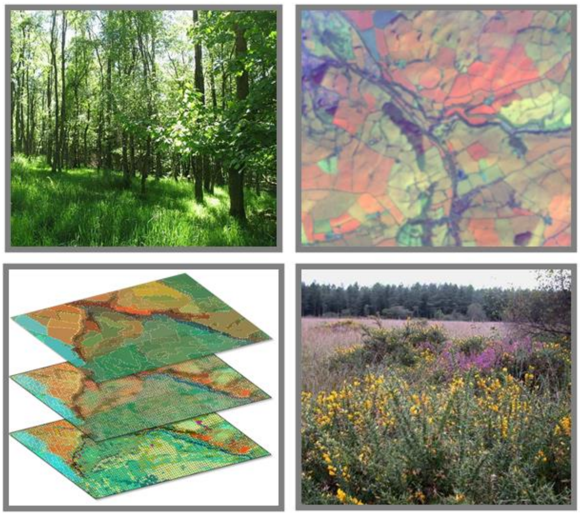
Making Earth Observation Work for UK Biodiversity Conservation – Phase 3

Crick Framework User Manual: Update, Phase 3



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What is new for Phase 3

This user manual has been updated as part of Phase 3 of the project in light of new thinking and further development of the project. It makes reference to the other documents produced during this phase, particularly the material for the outline business case document which includes practicalities of taking a Crick approach forwards in a national context and the rationale for doing this. The assessment of Crick classes for each of the BAP priority and Annex I habitats have been checked in light of the phase 3 pilot in the northern upland chain of England and an area of alpine habitats in the Cairngorm mountains of Scotland and updated accordingly.

Who is the User Manual for?

This manual is suitable for users who wish to explore the capacity of earth observation (EO) for monitoring habitat stock, condition and change. Whilst the manual has relevance to all users involved in habitat monitoring and surveillance, it is specifically designed with habitat specialists in mind, therefore users who are interested in developing the EO-based solutions to habitat monitoring but who may not have extensive experience of EO applications. The descriptions and earth observation guidelines require the user to have an ecological knowledge of the habitats under investigation. The aim of the manual is to help environmental managers use their knowledge of the habitat systems to identify suitable EO and ancillary data needed for the identification of features of interest.

What Guidance does it provide?

The “User manual” describes the “Crick Framework” which is a systematic description of the potential use of EO in habitat mapping. The user manual also describes the purpose and current content of the Crick Framework and shows how it can be used to support the evaluation of opportunities for mapping different types of habitats from EO data. Together, this manual and framework allow users to determine whether a particular habitat can be mapped from EO data and if so:

a) What kinds of EO data are required (type, resolution, time series frequency, etc.),

b) What other *ancillary* data are needed to support EO analysis of the habitat (e.g. soils elevation, etc.),

c) Whether a particular method of analysis is required to monitor a particular habitat.

This manual uses as its reference the habitats listed under Annex I of the Habitats and Species Directive and the Biodiversity Action Plan (BAP) Priority Habitats.

What are Annex I and BAP Priority habitats?

There are a number of ways of describing the natural landscape and classifying it into identifiable habitats, however the main classification systems focused on in this work are the Habitats Directive Annex I habitats and the Biodiversity Action Plan (BAP) Priority Habitats. These classifications consider habitats at a very detailed level and that are important internationally in a European context and nationally, respectively.

Earth Observation Context

Habitat mapping and monitoring are important components of environmental assessment. Member States are required to report to Europe on the extent and condition of Habitats Directive Annex I habitats; in addition currently BAP Priority Habitats are also monitored within the UK. For both economic and practical reasons it is becoming increasingly difficult to monitor these habitats by detailed field survey alone, frequently enough to evaluate change. Earth observation techniques can provide users with viable solutions to help with these delivery issues. There is a need to both:

- categorise habitats in terms of their ability to be mapped remotely; and,
- provide detailed descriptions of what EO can 'see' and how these can infer habitat characteristics.

The research leading to the Crick Framework was commissioned to evaluate the potential of using EO techniques for reporting on the extent and condition of Annex I and BAP Priority Habitats. These are not the only habitat classification systems for which there is a demand for information on stock, condition and change, therefore this framework has a wider relevance.

The Crick Framework and this user guidance are aimed at potential users who recognise that EO might assist with habitat mapping and must overcome a number of barriers:

Barrier 1:

EO has potential to assist with mapping habitats but there are perceived issues with:

Proof of the suitability of EO for detailed habitat mapping,

Proof of the cost-effectiveness of using EO compared with current fieldwork methods,

Availability of suitable imagery for the feature of interest and contextual ancillary data,

The amount of expertise and software required for image processing and analysis.

Barrier 2:

Habitat classification systems have often been derived from a field survey perspective. There are many commonly used systems which vary in detail from broad species assemblages, to very specific habitats defined by one or two species present within the sward. Trying to apply EO-based approaches to what is seen on the ground becomes difficult.

