim of maximising the classification accuracy for each habitat.

Table 3. Vector-based classification hierarchy.

Order	Habitat	Dataset	Overlap Criteria
1	Built-up Areas and Gardens	OS Vectormap Buildings	33%
2	Coastal Saltmarsh	EA Coastal Saltmarsh Extent and Zonation (*EA Saltmarsh Extent and Zonation 2021*)	50%
3	Water	Living England bespoke layer	50%
4	Bare Ground	Living England bespoke layer	100%
5	Arable and Horticultural	RPA Crop Map of England (*RPA Crop Map of England 2019*)	50%
6	Built-up Areas and Gardens	Living England bespoke layer	50%
7	Unclassified	Living England Sentinel-2 cloud mask	10%

3.5 Model-Based Classification

Using the segmentation layer created in Section 3.3 Segmentation classification model is used to determine probable habitat classes for each segment, by comparing the relationships between the validated training data and the model input data shown in Table 2. Common statistical indicators (mean, minimum, maximum, standard deviation) are calculated per segment for each data layers in Table 2, using the *exactextractr* R package (version 0.7.2). The Living England classification approach uses the machine learning algorithm, 'Random Forest' (implemented using the *randomForest* R package (version 4.6-14)), to match the known characteristics of each habitat type, as defined by the training data, with specific characteristics observed from the model input data for each segment.

A random subset of 20% of the training data was held back to validate the model predictions. The model was first run with all the model input variables to determine the importance of the inputs in determining patterns for predicting habitat classes, and then a subset of the most important variables were selected for the final model run. This subset was determined through a calibration process using bootstrapping to assess this parameter alongside other model parameters and optimise these for each BGZ. The final model was run 500 times to predict the most likely habitat type for each segment. The results are finally collated and reported as percentages by habitat class. This tells us how many of the model runs predicted each habitat class, for example 70% bog and 30% dwarf shrub heath. The habitat class with the highest percentage is assigned to the segment as the 'primary habitat'. This percentage value is then taken to represent the 'probability' that this habitat is the primary habitat type within the given segment. For example, some segments may be classified with a high probability (e.g., 80% for one habitat class), demonstrating greater certainty in the model's prediction, whilst others may report a lower probability (e.g., 30%), indicating lower confidence in the model's predicted classification. This process helps to optimise the overall habitat classification accuracy and provides valuable information about classification certainty.

3.6 Model Validation

The classification outputs are validated using the randomly selected validation dataset. For each BGZ, this reports the habitat probabilities, which are the likelihood of a segment being correctly classified for each habitat type. The model also reports accuracy measures of the User's accuracies and Producer's accuracies, which describe for a given class the

number of segments which have been correctly identified both on the ground and in the reference validation data. Finally, the overall BGZ and national statistics are reported to compare model performance across the different zones.

3.7 Data Outputs

The classified segments from the vector based-classification and model-based classification workflows are merged to create maps with completed habitat classifications for each BGZ. The predicted habitat classifications for each BGZ are then merged, and the final product is clipped to the Mean Height Water Springs (MHWS) extent to produce the final Living England national habitat map.

4. Phase IV Results

Table 4 provides a summary of the optimum parameter overall habitat probabilities obtained for each BGZ, calculated by the random forest model. These probabilities are calculated for the model-based classifications, and do not include the habitats classified via the Vector Classification process. The accuracies of the Crop Map of England and Coastal Saltmarsh Extent and Zonation datasets used within this process can be found in the relevant dataset documentation (RPA Crop Map of England 2019, EA Saltmarsh Extent and Zonation 2021). The final classified Living England habitat map is displayed in Figure 5.

Table 4. Summary of overall habitat probabilities per BGZ.

Biogeographic Zone	Probability	Biogeographic Zone	Probability
BGZ01	*86.64*	**BGZ08**	*90.04*
BGZ02	*92.34*	**BGZ09**	*92.12*
BGZ03	*78.73*	**BGZ10**	*85.21*
BGZ04	*92.26*	**BGZ11**	*90.37*
BGZ05	*85.65*	**BGZ12**	*81.82*
BGZ06	*91.4*	**BGZ13**	*89.71*
BGZ07	*92.73*	**BGZ14**	*89.71*

