



**JNCC Report  
No: 469**

**Spatial framework for assessing evidence needs for operational ecosystem approaches**

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## Executive Summary

The ecosystem services approach is a key element of planning for sustainable development. This report outlines the results of a study undertaken for the Joint Nature Conservation Committee (JNCC) to develop the use of spatially-based biodiversity data for the delivery of work on ecosystem services. The project demonstrates the process and outcomes of taking a pragmatic approach to assessment of ecosystem services, with emphasis placed on utilising the large body of data already available to inform policy decisions at national, regional and local levels. Using these datasets, an ecosystem service 'spatial framework' has been developed to assist users and demonstrate what is currently possible when it comes to mapping and modelling of ecosystem services. This research builds on earlier projects for Countryside Council for Wales (CCW) and Bridgend County Borough Council undertaken by Environment Systems Ltd (Medcalf & Small, 2012).

This project takes the UK NEA descriptions of environmental goods and services and further analyses these in terms of current data and knowledge about each service, for each ecosystem. This project extends and expands on the work of the UKNEA and the Welsh NEF, considering how the knowledge and understanding within the NEF can best be mapped using existing datasets, so that policy makers and others can begin to appreciate the spatial extent of the ecosystem services presented.

The resulting framework sets out the data and information about the relevant habitat that will be important in helping to quantify and map its role in ecosystem service mapping. Behind the rationale of the work is the basic premise that every parcel of land affects the delivery of many ecosystem services in some way, even if this contribution is only small (or has a negative effect on that service). The framework shows how to link the physical and biological characteristics of habitats and the major ecosystem services that they provide.

Using case study areas from around the UK, the framework approach was tested using selected terrestrial and marine habitats, firstly to establish the validity of the approach and then to ensure that it was applicable for a range of habitats in different biogeographical zones and in areas with differing data availability. These case study areas were chosen with 'transferability' in mind, so that the habitats and services studied produced results which are widely applicable geographically.

The project identifies areas of the country where ecosystem services knowledge is good, with readily available data and complete spatial coverage. In other areas, where either knowledge or data was partially complete ecosystem services may still be modelled, although with less certainty, and with a wider margin for error. The process has identified critical knowledge gaps and uncertainties in this existing information, as well as strengths of current data for this style of assessment.

In approach, the framework provides a logical and transparent process for evaluating the role of habitat information in delivering ecosystem services; this can be extended beyond the studied systems to other habitats and other ecosystem services. Current understanding of the relationships between terrestrial habitats and ecosystem services is generally good for most regulating, provisioning and supporting services, although less so for cultural services. Understanding for marine habitats is generally under developed.

The project has shown the wide range of terrestrial datasets currently available for evaluating ecosystem services, although data availability is generally less advanced for cultural services. The differences that exist in quality, resolution and scale are further illustrated by the case study mapping.

As work in this area develops, there is a need for more consistent and compatible data across wider areas of the terrestrial landscape to support decision-making at a variety of spatial scales. Consideration of fitness-for-purpose is also important; high quality data is not always required, especially for strategic purposes, but for more local practical planning purposes high quality high resolution data provides a more effective tool.

This report is accompanied by a User Manual and a list of datasets considered suitable for ecosystems services modelling.

# CONTENTS

<b>Glossary</b> .....	<b>1</b>
<b>1 Introduction</b> .....	<b>1</b>
1.1 Background to user needs .....	1
1.2 Project objectives .....	1
1.3 Ecosystem approach.....	1
1.4 Ecosystem services.....	2
1.5 Links to the UKNEA.....	2
<b>2 Project Approach</b> .....	<b>4</b>
2.1 Rationale .....	4
<b>3 Development of the Framework</b> .....	<b>6</b>
3.1 Design .....	6
3.2 Choice of services .....	7
3.3 Choice of habitats studied .....	8
3.4 Framework structure .....	8
<b>4 Testing the framework concept - mapping and modelling ecosystem services</b> .....	<b>11</b>
4.1 Choice of study areas.....	11
4.2 Mapping and modelling ecosystem services.....	12
<b>5 Evaluation - Application of the framework approach</b> .....	<b>18</b>
5.1 Scoring of the Tiers for Grassland, Woodland and Marine Habitats .....	18
5.2 Evaluation of individual ecosystem services .....	24
5.3 The Challenges of mapping ecosystem function in the marine environment .....	31
<b>6 Forward Look - progressing the spatial framework approach</b> .....	<b>39</b>
<b>7 References</b> .....	<b>42</b>
Appendix 1 - Framework, guidance documents and other outputs.....	47
Appendix 2 – Ecosystem Service Maps.....	48