For broad habitat types, difficulties arise when there is a very wide variation of phenotypes within the assemblage, or where the habitat varies significantly in its constituents across the country.

Where the habitat is defined by only one or two small and low frequency indicator species, they are often obscured from above by the rest of the sward and are not visible in EO imagery.

Further development of this thinking has occurred during phase 3 with the construction of the outline material for the business case document which identifies a potential route for partnership areas to undertake a crick approach to their habitat mapping and considerations to cost and scale of workings required.

What is the Crick Framework?

This manual describes *The Crick Framework* which is named after Mark Crick of the JNCC, who worked hard to develop and promote the use of remote sensing in habitat mapping. Specifically the Framework addresses:

The capacity of EO to monitor habitats; and

The EO requirements for habitat mapping.

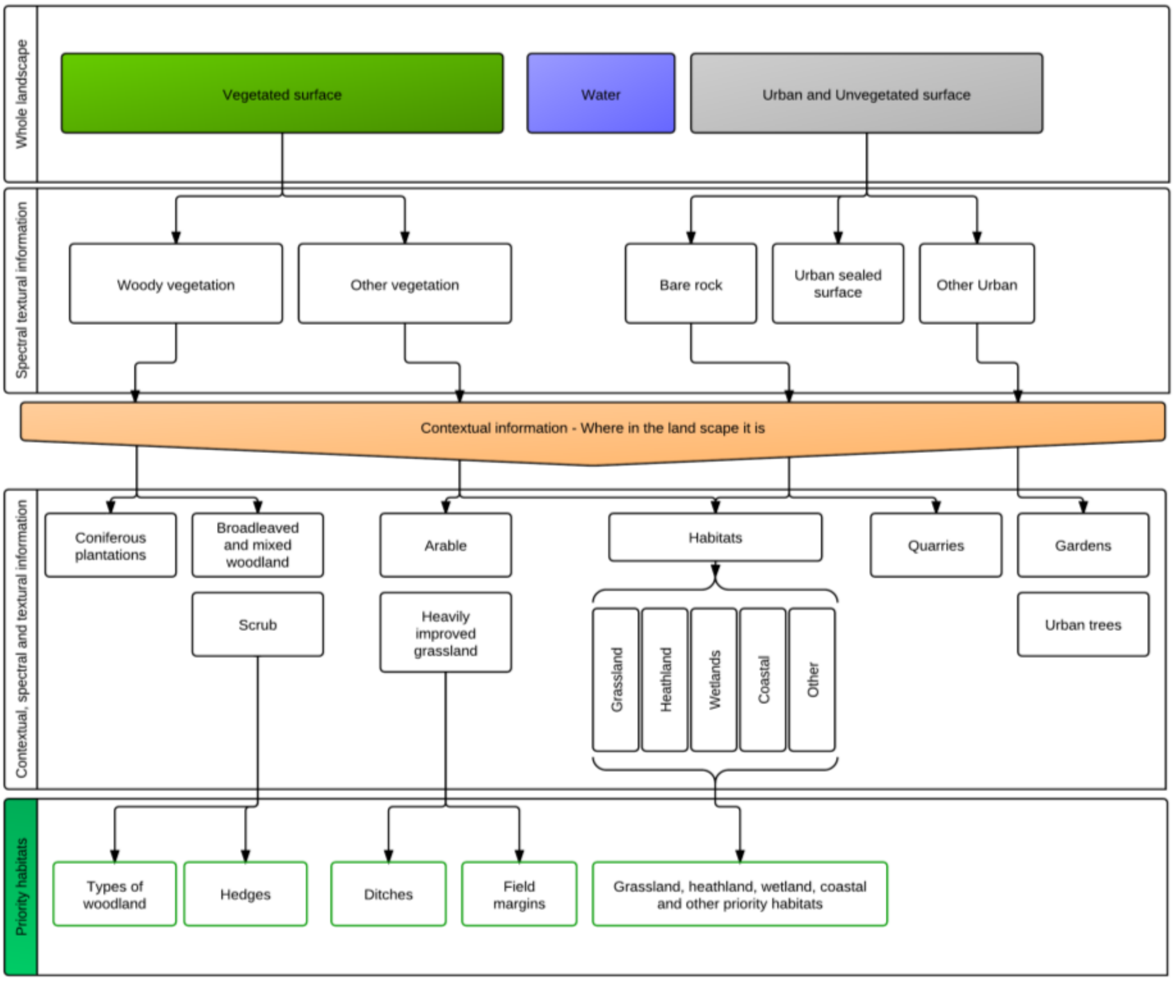
The Crick Framework sets out existing knowledge and the experience of implementing habitat mapping from EO including the EO data used, ancillary data, analysis approaches/rules, environmental constraints and thresholds. The first and most accessible component of the Crick Framework is a set of Tiers which provide a categorisation of habitats in terms of their ability to be mapped and monitored by remote sensing and ancillary data sets.

For each Tier, the capabilities of remotely sensed data and ancillary data to map a habitat of that particular tier level are described. Descriptions of the terminology are included in the sections below.