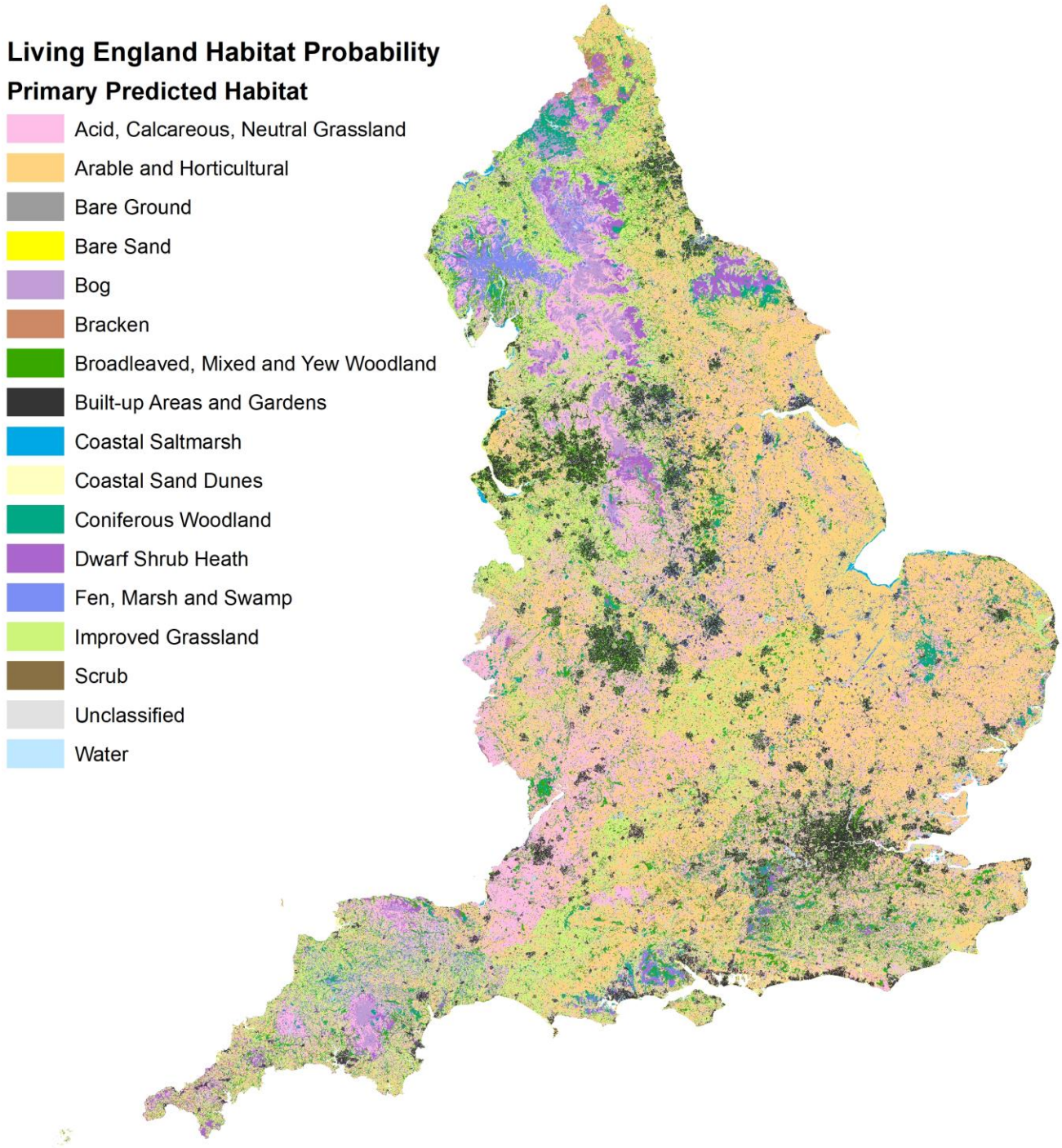

Figure 5: The Phase IV Living England habitat map.

4.1 Known Issues and limitations

- Through validating the model outputs and assessing these against satellite imagery, the Living England team has identified several regions where the classification is sub-optimal, despite the high overall product probability. **Acid, Calcareous and Neutral Grassland.** Observed over-mapping of the habitat class in the south-west, primarily replacing expected Improved Grassland classification.

- **Bare Sand.** Some regions of Bare Sand have been misclassified as a range of other habitats.

- **Built-up Area and Gardens.** Non-built-up urban areas and roads are often missed in the vector-based classification, with the segments subsequently classified as a range of habitats in the model-based classification.

- **Fen, Marsh and Swamp.** Observed over-mapping of the habitat class in the Lake District, primarily replacing expected Bog classification.

- **Unclassified.** Incorrect identification of potential cloud in urban areas.

The Living England map has been produced using a combination of recently collected field data from the 2020-21 season, as well as historical data. This should be taken into consideration when using these maps, in the knowledge that these are predicted habitat classes based on divisions using the satellite imagery and may not reflect actual conditions on the ground.