## Glossary

Adaptive management	A structured, iterative process of robust decision making in the face of uncertainty, with an aim to reducing uncertainty over time via system monitoring.
Agricultural Land Classification	A data set which splits the agricultural land into five cover classes, class one being the most productive highest value land and class five upland habitats only suitable for extensive grazing.
AP	Aerial Photography
Convention on Biological Diversity	An international legally binding treaty. Its objective is to develop national strategies for the conservation and sustainable use of biological diversity.
DTM	Digital Terrain Model – land surface model
Functioning ecological network	Habitat patches suitably linked together forming a network allowing free movement of species between them.
Geo-informatic	The ability to model and statistically evaluate spatial data.
GMES	Global Monitoring for Environmental Security is a European Space Agency project.
Habitat connectivity	The degree to which the landscape facilitates animal movement and other ecological flows.
Habitat network	This refers to a series of habitat patches which are linked together by suitable land cover types
HR	High resolution data – that is data with a fine spatial mapping scale
Landscape permeability	Landscape permeability refers to how freely organisms can move through a landscape
MasterMap	Ordnance survey mapping product
Proxy	Data to represent information which are not directly measurable.
RGB	Red Green Blue used to describe information contained within aerial photography
Rule-base	A rule-base is an ‘expert system’ that uses ‘scientific expert knowledge’ to come to a set of specific decisions.
VHR	Very high resolution data – that is data with a very fine spatial mapping scale

# 1 Introduction

## 1.1 Background to user needs

JNCC, together with other stakeholders, have identified a requirement to develop the use of spatially based biodiversity data for the delivery of work on ecosystem services. Biodiversity is both a key constituent of the major habitats of the UK, as well as a key target for enhancement and improvement under current EU and UK economic and social development strategies. The ecosystem services approach is a key element of planning for sustainable development. The requirement is for an approach, in the form of a spatial framework that sets out a logical process, includes current knowledge and makes full use of available biodiversity and habitat-related data to assist ecosystem services mapping.

Previous work on the role of remote sensing in identifying habitat attributes has shown that a spatially tiered framework<sup>1</sup> provides a logical process driven means of setting out information and knowledge that users can draw on and that is not prescriptive in nature. A similar approach was envisaged for assisting users with identifying the attributes of habitats and their importance in delivering ecosystem services. The aim is to tie the thinking and evidence together in a way that illustrates and compares the process across different habitats, rather than create a narrowly defined tool.

## 1.2 Project objectives

The overall project aim is:

- To aid the practical quantification and valuation of ecosystems services for a range of decision making processes at local, landscape and country levels and in doing so inform on-going development of UK-level biodiversity data collection surveys and schemes and data access provision.

The spatial framework approach should contribute to the objective of facilitating users:

- To describe the biophysical characteristics occurring within a landscape
- To make links between the physical and biological characteristics of habitats and the major ecosystems services being provided;
- To identify practical and appropriate ways in which habitat (and other biodiversity) data can be used to identify and understand ecosystem service provision;
- To identify ways in which habitat data can be used to describe landscape characteristics and understand how this varies spatially;
- To understand the affect the condition of habitats and the way they are managed has on ecosystem service delivery in different landscapes.

## 1.3 Ecosystem approach

The ecosystem approach emerged as a central principle in the implementation of the Convention on Biological Diversity (CBD, 2004) which strongly focuses on the holistic and integrated management of land, water and living resources to promote conservation and sustainable use. The ecosystem approach provides a mechanism which can be used to look at whole ecosystems during the decision making process, and for valuing the ecosystem services they provide, ensuring that society can maintain a healthy and resilient

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<sup>1</sup> Medcalf K. A., Parker J.A., Turton, N., and Finch C (2011) Making Earth Observation Work for UK Biodiversity Conservation – Phase 1. PART A - Final report. *Report to the JNCC and Defra.*

natural environment for current and future generations. The ecosystem approach focuses on the three objectives of the Convention:

- Conservation of biological diversity;
- Sustainable use of its components;
- Fair and Equitable Sharing of benefits arising from genetic resources.

Implementing the ecosystem approach requires the consideration of adaptive management, in order to be able to respond to such uncertainties which arise when dealing with the complex nature of ecosystems and the absence of complete knowledge or understanding of their functioning (CBD, 2004). In the context of sustainable development, decisions need to be made within environmental limits and at an appropriate spatial scale, whilst recognising the cumulative impacts of decisions. This project contributes to the ecosystem approach by helping to provide and develop the evidence base on which decisions can be made.

## 1.4 Ecosystem services

Ecosystem services are a fundamental part of the ecosystem approach. The environment is our life support system, important for its intrinsic value, as well as providing water, producing our food, energy and timber, sustaining our wildlife and creating employment and income worth billions of pounds (TEEB, 2010). Ecosystem Services (ESs) are the multiple benefits humans obtain either directly or indirectly from these ecological systems and include services pertaining to food provision, carbon sequestration, water regulation and many others, all of which are essential for human well-being (Millennium Ecosystem Assessment (MEA), 2005; Troy & Wilson, 2006). The MEA is a widely accepted conceptual framework which categorised ecosystem services into four broad categories (Table 1).