Tier 1	**Likely to be classified solely using EO**			
Tier 2	**Likely to be classified using EO and ancillary data**			
	Tier 2a - Likely to be classified using EO together with ancillary data	**Tier 2b** - Likely to be classified using VHR EO together with ancillary data	**Tier 2c** - Likely to be classified using EO data (in some cases VHR) but ID dependent on good geological data	**Tier 2d** - Likely to be classified using EO including LiDAR to give detailed information about vegetation structure
Tier 3	**Likely to be classified using EO, ancillary data and dependent on availability of time series imagery**			
	Tier 3a - Likely to be classified using EO together with ancillary data and needing time series imagery	**Tier 3b** - Likely to be classified using VHR EO together with ancillary data and needing time series imagery	**Tier 3c** - Likely to be classified using EO data (in some cases VHR) but ID dependent on good geological data and needing time series imagery	**Tier 3d** - Likely to be classified using EO including LiDAR to give detailed information about vegetation structure, and needing time series imagery
Tier 4	**Currently unlikely to be classified using EO**			
	Tier 4a - Habitats distinguished by low frequency or small features		**Tier 4b** - Habitat hidden from above for most of the year	
Tier 5	**Cannot be classified using EO**			

The tier into which each habitat falls is determined by a detailed analysis of habitat descriptions against the known current capabilities of EO systems and available ancillary data. For instance, field margin habitats are narrow and can therefore only be mapped with spatially detailed, very high spatial resolution (VHR) image data. This would place them in tier 2b or 3b. Similarly, certain habitats are only associated with particular geological substrate conditions so they are likely to be in the tier 2c or 3c. The detailed analysis of the habitat descriptions and the derivation of the appropriate tier are given later in this manual. For tier 2c and 3c, if sufficient geology and soils data is not available, confirmation will have to be by field survey to identify underlying geology either directly or by characteristic species.

To fully utilise the tier information within the Crick Framework it is necessary to separate out the main constituents of the different components of the landscape. This separability is an important first step in using EO for habitat mapping. A standard separability diagram is shown below; however for specific cases a customised separation may be necessary.



EO is a powerful tool for identifying habitats, however the information in the Crick framework suggests it may not provide the sole answer for every habitat. One of the most valuable roles of the framework is to allow EO to aid in the targeting of field effort as part of the “toolbox” of techniques used for habitat mapping and monitoring.

What data and techniques are available to support mapping?

Earth Observation

Remote Sensing (RS) is the process of obtaining information about a range of phenomena through analysis of data from a device which is not in contact with the phenomena. RS is associated with imaging systems such as cameras, but may include other geophysical systems and sensors such as magnetics and radar returns.

Earth Observation (EO) is the 'Earth facing' component of RS. EO data from satellite and airborne systems allows mapping and monitoring of the surface of the Earth. EO technologies historically were most commonly encountered through the acquisition and use of aerial photography, with satellite-based EO starting in 1972 with the launch of the first Landsat satellite. Since then, there have been progressive improvements in spatial, temporal and spectral resolution, across a range of mapping scales for a variety of mapping requirements.

EO data can be characterised by a range of factors;

i) The <u>spatial resolution</u> of an image collected by some remote sensing device is the limit of detail of the image, usually measured in metres. An image with a ground resolution of 10 metres shows no ground features smaller than 100 metres^2. Each data cell, or pixel, in such an image contains a value for a distinct 10 x 10 metre surface area.

Four spatial resolution classes are typically used in data descriptions:

Spatial resolution classes		**Pixel size**	**Further classification used by the GMES Data Warehouse**	
Very High Resolution	VHR	<=4m	VHR1 VHR2	<= 1m >1m – <=4m
High Resolution	HR	>4m – <=30m	HR1 HR2	>4m – <=10m >10m – <=30m
Medium Resolution	MR	>30m – <=300m	MR1 MR2	>30m – <=100m >100m- <=300m
Low Resolution	LR	>300m	LR	>300m

ii) The <u>image extent</u> is the area covered by a single image and can range from a few kilometres to hundreds of kilometres. Higher spatial resolution typically means a smaller image extent. However wider area coverage can be achieved by mosaicing several images together taking any timing differences into account.

iii) The <u>waveband properties</u> are the colours or spectral information that is recorded for each image pixel. Common waveband combinations for optical sensors include:

- True colour Red, green, blue
- False colour infrared Green, red, near infrared
- Visible / NIR Red, green, blue, near infrared
- Visible / NIR / SWIR Red, green, blue, near infrared, shortwave infrared

Generally the number of wavebands is related to the amount of discriminating power in the image.

iv) <u>The temporal resolution</u> is related to the repeat frequency with which a system can acquire images of the same location. Although this may be fixed for a satellite-based acquisition system, environmental factors such as cloud cover limit the availability of usable images.

Although the above are generally associated with optical sensors similar properties exist for microwave or synthetic aperture radar systems.