The Living England project is focused on improving the classification around these known issues and is proactively working towards a standardised methodology to produce biennial releases of the habitat map. The Living England project will develop and optimise the methodology outlined in this document in the next phase of the project during 2022/23. Subject to the next phase of work, we aim to publish a new version of the 2021/22 habitat map that uses this new, standardised methodology during Phase VI (2023/24), alongside a new habitat map representing 2023/24 data. This will enable the assessment of change between iterations of the national habitat map, with the same methodology planned to be applied in subsequent years. The end-user should take this into consideration when assessing the suitability of the Phase IV habitat classification for their analyses.

If you find any further classification issues other than those outlined in this section, we encourage you to let us know using the contact details provided in Section 6.

5. Data Access and Format

5.1 Download and Data Format

The Living England Habitat Probability map is available to view on the Defra's MAGIC Platform (MAGIC, 2022), Natural England Open data portal (Natural England, 2021c) and Defra Data Services Platform (Defra 2022) with download access available via data.gov. Due to the size of the dataset, splitting of wider geographical download requests may be required.

5.2 Geographical Extent

The Living England dataset covers the entirety of England up to the Mean High-Water Springs (MHWS), as defined by the Ordnance Survey (Ordnance Survey Boundary Line, 2021).

5.3 Product Spatial Resolution

The objects used within the Living England classification are created during the segmentation process based on Sentinel-2 imagery (see section 3.3 Segmentation), which has a spatial resolution of 10 m. The final Living England map comes with a Minimum Mapping Unit (MMU) of 3 pixels (300 m^2) to ensure enough data variance is available in each segment to provide an accurate prediction within the model-based classification.

5.4 Data Attributes

For each segment within the Living England output map, a series of data attributes are provided. Table 5 shows the name, data type and a description of the attributes associated with each segment.

Table 5. Living England data attributes

Column Name	Type	Description
ID	Integer	Unique Living England segment identifier
A_pred	String	Primary habitat prediction
A_prob	Float	Primary habitat probability (%)
B_pred	String	Secondary habitat prediction
B_prob	Float	Secondary habitat probability (%)
SrcCode	Integer	Code representing the source of the segment classification. 1. Random Forest 10. Living England bespoke *Water* classification 11. Living England bespoke *Bare Ground* classification 12. Living England bespoke *Built-up Areas and Gardens* classification 20. Classified using Ordnance Survey Vectormap District (*Built-up Areas and Gardens*) 21. Classified using Environment Agency Saltmarsh Zonation and Extent (*Coastal Saltmarsh*) 22. Classified using Rural Payments Agency Crop Map of England (*Arable and Horticultural*) 99. *Unclassified* due to cloud-cover
ImagesSpr	String	Satellite imagery dates – spring
ImagesAut	String	Satellite imagery dates – autumn
Shape_Length	Integer	Segment perimeter length (m)
Shape_Area	Integer	Segment area (m^2)

6. Contact

For any queries or further technical detail, please contact the Living England team at earth.observation@naturalengland.org.uk.

The code used to create Living England is not currently publicly available due to the on-going development of the project. However, the Living England project is happy to share the R, Python and Google Earth Engine scripts that have been used to create this product, subject to licence conditions. Please use the above email address to log a request for access to the code.

Glossary

AGOL	=	ArcGIS Online
AWS	=	Amazon Web Service
BGS	=	British Geological Survey
BGZ	=	BioGeographic Zone
CROME	=	Crop Map of England
DEFRA	=	Department for Environment, Food & Rural Affairs
EA	=	Environment Agency
EO	=	Earth Observation
ELMS	=	Environmental Land Management Scheme
ESA	=	European Space Agency
EOCoE	=	Earth Observation Centre of Excellence
FR	=	Forest Research
GEE	=	Google Earth Engine
HAND	=	Height Above Nearest Drainage
IHM	=	Integrated Height Model
JNCC	=	Joint Nature Conservation Committee
MEOW	=	Making Earth Observation Work for UK Biodiversity
MHWS	=	Mean High Water Springs
MMU	=	Minimum Mapping Unit *(3 pixels / 300 m^2 for Living England)*
NCEA	=	National Capital and Ecosystem Assessment
NDVI	=	Normalised Difference Vegetation Index
NDVIre	=	Normalised Difference Vegetation Index - Red Edge
NEFU	=	Natural England Field Unit
NIR	=	Near Infrared
OGL	=	Open Government Licence
OS	=	Ordnance Survey
RPA	=	Rural Payments Agency
SLC	=	Single Look Complex
SNAP	=	Sentinel Applications Platform
SSGP	=	Space for Smarter Government Programme
SWIR	=	Short-Wave Infrared
VH	=	Vertical-Horizontal
VV	=	Vertical-Vertical
UKBAP	=	UK Biodiversity Action Plan
UKCEH	=	UK Centre for Ecology and Hydrology