**Table 1 Ecosystem Services Categories (MEA, 2005)**

Service Categories	Examples of specific services
Provisioning	Food, fibre, fuel, bio-materials and clean water.
Regulating	Climate regulation, flood protection, pollination, air/soil/water quality
Cultural	Education, cultural heritage, sense of place, health, recreation, tourism and aesthetic value
Supporting	Soil formation, nutrient cycling, water cycling and primary production

The UK's existing ecosystems are the product of continuous interactions between people and their surrounding environments, driven by societal changes e.g. demographic, economic, socio-political, technological and behavioural. These all influence our demand for goods and services and the way we manage our natural resources. The benefits we derive from the natural world are critically important to human well-being.

## 1.5 Links to the UKNEA

The UK has been at the forefront of developing an approach to identifying, mapping and quantifying ecosystem services. The National Ecosystem Assessment (NEA)<sup>2</sup> published in June 2011 was the first independent assessment of the state and trends in the UK's ecosystems and the benefits they provide to society and the economy. The NEA provides an evidence base of the services that nature provides, how these have changed over the

<sup>2</sup> <http://uknea.unep-wcmc.org/>

past decades, prospects for the future and the benefits of these to society. It reports the benefits that the habitats of the UK provide to society and continuing economic prosperity.

In Wales the Natural Environment Framework (NEF) focuses on managing the Welsh environment as a whole rather than focusing on separate parts. The ecosystem approach to managing resources is a key element of this, and the mapping of ecosystem services, together with the identification of synergies and trade-offs is critical to ensuring the ecosystem approach has a practical application at local level. Within Scotland, the Scottish Government have issued guidance on the importance of applying an ecosystem approach to land use.

This project extends and expands on the work of the UKNEA and the Welsh NEF. It takes the UK NEA descriptions and further analyses their environmental goods and services in terms of our current data and knowledge about each service for each ecosystem. This work also considers how the knowledge and understanding within the NEF can best be mapped using existing data sets so that policy makers and others can begin to appreciate the spatial extent of the ecosystem services presented.

## 2 Project Approach

### 2.1 Rationale

This project seeks to identify attributes of habitats which are important for, and influence the role of, those habitats in delivering ecosystem services. The framework needs to set out data and information about the relevant habitat that will be important in helping to quantify and map its role in ecosystem service mapping.

Behind the rationale of the work is the basic premise that each parcel of land affects the delivery of many ecosystem services in some way, even if this contribution is only small (or has a negative effect on that service). Whilst the focus of this work is on the delivery effects in certain key habitats, the same principles apply to all land.

The influence that a parcel of land (the basic area on which a habitat sits) exerts on the delivery of an ecosystem service depends on four main factors:

1. **What it is** – i.e. the land cover or habitat type and its condition
2. **What it is on** – i.e. the geology and soil type underlying the land
3. **Where it is** – i.e. the landscape context of the land (e.g. on a steep slope or valley bottom next to a river or proximity to an urban area)
4. **How it is managed** – i.e. the management regime, which in some cases is influenced to differing degrees by statutory or other designations imposed upon the site or voluntary agreements that specify aspects of management (e.g. intensive or extensive or little active management or designation as a SSSI or AONB, schemes such as Woodland Grant Scheme, agri-environment schemes)

From these four factors the framework identifies **three evaluation criteria**:

- a) The overall **importance** of the habitat in helping to deliver each ecosystem service
- b) The general state of **knowledge** about relationships between the habitat and each of the services
- c) The quality / availability of the **data** that exists to help quantify and map these services

The framework approach used for this project produces a 'Tier' table using these three evaluation criteria (importance, knowledge, data) with three levels of detail (illustrated in Table 2), assessing the effects of the focus habitat's biological / physical characteristics on delivery of each service.

For example, for a habitat scored as Tier 1(i)a:

Importance score = 1	The habitat is <b>very important</b> for provision of the specific ecosystem service that is of interest;
Knowledge score = i	There is <b>good knowledge</b> about the relationship of the habitat and the way the service operates; and,
Data score = a	There is <b>good data</b> available to begin the process of mapping.

**Table 2 Tiers of the spatial framework**

Example Habitat and Ecosystem Service										
Tier Importance of habitat for delivering the Ecosystem Service		Knowledge and scientific understanding of how the service operates								
		Good knowledge (i)			Some Knowledge (ii)			Little or no Knowledge (iii)		
<b>1</b>	The habitat has High Importance for the ecosystem service	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)
<b>2</b>	The habitat has Moderate Importance for the ecosystem service	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)
<b>3</b>	The habitat has Low Importance for the ecosystem service	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)

Note: The tier allocation may change in future as ecosystem understanding, data quality and data availability improves.