Ancillary data

Ancillary data can give additional information not available from EO such as geology or the location within the landscape of different vegetation types. For the identification of many specific features it is necessary to know "where in the landscape" you are, for example coastal grassland is only found in areas with a marine influence. Beyond very simple classification such as forest, urban or artificial surface, water, grass and arable it is necessary to have this type of locational data available.

Often there is not enough information in EO data to allow the separation of habitats by their spectral values alone. By including ancillary data, valuable information about the spatial context of the area being mapped is provided. Although many ancillary datasets are available, they should be assessed for their suitability for integration into the mapping process and comparison with the available EO data. Issues for consideration include;

- spatial resolution (scale),
- information content,
- currency (the date of the information stored in the data and amount of time it will remain relevant),
- quality (how well the data was collected and created)
- and traceability (where the data originated).

The most frequently used ancillary datasets in support of habitat mapping are outlined below with Annex I habitat examples for illustration:

- **Geology**: indicating nature of the underlying solid rock
    - H8120 - Calcareous and calcshist screes: Scree from base-rich rocks including limestone, calcareous-schists and the more basic igneous rocks, such as serpentine and basalt with some pioneer vegetation, defined by geology
- **Soils**: water and nutrient holding capacities, substrate types, composition etc.
    - H3160 - Natural dystrophic lakes and ponds: On or surrounded by peat based soil. High concentration of humic substances.
    - H6410 – *Molinia* meadows on calcareous, peaty or clayey-silt laden soils.
- **Elevation / slope / aspect**: often determining the biogeographical range and the geomorphological context i.e. steep valley side, plateau etc.
    - H4060 - Alpine and Boreal heaths: found at high elevations and in northern latitudes around and above the presumed natural tree-line.
    - H1220 - Perennial vegetation of stony banks: Mean high-water spring tide level. Also detailed elevation data to determine the ridge and troughs and the potential location of this coastal habitat.
- **Hydrological features**: describing water levels / tidal ranges, water quality, proximity to water bodies

- H1210 - Annual vegetation of drift lines: This habitat type occurs on deposits of shingle lying at or above mean high-water spring tides.

Other more specific ancillary data which may be used to constrain certain analyses include:

- Field boundaries (e.g. for identifying fields and field margins)
- Tidal boundaries (e.g. for delineating coastal habitats)
- Urban zonation (e.g. for "masking out" areas that are not of interest)
- Exposure (e.g. for sub-montane habitats)

Detailed description of the Tiers of the Crick Framework

Adopting an EO based perspective of habitats - the Crick Framework

Earth Observation data and analysis techniques are able to differentiate some vegetation types and habitats by identifying reflectance features that are shown up by different spectral bands or combinations of bands. Different types of surface require different amounts of EO data for them to be identified. The ease of separating out habitats varies with habitat complexity and spatial scale, as well as the need for specific contextual information. The tier system organises the information needed to identify habitats into a hierarchical system. The amount of data and spatial resolution of data required, increasing with the tiers, until the features cannot be identified remotely. This classification of habitats is described in more detail below.

Some vegetation complexes / communities and habitats can be readily identified from EO data alone, as they have distinct spectral properties that allow them to be separated from other habitats. With others more information is necessary, consider the following examples:

- Occasionally two habitats will have similar spectral features but different locations in the landscape, e.g. one is only found on steep slopes and another on wetter flat land. In this case the habitats can be distinguished using spectral data with ancillary datasets.
- Where habitat features cover small areas (e.g. patches of scrub), a fine spatial scale of imagery is needed.

In other cases, the difference in growth form between early spring and high summer can be used to distinguish one vegetation community from another.

The table below describes each tier of the Crick Framework system in more detail.