References

Batic, M. 2018 “Sentinel Hub Cloud Detector — s2cloudless”. Available from: https://medium.com/sentinel-hub/sentinel-hub-cloud-detector-s2cloudless-a67d263d3025

Bluesky International Ltd. & Getmapping PLC. 2020. Aerial Photography and Height Data. Available from: https://apgb.blueskymapshop.com/

Defra. 2022. Defra Data Services Platform. Available from: https://environment.data.gov.uk/.

EA Saltmarsh Extent and Zonation 2021. Available from: https://data.gov.uk/dataset/0e9982d3-1fef-47de-9af0-4b1398330d88/saltmarsh-extent-zonation.

Esri. 2021. “World Imagery” [basemap]. Scale Not Given. “Esri World Imagery”. https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9.

Esri ArcGIS Pro (version 2.9). 2021. Available from: https://www.esriuk.com/en-gb/arcgis/products/arcgis-pro/overview.

exactextractr (R package, version 0.7.2). 2021. Documentation available from https://www.rdocumentation.org/packages/exactextractr/versions/0.7.2.

Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315.

Forestry Commission. 2018. National Forest Inventory Woodland England 2018. Available from: https://data-forestry.opendata.arcgis.com/datasets/295e0278dc2641e2935c411d-28908be9_0.

Higginbottom, T., Field, C and Keane, R, Wright, A, Jones, L, Symeonakis, I and Caporn, S. 2018. From Space to Eye Lens: Monitoring protected sites with Earth Observation: Combining field data with CASI and Sentinel imagery. UNSPECIFIED. Manchester Metropolitan University.

The IDB Project 2021. Index Database: A database for remote sensing indices. Available from: https://www.indexdatabase.de/.

JNCC 2011. UK Biodiversity Action Plan Priority Habitat Descriptions. Available from: https://jncc.gov.uk/our-work/uk-bap-priority-habitats/.

Kilcoyne, A., Alexander, R., Cox, P. & Brownett, J. (2017) Living Maps: Satellite-based Habitat Classification. Evidence Project SD1705. Available online at: http://randd.defra.gov.uk/Document.aspx?Document=14198_SD1705_FinalReport.pdf

MAGIC (Defra). 2022. Available from: https://magic.defra.gov.uk/.

Medcalf, K.A., Parker, J.A., Turton, N. & Bell, G. 2014. Making Earth Observation Work for UK Biodiversity – Phase 2. JNCC Report No. 495, Phase 2, JNCC, Peterborough, ISSN 0963-8091.

MoorLIFE 2020. Blanket Bog: Decision Making Toolkit. Land Management guidance. Available from: https://www.moorsforthefuture.org.uk/__data/assets/pdf_file/0024/87441/Blanket-bog-land-manager-guidance-FAQs-Report.pdf.

Mountford, J.O. & Cooke, A.I. (editors), Amy, S.R., Baker, A., Carey, P.D., Dean, H.J., Kirby, V.G., Nisbet, A., Peyton, J.M., Pywell, R.F., Redhead, J.W. & Smart, S.M. 2013. Monitoring the outcomes of Higher-Level Stewardship: Results of a 3-year agreement monitoring programme. Natural England Commissioned Reports, Number 114.

Natural England 2021.National Character Areas. Available online at: https://environment.data.gov.uk/dataset/f955fff5-a132-4e25-8c7f-0d43664ff42e.

Natural England 2021b. Priority Habitat Inventory (England). Available from: https://data.gov.uk/dataset/4b6ddab7-6c0f-4407-946e-d6499f19fcde/priority-habitat-inventory-england.

Natural England, 2021c. Natural England Open Data Portal. Available from: https://naturalengland-defra.opendata.arcgis.com/.

Natural England 2017. Natural England's Long Term Monitoring Network (RP00316) Available from: http://publications.naturalengland.org.uk/publication/4654364897050624.

Nobre, A.D., Cuartas, L.A., Hodnett, M., Renno, C.D., Rodrigues, G., Silveria, A., Waterloo, M. & Saleska, S. 2011. Height Above the Nearest Drainage – a hydrologically relevant new terrain model. *Journal of Hydrology*, **404**(1–2): 13-29, doi: 10.1016/j.jhydrol.2011.03.051.