The use of a Tier table structure provides a logical way of highlighting existing gaps in knowledge and data, and a method of relating these to ecosystems services present in the studied habitats. This then provides a good indication of where further information would be needed for informed use. Tier scores are also a useful tool to include with spatial maps of the services, to indicate where knowledge is less certain and data may need to be used with caution or supplemented by further studies. Further explanation of the role of Tier tables in the spatial framework is provided in section 4.

### 3 Development of the Framework

The project framework needed to be able to logically set out the currently-available data and information about the characteristics of the focus habitats, and how these characteristics relate to the provision of ecosystem services in that habitat. This will help to clarify the potential and role of habitat data in quantification and mapping of ecosystem services. While the framework is not intended to be a comprehensive decision tool, it should be a guide to support decision-making at various levels, and enable more rapid evaluation of the information available for assessments.

There were three stages in the framework development:

1. Design
2. Testing
3. Evaluation

#### 3.1 Design

The whole process is designed to be iterative, able to be amended and further developed as new understanding, knowledge and data becomes available.

The main steps in the process of developing the framework are shown below.

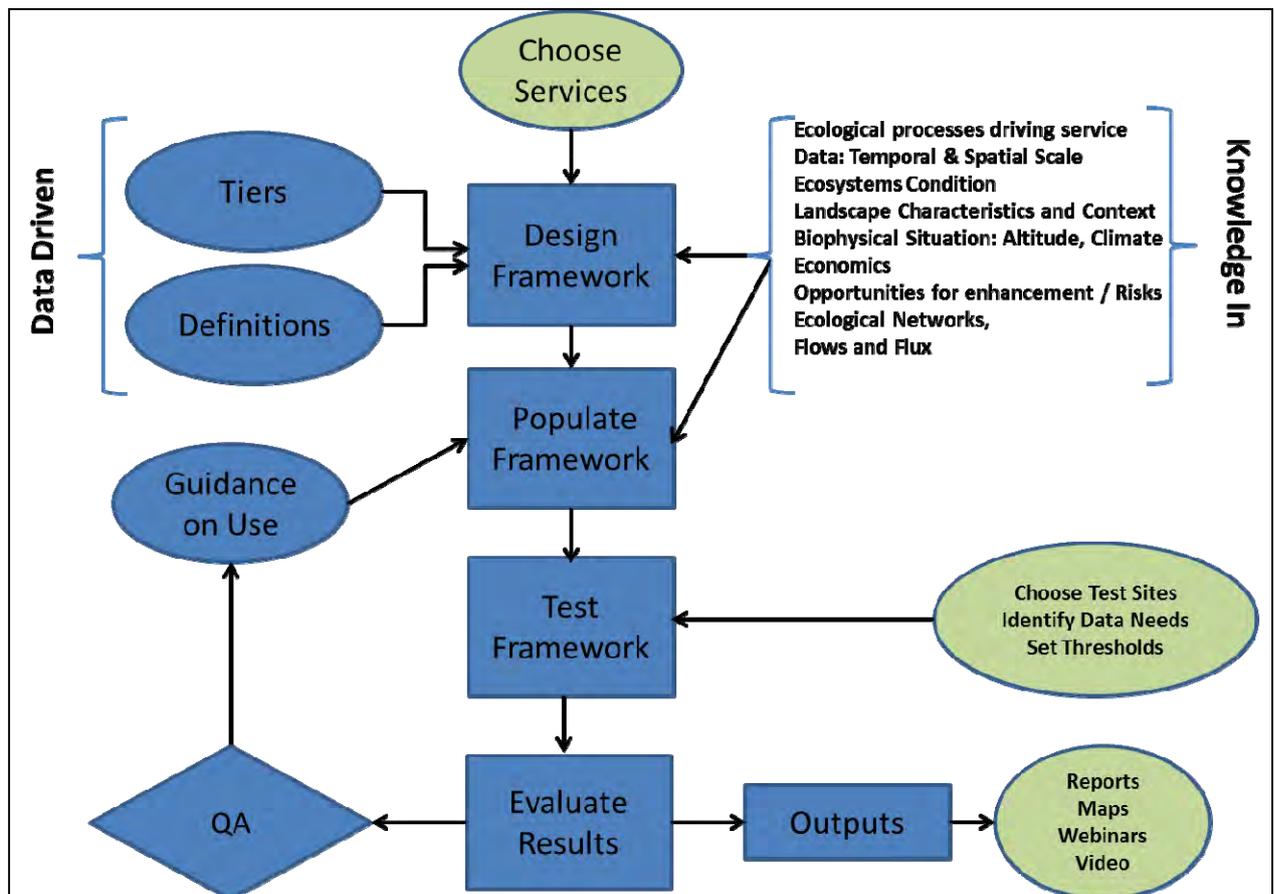


Figure 1 Overarching project approach

### 3.2 Choice of services

Within a framework development project it is not possible to consider all the ecosystem services provided by every habitat. The ecosystem services agreed for evaluation are shown in Table 3, and were chosen to include key services in terms of the most significant features provided by natural and semi-natural terrestrial habitats, together with pollination and biodiversity measures, which are also extremely relevant for the habitats under consideration.