Tier	Heading	General Description	Details and examples
Tier 1	**Likely to be identified solely using EO**	Easy to identify solely by spectral difference at a broad scale	Only very homogenous land cover types such as water, bare ground and coniferous woodland. This category does not contain any BAP priority, or Annex I habitats
Tier 2	**Likely to be identified using multispectral EO and ancillary data**		
	2a Likely to be identified using HR EO together with ancillary data	These habitats require spectral information plus contextual information such as their location in the landscape or characteristics which cannot be assessed remotely.	Habitats that have significant spectral differences but require additional contextual information to help confirm their occurrence.
	2b Likely to be identified using VHR EO together with ancillary data		Plant communities occur at fine spatial scales and therefore need data with a pixel coverage of ~1 metre (e.g. coastal habitats).
	2c Likely to be identified using EO data (in some cases VHR) but ID dependent on good soils or geological data		Plant communities such as species-rich grasslands, which require soils or geology information at a fine enough scale to distinguish calcareous, neutral and acidic areas.
	2d Unlikely to be identified using standard EO classification approaches but can be inferred from soft classifications such as fuzzy sets (see glossary for more information)		Plant communities that are defined by their mosaics of species and ecotones within a land use parcel, such as purple moor grass and rush pasture BAP priority habitat.
	2e Likely to be identified using EO plus detailed information about vegetation structure (LiDAR)		Habitats are very structurally distinct, such as flushes, which could be distinguishable with the inclusion of LiDAR data.
Tier 3	**Likely to be identified using EO and ancillary data but also dependant on the availability of time series imagery**		
	3a Likely to be identified using EO together with ancillary data	As tier 2 habitats but also have a strong cyclical temporal change / phenology therefore requiring multi-season or tide-dependent imagery as well as contextual information	Tier 3 includes communities where there are time critical features, such as dead litter in winter and strong growth in summer, for example many grassland and woodland habitats.
	3b Likely to be identified using VHR EO together with ancillary data		
	3c Likely to be identified using EO data (in some cases VHR) but ID dependent on good geological data		
Tier 4	**Currently unlikely to be determined using EO**		
	4a Habitats distinguished by low frequency or small features	Can determine the type of habitat at a broader level but specific habitats cannot currently be determined using EO supported by ancillary data as they are defined by low frequency or small features or are hidden from above for most of the year	Habitats are only distinguishable from other much more common plant communities by the inclusion of indicator species which are small in size and occur throughout the sward with low frequency; for these habitats field survey is crucial. However, EO can play an extremely valuable role in identifying the broad habitat or identification of areas likely to contain this habitat.
	4b Habitat hidden from above for most of the year		Communities are often occluded from above either by vegetation or by the tide e.g. eutrophic water bodies or sub-tidal vegetation.
Tier 5	**Cannot be identified using EO**	Completely obscured from above therefore cannot be identified using EO.	Habitats such as those within caves cannot be identified from above, therefore field survey is crucial.

To assess how well habitats can be identified by earth observation, it is first necessary to break down the characteristics of the habitat and determine which of the characteristics are amenable to measurement using earth observation.

Some of the reflectance features of vegetation that are used to identify habitats relate to properties or characteristics such as:

- the ratio of living plant material to dead plant material;
- the productivity of the vegetation;
- the wetness of the vegetation;
- the amount of 'woody' material;
- the number of plants with horizontal fleshy leaves as opposed to thin upright leaves etc.

These features are used to describe plant communities and may give an indication of the condition of specific habitats.

The systematic evaluation of Annex I and BAP habitats undertaken suggest that EO and ancillary data have much to offer in the surveillance and monitoring of habitats when combined with geoinformatic techniques and ecological knowledge. However, in a number of cases the habitat descriptions do not have sufficient detail or not specific enough to fully assess the potential of EO.

The following table sets out the headings against which these habitats are further analysed, with a description of what information will go in the table and examples. The interpretation of this analysis has led to the classification of each BAP priority and Habitats Directive Annex I habitat into Crick framework tiers.

No.	Term	Sub term	Description	Valid values / examples
1.1	**Habitat**	**Name**	ID and name from the nomenclature e.g. BAP Priority Habitats, the EU Annex I Habitats, etc.	"Arable field margins", "H6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)", etc.
1.2		**Description**	A short description of the habitat	Use common terms to describe the habitat that can be clearly understood.
1.3		**Source**	Source of habitat definition	e.g. BAP Priority Habitat, HSD Annex 1 habitat
2.1	**Biogeography**	**Geographical range / known locations**	Extent / range over which the habitat is found and examples of known locations	Could be a range of geographic representations such as UK, Scotland, Kent, southern Britain etc.
2.2		**Scale**	Size and pattern of habitat blocks	Does it appear as extensive blocks or individual plants?
2.3		**Variation**	Spatially discrete subtypes	How it changes across the UK
3.1	**Habitat character**	**Dominant species**	The dominant species which make up the habitat.	List of one or two key species
3.2		**Dominant substrate**	The dominant substrates which make up the habitat.	List of one or two key substrates.
3.3		**Dominant structure / features**	The dominant structure / features which make up the habitat.	List of one or two key structure features, e.g. grassland with scattered scrub, arable fields.
3.4		**Community characteristics**	How questions 3.1, 3.2 and 3.3 interact with the surrounding landscape, and each other, including species / substrate mixing, structure within patches, species variation	e.g. mosaic or discrete feature; single or multi-species, evenly or unevenly mixed, many or few species mixes.
3.5		**Temporal seasonal change**	Indication of any seasonal change	e.g. Large seasonal variation in habitat may be important for discriminating habitat from surrounding features i.e. can be found using the difference between Spring and Summer imagery
3.6		**Temporal lifecycle change**	Differences in appearance of the habitat at different points within its lifecycle, (not linked to a seasonal change)	e.g. Where the management / succession greatly alters the appearance of the habitat over the lifecycle of the habitat, not linked to seasonal change
3.7		**Contextual information**	Landscape controls. Conditions required for this habitat to be mapped. What must be present for it to occur? What must not be present?	e.g. only above certain elevations, along rivers etc.
3.8		**Conditional factors**	Mix with other habitats with similar features. Common confusions.	What / when / how much of an issue the confusion might be.
4	**EO datasets required**		Details of the minimum requirements for the EO data, spatial, spectral and temporal, to meet the habitat character defined above	A list of specifications or specific systems.
5	**Ancillary datasets required**		Details of the minimum requirements for the ancillary data to meet the habitat character defined above	A list of specifications (e.g. elevation on a 10 m support) and / or actual data sets (e.g. NEXTMap GB).