Ordnance Survey Boundary Line. 2021. Available from: https://osdatahub.os.uk/downloads/open/BoundaryLine.

Ordnance Survey Vectormap District. 2021. Available from: https://osdatahub.os.uk/downloads/open/VectorMapDistrict.

Osgouei, P.E., Kaya, S., Sertel, E. & Alganci, U. 2019. Separating Built-Up Areas from Bare Land in Mediterranean Cities Using Sentinel-2A Imagery. *Remote Sensing,* **11**: 345, doi: 10.3390/rs11030345

Pescott, O.L.; Walker, K.J.; Day, J.; Harris, F.; Roy, D.B. (2020). National Plant Monitoring Scheme survey data (2015-2019). NERC Environmental Information Data Centre. https://doi.org/10.5285/cdb8707c-eed7-4da7-8fa3-299c65124ef2. Available from: https://www.npms.org.uk/.

Python (version 3.7). 2018. Available from: https://www.python.org/.

R (version 4.1.1). 2021. Available from: https://www.r-project.org/.

randomForest (R package, version 4.6-14). 2021. Documentation available from: https://www.rdocumentation.org/packages/randomForest/versions/4.6-14/topics/randomForest.

Rouse, J.W, Haas, R.H., Scheel, J.A., and Deering, D.W. 1974. Monitoring Vegetation Systems in the Great Plains with ERTS*. Proceedings, 3rd Earth Resource Technology Satellite (ERTS) Symposium*, **1**(A): 309, https://ntrs.nasa.gov/citations/19740022614.

RPA Crop Map of England, 2019. Available from: https://data.gov.uk/dataset/8c5b635f-9b23-4f32-b12a-c080e3f455d0/crop-map-of-england-crome-2019.

RStudio (version 2021.09.0). 2021. Available from: https://www.rstudio.com/.

Sentinel Applications Toolbox (version 8.0). 2020. Available from: https://step.esa.int/main/.

Trimble Geospatial (version 9.2). 2022. eCognition. Available from: https://geospatial.trimble.com/products-and-solutions/trimble-ecognition.

Zhou, Y., Dong, J., Xiao, X., Xiao, T., Yang, Z., Zhao, G., Zou, Z. & Qin, Y. 2017. Open Surface Water Mapping Algorithms: A Comparison of Water-Related Spectral Indices and Sensors. *Water*, **9**(4): 256, doi: 10.3390/w9040256

Appendix 1: Model training datasets

Dataset	Survey Year	Owner	Surveyors	Purpose	Method	Reference
Agri-Environment Higher Level Scheme (HLS) Monitoring	2009 to 2011	NE	UKCEH	Evaluation of HLS options	Common Standards Monitoring	Mountford et al. 2013
Coastal Dune Geomatics Mapping: Ground Truthing	2012 to 2018	EA	NE	Ground truthing coastal dune habitat classification map	Walker over rapid method collecting habitat class points	
Dark Peak Bog State Survey	2019	NE	NE	Assessment of different states defining bog condition	Walker over rapid method collecting points indicating bog state using Blanket Bog Toolkit (MoorLIFE, 2020).	
Desktop Validation and Manual Points	2020 & 2021	NE	NE	Validate Living England accuracy & create manual training points from comparison with higher resolution imagery	Living England Desktop Validation Excel method & Interactive Esri ArcGIS Online Map	
Living England Collector App	2020 & 2021	NE	NE	Target collection of habitat training points aligned to segmentation for model training purposes	ArcGIS Online Collector App recording Living England UKBAP classes at broad, detailed level & higher priority habitat resolutions	
Long Term Monitoring Network (LTMN)	2014 to 2019	NE	NE & Contractors	Long-term monitoring of plant communities to identify change and the possible drivers of change	LTMN/Environmental Change Network vegetation survey protocol, collation & QA methodology	Natural England 2017
Lowland Heathland Survey	2015	NE	Contractors	Environmental Stewardship Monitoring and	Common Standards Monitoring	