**Table 3 Ecosystem services considered during this project**

Service Categories	Specific services
Provisioning	Agricultural goods Forestry goods Pollination
Regulating	Carbon sequestration Water regulation Water quality
Cultural	Recreation and cultural services
Supporting	Biodiversity

Ecosystem services originating from the marine environment can be categorised in a similar way. The breakdown of services considered within this study is shown below in Table 4. Fletcher *et al* (2012) in their report for Natural England used the TEEB terminology in their study; the services identified here follow those identified by Fletcher, but reinterpreted into the service categories from the CBD definition to facilitate comparison with the terrestrial systems studied.

**Table 4 Ecosystem services considered within the marine environment within this project**

Service Categories	Specific services
Provisioning	Larval / Gamete / fish supply Fertilizer / feed supply Renewable energy
Regulating	Carbon sequestration Biogas regulation Water purification (pollution regulation and waste detoxification) Erosion control
Cultural	Recreation and tourism services
Supporting	Biodiversity

### 3.3. Choice of habitats studied

Within the time available to the project it was not possible to study all the habitat types occurring within the UK. Wetland and mire features have been worked on by a number of other studies (Maltby, 2010; Orr, 2008). Woodlands and grassland are major habitats that have been less well described by other work, and cover large parts of the UK; therefore these two terrestrial systems were chosen to help test the framework structure and its transferability. JNCC were keen to also include a marine habitat, to illustrate how the process could be applied to the marine environment.

The habitats agreed for evaluation include:

- 1) Woodland, including:
  - a. Broadleaved woodland
  - b. Mixed woodland
  - c. Coniferous woodland
  - d. Scrub
- 2) Grassland, including:
  - a. Agriculturally improved grassland
  - b. Acid grassland
  - c. Calcareous grassland
  - d. Neutral grassland
  - e. Marshy grassland
  - f. Urban Gardens
- 3) Shallow Sub-tidal Sediments, including
  - a. Sandbanks

Marine sandbanks were included, whilst accepting that the level and quality of data, knowledge and understanding was likely to be much lower than for terrestrial habitats.

### 3.4 Framework structure

The example frameworks for the study habitats listed in 3.3 can be found in the accompanying technical documents to this report. The framework has been developed as a large matrix, designed to be read from left to right and become more specific as it is read, starting with the broadest categories of ecosystem services, and focusing down to comment on individual contributing datasets. For each habitat, rows show the ecosystem services and columns show the assessment criteria (see section 2.1.) of importance, knowledge and available data quality, and the tier allocation.

A wide range of datasets were considered in relation to the key ecosystem services, focusing on the use of existing data and highlighting the most significant data gaps. Existing information was often found not to be ideal for service assessments (due to scale, incomplete understanding of processes, etc), and a pragmatic approach was taken when quantifying the effectiveness of the available data. It is mostly possible within existing knowledge to categorise information into 'high', 'medium' and 'low' significance for use in assessments, and these categories are used in the framework tables.

Even with less than ideal data and a less than exact knowledge about the interactions between the habitats, their location, management and the available services, it is possible to grade existing understanding into this simple three step categorisation. As research progresses and new datasets are found it will be possible to become more exacting with these classifications.

The following table (Table 5) shows a snapshot of the framework structure, identifies the range of framework headings and shows the assessment for the tier allocation process for an example habitat. The framework provides, for each habitat studied, a logical structure for presenting and collating information on the importance of the habitat for each ecosystem service, knowledge of the understanding of what habitat attributes contribute to that importance, and an assessment of what data exists to quantify those attributes and assist the mapping process.

Throughout the process of developing a framework there was recognition that the quantification and mapping of ecosystem services is a young and developing science, where knowledge and data are likely to improve as new work is carried out and new insights developed into factors important for the delivery of those services.