No.	Term	Sub term	Description	Valid values / examples
6	**Method**		A description of the methods that have been applied successfully or could potentially be applied.	E.g. Indices, pixel-based, object-based, statistical, rule-based, supervised / unsupervised, etc.
7.1 7.2	**Accuracy**	**Mapping accuracy** **Variability**	How accurately can this habitat be mapped? Level of confidence or spatial variability in the accuracy result.	Means of assessment, score from published work
8	**How far can EO go?**		A summary of the role the EO would play.	E.g. Is EO is the key driver or just a support, can a more generalised habitat class be derived?
9	**Level of definitions**		Indicator of confidence, specificity of habitat description and understanding of the habitat interactions	Red - all pretty vague, amber - partially defined, green - fully defined, very specific
10.1 10.2	**Habitat Tier**	**Original Tier** **New Tier**	In the Crick table 2a etc. After review	Code from first version of the framework Revised code
11.1 11.2 11.3 11.4	**Status**	**Level of implementation** **Potential** **Common problems** **References**	Evidence or not? Brief description of how the habitat may be mapped operationally EO issues to be overcome Links to actual uses where possible	E.g. Operational (O), Near Operational (NO), Professional belief (PB) I.e. things that do not work
12	**Features pertaining to good condition**		Extension of the table to be added.	
13	**Mechanisms for monitoring**		Requirements for a fully operational monitoring system	E.g. Ownership, governance, resources etc.

Possible approaches to the framework

Examples of how a user may approach the Crick Framework

Data: Unknown amount of data | Some data | Lots of data

Habitats: Unknown habitat focus | Looking at a particular habitat | Looking at lots of habitats

Unknown habitat focus – Some data / Lots of data

A user has existing data and wishes to know what they can do with it.

Determine the general characteristics of the available data

Compare these to the tiers to identify which tier of habitats are mappable

Find all the habitats with that tier or lower in the habitat characterisation table

Compare this habitat list to those required.

Evaluate the available approaches and select the most appropriate given the available equipment, expertise and experience.

A user wishes to map a particular habitat and will undertake a new survey

Find the required habitat in the habitat characterisation table

Extract the specifications of the required EO and ancillary data and procure them

Evaluate the available approaches and select the most appropriate given the available equipment, expertise and experience

A user wishes to map a particular habitat with existing data

Find the required habitat in the habitat characterisation table

Compare the available EO and ancillary data to the requirements in the table

- If sufficient → Evaluate the available approaches and select the most appropriate given the available equipment, expertise and experience
- If insufficient → Re-evaluate the availability of data, or how far current data availability can get you towards the habitat

A user wishes to map multiple habitats

For each of the required habitats extract the tier code from the habitat characterisation table.

For the habitats with the highest tier code extract the specifications of the required EO and ancillary data

- If data is available and within budget → Procure the data → Evaluate the available approaches and select the most appropriate given the available equipment, expertise and experience.
- If data is not available or out of budget → Re-evaluate the availability of data, which habitats are going to be mapped or how far available data can get you towards the habitats in the higher tiers

Glossary

Pre-processing

Radiometric image preparation

This process removes the effects of atmospheric particulate (dust and aerosols including water vapour) and converts image data into units of surface reflectance (%). This removes some variation allowing comparison with other images.

Ortho-rectification

Ortho-rectification is the process of removing geometric distortion from a spatial dataset, by aligning it to features within another spatial data source. Ortho-rectification of imagery should use the highest specification topographic reference or Digital Elevation Model (DEM) available. When multiple datasets are combined within an analysis, it is essential that they are not distorted; otherwise the boundaries of features can be confused.

Topographic correction

In mountainous areas there is a strong influence of the topography on the signal recorded by optical satellite sensors, which often causes shadows on north facing slopes and glare on south facing slopes. The same land cover in each situation will appear differently and can significantly reduce the accuracy of any image classification or the spatial consistency of an analysis. Topographic correction of the data should be undertaken to minimise these differences in illumination as a function of slope and aspect.

Preparation of ancillary datasets

Contextual layers and pre-existing mapping data can be included in the stack of data to be analysed. These datasets need to be checked for alignment with the other imagery and corrected if necessary. The features of interest may need aggregating or re-coding to fit in with the system of classification required.

Quality assessment of input data

The user must always consider the fitness-for-purpose of the imagery. This includes the suitability of the timing of when the images were captured, the spatial resolution of the imagery and whether the image is clear enough from cloud or haze to allow the feature of interest to be seen (by the user).

Is the image recent enough to represent the feature of interest and at a suitable time of year if the feature varies throughout the year with seasonal growth cycles or shadows in mountainous areas? Spatial suitability is also an important consideration, the resolution of the imagery must be smaller than the features of interest. The more pixels representing each feature, the better the information about the feature. However the higher the spatial resolution of the imagery, the larger the size of the dataset, which makes it more time consuming and has processing implications.