Dataset	Survey Year	Owner	Surveyors	Purpose	Method	Reference
				Evaluation of HLS Lowland Heathland options		
Northumberland Border Mires Survey	2017	NE	Newcastle University, Helen Adamson & John O'Reilly	Assess bog, mire condition and wetness	Wet Bog Quality Index Survey developed by Helen Adamson, Newcastle University	
National Forest Inventory (NFI)	2018	FR	FR	National Forest Inventory programme monitors woodland and trees within Great Britain	A satellite derived model of forest extent informed by an extensive habitat survey dataset	Forestry Commission, 2018
Natural England Field Unit (NEFU) Surveys	2018 to 2020	NE	NE	Condition and habitat extent surveys	National Vegetation Classification, Common Standards Monitoring	
National Grassland Survey	2017 & 2018	NE	Contractors	Resurvey of a sample of priority grasslands outside of SSSIs to determine impact and effectiveness of Environmental Stewardship agreements in delivering outcomes	Grassland stands re-surveyed using Hewins et al, 2004 method a stand assessment and a structured walk.	
National Plant Monitoring Scheme (NPMS)	2015 to 2021	Botanical Society of Britain & Ireland, JNCC, UKCEH, Plantlife	Citizen Science	Collection of data to provide an annual indication of changes in plant abundance and diversity	Recording of plant 'indicator species' in five plots within a 1km square by volunteers.	Pescott et al. 2020
Priority Habitat Inventory (PHI): B Button	2016 to 2018	NE	NE	Describes the geographic extent and location of Priority Habitats in England	Habitat extent map derived by combining previous BAP Habitat Inventories. B Button dataset is corrected habitat areas	Natural England 2021b

Dataset	Survey Year	Owner	Surveyors	Purpose	Method	Reference
Sentinel-2 Water Mask	2018 to 2021	NE	NE	Specifically undertaken for Living England	Points created from largest water bodies, identified from Sentinel-2 imagery	
Space2Eye Lens: Ainsdale NNR	2012 to 2018	NE, Manchester Metropolitan University	Contractor, UKCEH, NE, Manchester Metropolitan University	Ainsdale Coastal Dune Map derived from Sentinel Satellite Imagery to pilot capability to monitor change & dune restoration	Existing & new ground data collated for training data to inform model includes National Vegetation Classification (NVC), UKCEH Dune Slacks Survey, Space2Eye Lens Ground Truth survey	Higginbottom et al. 2018
Space2Eye Lens: State of the Bog Training Data	2012 to 2018	NE, Manchester Metropolitan University, United Utilities & Moors for the Future	NE, Manchester Metropolitan University (Carlos Bedson)	Baseline habitat condition and Bog Wetness Index models derived from Sentinel Imagery to inform Upland Blanket Bog restoration for targeting re-wetting	Existing survey data collated & new ground data collected to train the model; includes CSM, Carlos Bedson Mountain Hare Habitat Survey, Long Term Monitoring Network (LTMN), Bowland adapted CSM Bog State survey, West Pennine Moors National Vegetation Classification (NVC)	Higginbottom et al. 2018
Uplands Inventory	2008 to 2011	NE	ADAS	Condition survey of PHI blanket bog, heath and upland calcareous grasslands to report on condition, effects of designation and Agri-Environment Schemes to inform Management	Common Standards Monitoring	
Wetland Inventory	2012 to 2017	NE	NE & Contractors	Development of inventories for Annex 1 wetland habitats	Collation of data for inventory, supplemented with field survey of main areas lacking data.	

Appendix 2: Data Licensing

Dataset	Description	Licensing summary
Agri-Environment Higher Level Scheme (HLS) Monitoring	Evaluation of HLS options using Common Standards Monitoring (CSM). Stands of Priority Habitat mapped in the field using handheld tablets.	A Memorandum of Agreement was drawn up by Natural England, Centre for Ecology and Hydrology and DEFRA in November 2008. This agreement was drawn up prior to the existing Public Sector Geospatial Agreement and due to the use of Ordnance Survey Master Map data an exemption needed to be granted to use the data in its derived format in the Living England Habitat Map. Ordnance Survey granted the exemption for Living England to publish the derived data under the Open Government Licence in November 2021.
BGS Bedrock Mapping 1:50k	Data identifying landscape areas (shown as polygons) attributed with geological names. The scale of the data is 1:50 000 scale. Onshore coverage is provided for all of England, Wales, Scotland, and the Isle of Man. Data are supplied as five themes: bedrock, superficial deposits, mass movement, artificial ground, and linear features.	The licence for this data made between the British Geological Survey (BGS) and Natural England stated that permission must be given by BGS to use the data in a derived format. BGS granted Living England an exemption to use data in a derived format under the Open Government Licence in July 2021.
Coastal Dune Geomatics Mapping: Ground Truthing	This habitat map is a remotely sensed product which classify site relevant habitats visible at the time of CASI and LIDAR capture. The classification uses supervised classification techniques; these are techniques which are trained using ground data. The final habitat map has been critically evaluated using Aerial Photography captured simultaneously with the CASI data by the processors and independently by habitat specialists.	All data published under the Open Government Licence by the Environment Agency in 2019.
Crop Map of England (RPA)	Crop Map of England (CROME) polygons consisting of 20 main crop types, grassland, and non-agricultural land covers.	All data Published under the Open Government Licence by the Rural Payments Agency in 2020