**Table 5 Overview of the framework structure**

<b>Framework example for Broadleaved Woodland (BLW):</b>							
<b>Ecosystem service:</b>			<b>Assessment:</b>			<b>Contextual data:</b>	
Services are most easily mapped at the specific level. The maps can then be combined to give the Intermediate level and high level service picture using geoinformatics techniques			Each habitat is assessed in terms of the importance of the habitat in its contribution to the service and therefore the risk to the service if the habitat is not maintained. The knowledge available about how the habitat functions is then assessed and the data sets available to map the systems are considered within the data column			Contextual data is essential to understand how the habitat relates to its surroundings in terms of ecosystem services. The available, type and relevance of contextual data is outlined in these parts of the framework.	
<b>High Level</b>	<b>Intermediate Level</b>	<b>Specific Service</b>	<b>Importance</b>	<b>Knowledge</b>	<b>Data</b>		
Climate regulation	Carbon flux	Carbon sequestration Soil	Highly important for climate regulation	Identifies what attributes are important and can be measured.  e.g. Extent of woodland, type of woodland,	What existing datasets are available to quantify those attributes  e.g. Phase 1, LCM, AW, NFI	Scale of data availability: National, regional, local + suitability	Where the habitat is – landscape context What substrate the habitat is on – underlying geology How the habitat is managed
		Carbon sequestration Vegetation					
	Carbon storage	Carbon Storage Soil					
		Carbon Storage Vegetation					
<b>Tier allocation categories for assessment.</b>							
<b>Scored:</b>							
High/Med/Low +ve or -ve			High/Med/Low		High/Med/Low		
<b>Assessment for Broadleaved Woodland:</b>							
H+			M		H		

## 4 Testing the framework concept - mapping and modelling ecosystem services

The framework was tested on five case study areas.

### 4.1 Choice of study areas

In consultation with the JNCC, five study areas were selected:

- 1) Bridgend County Borough Council (a unitary authority in Wales),
- 2) Scottish Borders County
- 3) Norfolk Broads Catchment (part of Norfolk County),
- 4) The Purbeck AONB area of Dorset County
- 5) The Dogger Bank (a well-known marine area in the North Sea)

The study areas were chosen for three main reasons:

- Wide geographical coverage across the UK
- Wide coverage of landscape types, from upland to lowland and marine
- Wide range of data availabilities, quality, scale and coverage

The study areas were chosen to help illustrate the mapping process, rather than to provide definitive maps to be used in any formal planning sense. They also fulfil a role in demonstrating the transferability of the method, and the scope for using the method with both detailed, well categorised data for local studies, and more strategic data, which supports general policies by providing a broad-scale overview. The case study areas are described in more detail below:

#### **Bridgend County Borough Council**

Bridgend CBC is a unitary authority in South Wales. It is rich in wildlife and characterised by diverse landscapes. The county is important for the following BAP priority habitats: upland oak woodlands, lowland purple moor-grass and Rhos pasture, ancient and species rich hedgerows and coastal and floodplain grazing meadow. The area was previously evaluated in detail in "Practical application of Ecosystem services mapping for Bridgend" (Medcalf & Small, 2012), as an input to the Welsh SCCAN project.

#### **Purbeck, Dorset**

Dorset is a county with a rich biodiversity, landscape and quality of life, reflected in the AONB status given to the coastal area. Much of the biodiversity is linked to a range of habitats across the county. The Purbeck area is the south-eastern coastal part of Dorset and falls within a Nature Improvement Area (NIA) within Dorset AONB. Purbeck is recognised for its heathlands, valley wetlands and its Jurassic coast, reflected in the AONB status given. Northern parts of Purbeck are characterised by undulating lowland heath, tracts of heather, stunted pine and gorse scrub. Southern Purbeck is a distinctively diverse landscape, strongly influenced and characterised by underlying chalk, limestone, shale and clay rocks. Purbeck's geological diversity gives rise to a range of soils which support a wide diversity of habitats and species across the county

#### **Norfolk Broads**

The Norfolk Broads is a part of Norfolk County that contains a large area of navigable rivers and fresh water habitats which are surrounded by arable and grassland systems. There are significant areas of wet woodlands, wetland and fen vegetation and grazing marsh which together support a wide range of protected species. Due to variation in the underlying bedrock the different rivers feeding into the Broads support different habitat and species assemblages.

### **Scottish Borders**

The Scottish Borders County contains a number of important habitat types, including woodland, wetland, species rich native grasslands and heathland. Each of these habitat types contribute significantly to the biodiversity of the area. However, the extent of these habitats is comparatively limited and they are all under threat from other land uses, such as intensive agriculture, commercial forestry and urbanisation.

### **Dogger Bank**

The Dogger Bank is an extensive Annex I Sandbank habitat (1110) in the southern North Sea, comprising sub-littoral sandbank, covering an area of approximately 17,600km<sup>2</sup>. The sandbank is non-vegetated and comprises moderately mobile, clean sandy sediments. The diversity and types of community associated with this habitat are determined particularly by sediment type together with a variety of other physical, chemical and hydrographic factors such as topographical structure, turbidity and salinity of the surrounding water. The site has historical importance, particularly for fishing, formerly for cod and herring. Nowadays, the site is important for both ground fish and sand eel commercial fishing, and the site has been identified as an area which experiences high phytoplankton production activity. Several shipwrecks lie on the bank.