Masking can be used to remove any areas of the image covered by cloud, or cloud shadow on the ground. An optical reflectance signal from the ground cannot pass through cloud and is therefore hidden from the sensor by the cloud. Cloud shadow causes the vegetation signal to be obscured. The areas of the image affected need to be considered differently or omitted from any classification.

Analysis

Indices

Indices are combinations of spectral bands which can give additional information. The Normalised Difference Vegetation Index (NDVI) is one of these indices, it summarises the relative red and NIR responses of the ground and is related to vegetation productivity.

Spectral unmixing

In a multi-spectral image, where the information contained within a pixel is from a homogeneous area, the values measured can be considered as a “pure” example of the feature of interest. For example a large coniferous forest, considerably larger than the spatial resolution, will provide numerous pure coniferous pixels. However, this is not always the case and the information contained within a pixel may represent a number of ground components. Linear spectral unmixing (also referred to as spectral mixture analysis) is a method for estimating the proportion of each pixel that is covered by a known set of features. It involves collecting endmember spectra, which are pure examples of each known feature of interest, often interpreted from the image (for example areas of shade, heath or water etc.). These can give an estimate of the relative amount (fractions) of these features within each pixel and can also be related to objects (see segmentation below) later on the classification process.

Segmentation

Segmentation is a process that divides the image up into objects, similar adjacent pixels are grouped together. The objects possess size, shape, and geographic relationships with the real-world features they describe.

Classification

Supervised / Unsupervised classifiers

Supervised and unsupervised classification methods use the spectral information present within each pixel or object. Unsupervised classifications look at the entire image and identify groupings present in the spread of image values, these groupings are then associated with land cover classes by the user. Supervised classifications use a number of known sites within the image to define a range of pixel values that classify particular land cover classes, these are used to find other sites with the same characteristics across the rest of the image.

Object-based and Rule-based classifiers

Object Based Classifiers analyse the image by groups of pixels or segments with similar characteristics. The characteristics of the whole object are used for the classification. Rules and thresholds can be used for discriminating between variables in the classification process allowing different image objects to be separated into groups based on membership to a described class and spatial relationships.

Fuzzy classifiers

The ecological boundary between two vegetation types may not be a hard line, but a soft boundary. Fuzzy classifiers compare features, in relation to how closely they relate to the 'standard' or 'ideal' set of features. An example of this may be the ecotone between dry heath and wet heath, within a small area dry heath, wet heath or a combination of the two could be present.

Statistical classifiers

The Maximum Likelihood Classifier (MLC) is a common statistical classifier. Sample areas are selected as training data for each feature to be mapped. The maximum likelihood process computes the statistical properties of these features and the statistical characteristics which separate feature types and builds an identification model. Each part of the image is then tested against this model to see which class it most probably belongs to.

Nearest Neighbour classification is a form of supervised statistical classification. Each area of interest is identified on the image and new features are classified by identifying the nearest feature in terms of "mathematical distance" to the input data.

Support vector machines are supervised learning models that analyse data and recognize patterns. These models are a representation of the data as points in space. New examples are then mapped into that same space and are classified based on where they fall.

Neural Networks are non-linear statistical data modelling tools usually used to model complex relationships between inputs and outputs or to find patterns in data, and can be used for land cover classification by finding patterns in the input data.

Random forest is an ensemble statistical classifier that includes the creation of many decision trees, which are independent of each other and each constructed using a small representative subset of the input data. The output of the classification is dictated by the most common result from all the decision trees.

Integration of ancillary data

Geoinformatic processes allow many datasets to be combined and analysed within one system. Multi-step systems and rules can be used to integrate existing data to exclude or target areas for different features of interest. This type of incorporation of knowledge allows for a better description of the natural environment within the classification system.

Evaluation

Validation

Validation is an important stage in the creation of earth observation products, testing the accuracy or fitness for purpose of the data products. This can occur at the end of the process or within the iterative process of developing and refining a classification system.

Qualitative-systematic accuracy reviews manually compare the classification output using expert knowledge, imagery and other existing map sources within a number of sub-regions.

A number of classification algorithms and fuzzy mapping systems produce a measure of confidence for each pixel or object that quantifies how closely a classified observation matches the examples provided in the training set or membership to a described class. These confidence values can be mapped themselves or used as classification thresholds and for describing vegetation within other habitat classification systems and for ecotones.

Statistical estimates of accuracy allow for the identification of classification errors. This can be assessed by comparing the classification against field data or other sources of land cover data. Random sampling of these comparison points is ideal for unbiased assessment, however class distribution and the availability of resources mean that this is not always suitable, in which case spatially limited samples will give good indications of the types of errors present.

Geographically weighted methods of accuracy are starting to emerge where the spatial variation of errors can be identified. The distribution of land cover classes have a large impact on these measures and must be considered during interpretation of the results.