Dataset	Description	Licensing summary
Dark Peak Bog State Survey	Blanket Bog Walk over rapid method to collect bog state points from 1 to 6. Dataset collected by Natural England advisers during site visits to inform habitat mapping work for uplands casework or for SSSI condition monitoring. All data collected and owned by Natural England.	All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.
Desktop Validation and Manual Points	Validate the accuracy of the Living England Phase III output and creation of manual training points from comparison of aerial imagery against the Sentinel-2 Phase 3 mosaic, segmentation, and habitat classification across each Biogeographic Zone.	This method adheres to the licence agreement made between Natural England and the Environmental Systems Research Institute (Esri).
EA Integrated Height Model 10m	Digital Height data covering England. Combination of EA Aerial LiDAR and APGB height. Data natively 2m resolution, resampled to 10m using bilinear resampling.	The licence for this data between the Environment Agency and Natural England stated that data contributed by Aerial Photography GB (Bluesky/GetMapping Plc) requires permission to be used. GetMapping granted Living England an exemption to use the data in a derived form under the Open Government Licence in August 2021.
EA Saltmarsh Zonation and Extent	Polygon data layer showing the extent of Saltmarsh in Coastal and Transitional waters for use by both Flood and Coastal Risk Management and the implementation of Water Framework Directive.	All data published under the Open Government Licence by the Environment Agency in 2020
Esri World Imagery	Aerial imagery provided in ArcGIS Online (AGOL) as base mapping for Desktop Validation Interactive mapping work	This method adheres to the licence agreement made between Natural England and the Environmental Systems Research Institute (Esri).
Natural England Field Unit (NEFU)	Site surveys and SSSI monitoring commissioned by NE national and Area teams.	All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.

Dataset	Description	Licensing summary
Living England Collector App	All data collected by Natural England as bespoke targeted Training Data for Living England.	All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.
Long Term Monitoring Network (LTMN)	Long-term monitoring of plant communities to identify change and the possible drivers of change	Published under the Open Government Licence by Natural England in 2020.
National Lowland Heathland Survey	An evaluation of Environmental Stewardship options looking at the effectiveness of Lowland Heathland Higher Level Stewardship options.	Data collected under the Environmental Stewardship Monitoring and Evaluation Framework by external contractors for Natural England. All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.
National Forest Inventory (NFI)	The National Forest Inventory (NFI) programme monitors woodland and trees within Great Britain. It includes the most in-depth survey carried out on Britain's woodland and trees to date. The NFI provides an extensive and unique record of key information about our forests and woodlands.	All data published under the Open Government Licence by the National Forest Inventory in 2018.
National Grassland Survey	Resurvey of a sample of priority grasslands outside of SSSIs to determine impact and effectiveness of ES agreements in delivering outcomes.	Data collected under the Environmental Stewardship Monitoring and Evaluation Framework by external contractors for Natural England. All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.

Dataset	Description	Licensing summary
National Plant Monitoring Scheme	The NPMS is a habitat-based plant monitoring scheme designed by the Botanical Society for the British Isles (BSBI), the Centre for Ecology & Hydrology (CEH), Plantlife and the Joint Nature Conservation Committee (JNCC). The aim is to collect data to provide an annual indication of changes in plant abundance and diversity. It is a scientific survey, which involves recording plant 'indicator species' in five plots within a 1km square.	All data published under the Open Government Licence by UK Centre for Ecology and Hydrology in 2020
Northumberland Border Mires	Wet Bog Quality Index (WBQI) Survey carried out by Helen Adamson or Newcastle University on behalf of Natural England.	Original agreement states that all data and intellectual property rights are owned by Natural England and that any data collected as a result of the survey is owned by Natural England and is publishable under the Open Government Licence.
OS Vector Map District	OS VectorMap® District is a map on which you can overlay your own information. It can also be customised by selecting and styling different features in different ways. Ideal for creating web applications, OS VectorMap District contains only the most important information to give you a clear, uncluttered backdrop map. ESRI® Shapefile interchange format (Vector).	Freely available for commercial or non-commercial use under the OS OpenData Open Government Licence and can be downloaded from the OS directly but must credit OS OpenData if used.
Priority Habitats Inventory (PHI): B Button	Spatial dataset that describes the geographic extent and location of Natural Environment and Rural Communities Act (2006) Section 41 habitats of principal importance. B Button allows people to report errors in the data which are then updated on the next PHI publication with GDPR removed.	Data used was collected between 2017 and 2019 and as a result has been published as a part of the Priority Habitats Inventory under the Open Government Licence in 2020.
European Space Agency (ESA) Sentinel-	The Sentinel Series of Satellites 1 & 2 have been launched as part of the Earth observation missions from the Copernicus Programme.	The Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub) provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products, starting from the In-Orbit Commissioning Review (IOCR).