## **4.2 Mapping and modelling ecosystem services**

The mapping methodology followed that developed by Environment Systems for the SCCAN (System Cynorthwyo Cynllunio Adnoddau Naturiol)<sup>3</sup> CCW project. This involved a number of stages of work. These stages are shown in Figure 2 below. Each of the stages of work was underpinned by existing scientific knowledge and checked with both JNCC scientists and where time allowed, with experts from the relevant case study areas who had detailed knowledge of how the features of interest manifested on the ground. As such it was an iterative process with the maps and rule-base being updated as new data and knowledge was added. The intention was to test, illustrate and compare the mapping process across different areas rather than provide definitive maps.

For the case studies it was agreed that all land in the study areas should be mapped, not just the habitats assessed in the framework. This was with the acceptance that habitats do not exist in isolation, but are a part of the landscape and wider ecosystem in which they occur.

Mapping followed the methodology shown in Figure 1 below.

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<sup>3</sup> System for Helping to Plan Natural Resources

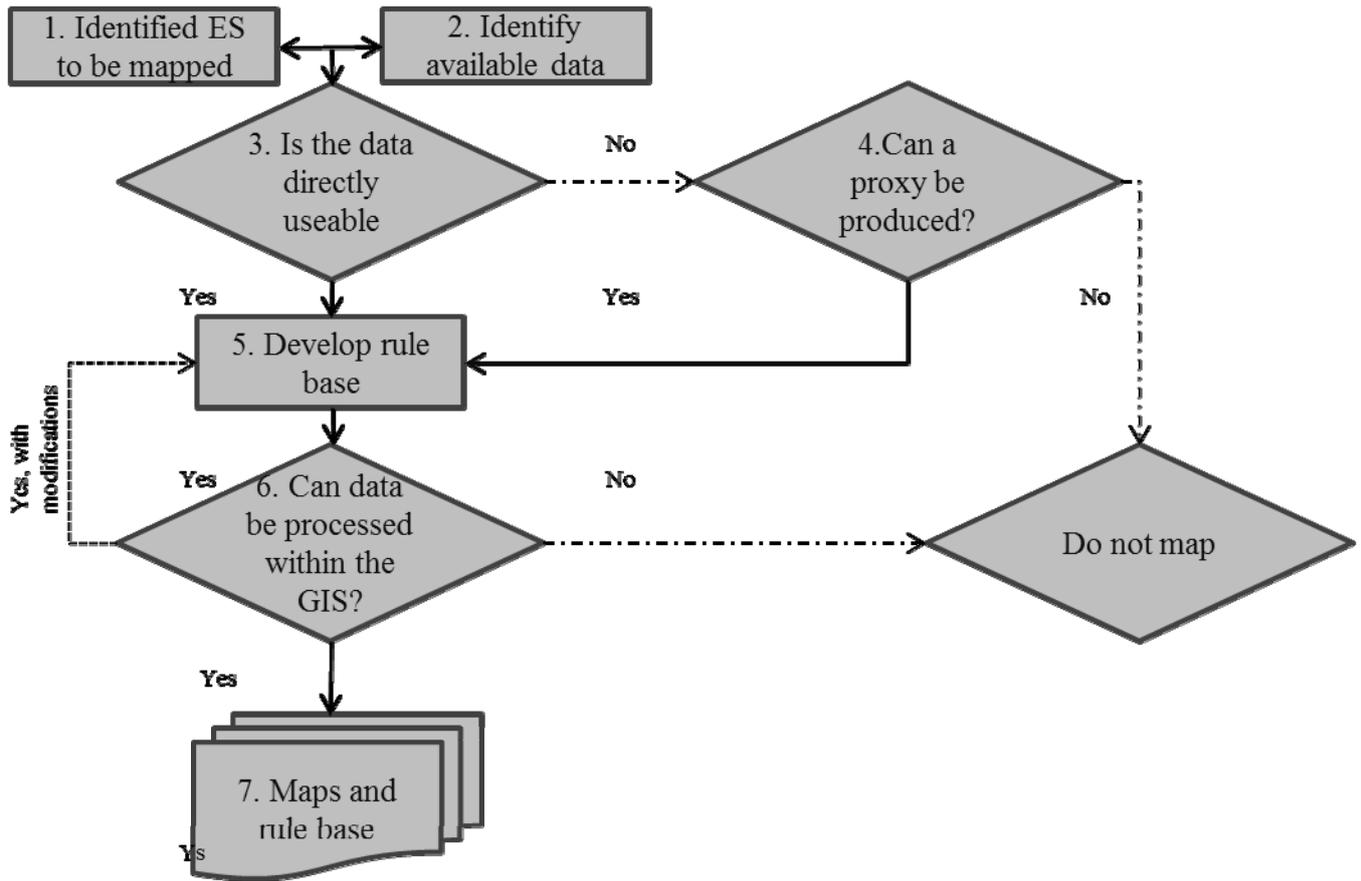


Figure 2 Methodology stages in ecosystem mapping

### Stage 1 Identification of Ecosystem Services to be mapped

Stage 1 involved identifying the services of relevance that could be mapped within each case study area. Not all ecosystem services are relevant to each area and not all ecosystem services needed to be mapped within each area to illustrate the mapping process. In summary, Table 6 shows the services mapped in each area and Table 7, the data used.