References referred to in the tables

Brown, K., Hambidge, C., and Matthews, A., 2003, The development of remote sensing techniques from marine SAC monitoring. *English Nature research report 552*.

Brown, I., Gimona, A., Poggio, L., Castellazzi, M., Aitkenhead, M. & Brooker, R. (2011). Inventory of Upland BAP and Annex I habitats – Developing habitat inventories. Scottish Natural Heritage Commissioned Report No. 494

Chapman, D., Bonn, A., Kunin, W. and Cornell, S., 2010, Random Forest characterization of upland vegetation and management burning from aerial imagery. *Journal of Biogeography*. **37**, 37-46.

Friess, D.A., Spencer, T., Smith, G.M., Möller, I., Brooks, S.M. and Thomson, A.G. (2012) Remote sensing of geomorphological and ecological change in response to saltmarsh managed realignment, The Wash, UK. International Journal of Applied Earth Observation and Geoinformation, 18, 57–68.

Hambridge, C. and Petchey, S. (2010) Dartmoor National Park Authority Remote Sensing Pilot Project, Environment Agency Geomatics Group, Bath.

Hill, C.T., Downes, R.H.E. & Harfoot, A. J. P. 2006. Maritime Cliff and Slope Inventory 2004/2005. Natural England Research Reports, No NERR003.

Keyworth, S., Jarman, M. and Medcalf, K., 2009, (1) Assessing the Extent and Severity of Erosion on the Upland Organic Soils of Scotland using Earth Observation - A GIFTSS Implementation Test.

Lucas, R., Medcalf, K., Brown, A., Bunting, P., Breyer, J., Clewley, D., Keyworth, S. and Blackmore, P., 2011, Updating the Phase 1 habitat map of Wales, UK, using satellite sensor data, *ISPRS Journal of Photogrammetry and Remote Sensing,* **66** (1), pp81-102.

Medcalf, K., Cameron, I., and Turton, N. 2012. Remote sensing methodology: Fieldwork and additional rule base development for Scottish upland habitats. *Scottish Natural Heritage Commissioned Report No.* - 514

Medcalf, K., Jarman, M and Keyworth, S., 2010, Provision of assistance to the Environmental Protection Agency in establishing suitability of rule-based feature extraction and classification processing methods to a habitat mapping solution for a study area in Ireland. *Report for the EPA of Ireland.*

Medcalf, K., and Williams, J., 2010, Tweed Aerial Survey Phase 2 Aerial Photography Interpretation Land Cover Classification & Habitat Mapping. *Scottish Borders Council & Tweed Forum Consortium*.

Milton, E J, Hughes, P D, Anderson, K, Schulz, J, Lindsay, R, Kelday, SB, and Hill, C T. Remote sensing of bog surfaces *JNCC Report No. 366.*

Morton, D., Rowland, C., Wood, C., Meek, L., Marston, C., Smith, G., Wadsworth, R. and Simpson, I.C. (2011) Final Report for LCM2007 - the new UK Land Cover Map, CS Technical Report No 11/07. Centre for Ecology & Hydrology (Natural Environment Research Council).

Murdock, A., Hill, A.N., Cox, J. & Randall, R.E. 2010. *Development of an evidence base of the extent and quality of shingle habitats in England to improve targeting and delivery of the coastal vegetated shingle HAP*. Natural England Commissioned Reports, Number 054.

Murdock, A.P., Hill, C.T., Randall, R. and Cox, J. (2011). Inventory of coastal vegetated shingle in Scotland. GeoData Institute, Scottish Natural Heritage Commissioned Report No.423

Petchey, S., Brown, K., Hambidge, C., Porter, K. and Rees, S. (2011) Natural England / Environment Agency Collaboration: Operational Use of Remote Sensing for Environmental Monitoring Joint Report.

Phelan, N., Shaw, A., and Bayis, A., DRAFT FINAL REPORT. The Extent of Saltmarsh in England & Wales: 2006-2009. Report for the Environment Agency.

The GeoInformation Group (2011). Inventory of upland BAP and Annex I habitats –Methodology for mapping upland habitats*. Scottish Natural Heritage Commissioned Report No. 495*

Thomson, A. G., Fuler, R. M., Yates., M. G., Brown, S. L., Cox, R., and Wadsworth, R.A., 2003, The use of airborne remote sensing for extensive mapping of intertidal sediments and saltmarshes in eastern England, *International Journal of Remote Sensing*, **24**, 13, pp2717-2737.

Towers, W., Hall, J., Hester, A., Malcolm, A., and Stone, D., 2004, The potential for native woodland in Scotland: the native woodland model. A report for Scottish Natural Heritage.

Yallop, A., Clutterbuck, B. and Davies, S., 2008, The application of remote sensing to identify and measure changes in the area of moorland which has been burned as part of a management strategy. Report for British National Space Centre and Natural England under the GIFTSS initiative. Cranfield University: BNSC/ITT/0S. 01 .O4l/116C Final Report.