Dataset	Description	Licensing summary
1 and Sentinel-2		
Space2 Eye Lens: Ainsdale NNR	Baseline habitat condition model pilot for monitoring change across Coastal Dunes of Ainsdale NNR & Long-Term Monitoring Network (LTMN) site using Sentinel-2.	A Memorandum of agreement was made between Natural England and Manchester Metropolitan University where both parties collected data across the Ainsdale NNR and Sefton Coast and was used as training data for model production by Manchester Metropolitan University on behalf of Natural England for the Space 2 Eye Lens project. All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.
Space2Eye Lens: State of the Bog Bowland Survey	Baseline habitat condition and Bog Wetness Index models to inform Upland Blanket Bog restoration across the Uplands. Informing Long Term Upland Management Plans and monitoring success, over time. State of the Bog and Wetness index used to map Natural Capital assets for targeting re-wetting to improve ability to hold water acting as an Ecosystem Service and bog resilience in carbon sequestration for Climate Change.	A Memorandum of agreement was made between Natural England (NE) and Manchester Metropolitan University across the Bowland SSSI and was used as training data for model production by Manchester Metropolitan University on behalf of Natural England for the Space 2 Eye Lens project. All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.
Space2Eye Lens: State of the Bog Dark Peak Condition Survey	Spatial dataset collected by NE during site check visits to blanket bog in the Dark Peak SSSI during the winter 2018/19 survey season. Comprises vegetation cover data for selected indicator species in 2m x 2m quadrats (CSM dataset) and at the vegetation stand level (Bog State dataset).	Dataset collected internally, gathered by local Natural England advisers during site visits to inform habitat mapping work for uplands casework or for SSSI condition monitoring. All data collected and intellectual property rights owned by Natural England and is publishable under the Open Government Licence.

Dataset	Description	Licensing summary
Space2Eye Lens: State of the Bog Manchester Metropolitan University Mountain Hare Habitat Survey Dark Peak	Mountain Hare Habitat Survey Dark Peak. Extensive 2m plot habitat survey recording to species level.	Licence drawn up with Carlos Bedson of Manchester Metropolitan University allowing the use of Mountain Hare Habitat Data in the Living England Habitat Map under the Open Government Licence.
Uplands Inventory	Condition survey of a representative national stratified random sample of PHI blanket bog upland (wet and dry) heath and upland calcareous grassland habitat polygons.	Data used was collected between 2008 and 2011 and has been published as a part of the Priority Habitats Inventory under the Open Government Licence in 2020.
West Pennine Moors National Vegetation Classification (NVC) Survey	Detailed vegetation survey to inform the boundary of the West Pennine Moors SSSI for notification. This document formed the basis of the WPM SSSI special features maps, as per notification.	This survey was carried out on behalf of Natural England by Penny Anderson Limited Contractors. The original contract states that data is owned by Natural England and all derived data and intellectual property rights belong to Natural England and is publishable under the Open Government Licence.
Wetland Inventories	Development of inventories for Annex 1 wetland habitats - alkaline fens, transition mire and quaking bog, calcareous fen with Cladium, Molinia meadows (partial) and Depressions on peat (partial).	Data used by the Living England Habitat Map was collected between 2012 and 2017. All data was collected either by Natural England staff or by external contractors. All contracts state that any data collected as a result of the survey is intellectual property of Natural England and is publishable under the Open Government Licence.
WorldClim - Global Climate Data	WorldClim version 2 has average monthly climate data for 19 bioclimatic variables (including precipitation and minimum, mean, and maximum temperature) for 1970-2000 at up to 1 x 1 km resolution.	WorldClim data is provided as Open Source data.

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

Natural England publications are available as accessible pdfs from www.gov.uk/natural-england.

Should an alternative format of this publication be required, please contact our enquiries line for more information: 0300 060 3900 or email enquiries@naturalengland.org.uk.

ISBN 978-1-78354-921-4

Catalogue code: NERR108

NATURAL ENGLAND