**Table 6 Ecosystem services mapped in each case study area**

<b>Ecosystem Service</b>	<b>Bridgend</b>	<b>Map</b>	<b>Scottish Borders</b>	<b>Map</b>	<b>Norfolk</b>	<b>Map</b>	<b>Purbeck</b>	<b>Map</b>
<b>Carbon Storage in soil</b>	Draft revised Phase 1, Soil	1	Phase 1, Water buffer, Relief	2	LCM, Soil, Management	3	*	
<b>Carbon Storage in vegetation</b>	Draft revised Phase 1 (with hedgerows), LPIS	4	Phase 1	5	LCM	6	*	
<b>Water Regulation</b>	Draft revised Phase 1 (with hedgerows), Soil, Relief, Floodplain	7	Phase 1, Relief, Floodplain	8	LCM, Relief, Soil, Floodplain, Groundwater	9	*	
<b>Soil erosion risk</b>	Draft revised Phase 1, Soil, Relief	10	*		*		LCM, Soil1, Relief LCM, Soil2, Relief, ALC	11i 11ii
<b>Forestry goods</b>	Draft revised Phase 1	12	Phase 1	13	*		*	
<b>Agricultural goods</b>	Draft revised Phase 1, LPIS	14	Phase 1	15	*		LCM/	16
<b>Landscape Aesthetics</b>	LANDMAP	17	*		*		LCM, Landscape Character, Designated sites	18
<b>Biodiversity</b>	Draft revised Phase 1, Protected site status Habitat networks, CCW species data	19	*		*		*	

**Table 7 Data used for the ecosystem services mapped in each case study area**

	<b>Bridgend</b>	<b>Scottish Borders</b>	<b>Norfolk</b>	<b>Purbeck</b>
<b>Data used:</b>	Draft revised Phase 1(VHR based on 2006 imagery) Relief derived from NEXTMap Soil based on 1:250,000 soil map of Wales LPIS crop code data (courtesy of the Welsh Government) LANDMAP visual and sensory layer (courtesy of CCW) Floodplain data based on EA 100yr flood risk map	Phase 1 (VHR based on 2009 imagery, supplemented by local NVC data) Water buffer of 1km around water bodies Relief derived from OS Panorama LCM (HR based on 2007 imagery), supplemented and updated where possible with local data Floodplain data based on EA 100yr flood risk map	LCM (HR based on 2007 imagery), supplemented and updated where possible with local data Relief derived from OS Panorama Soil based on 1:250,000 soil map of England Management data based on Environmental Stewardship membership (courtesy of NE) Floodplain data based on EA 100yr flood risk map Groundwater flooding based on EA groundwater flood risk map	LCM (HR based on 2007 imagery), supplemented and updated where possible with local data Relief derived from OS Panorama Soil1 based on Natmap Soil2 based on Soilscape ALC based on ALC map of England

- Note: Not all services were mapped for all areas. Those examples marked with an asterisk have not been included as maps in this report, due to time constraints and the comparative nature of the project.

## Stage 2 Identification and assessment of available data

For each habitat, spatial information was collected from readily available environmental datasets to represent those attributes (such as soil type, land cover and terrain) that contribute to the delivery of each ecosystem service.

The datasets collected were essentially spatial datasets and included both point and polygon vector data, and raster data, compiled at a variety of different scales, from different dates and with a variety of accuracies, resolutions, degrees of comprehensiveness and sensitivities. An example of some of these datasets is included in Table 8. These were manipulated within the Geographical Information System environment to allow comparative statistical analysis.

**Table 8 Core datasets used in the project**

				Purbeck (AONB)	Norfolk	Scottish Borders	Bridgend
	Thematic Layer	Datasets	Dataset importance				
<b>Carbon Sequestration (Soil)</b>	Soil	NATMAPvector		Y	Y	N	Y
<b>Carbon Storage (Soil)</b>		NATMAPsoilscapes		Y	N	N	N
	Geology	DiGiMap625		Y	Y	Y	Y
		DiGiMap250		Y	Y	Y	Y
		DiGiMap50		Y	Y	Y	Y
<b>Carbon Sequestration (Vegetatio</b>	Land Cover	Phase 1		Y	Y	Y	Y
<b>Carbon Storage (Vegetation)</b>		Phase 1 Hedges		N	N	Y	Y
		NVC		N	N	Y	Y
		Land Cover Map 2007		Y	Y	Y	Y
		Agricultural Land Classification		Y	Y	N	Y
	Sealed Surfaces	MasterMap		Y	N	Y	Y
		Land Cover Map 2007		Y	Y	Y	Y
<b>Water Quantity Regulation</b>	Soil	NATMAPvector		Y	Y	N	Y
		NATMAPsoilscapes		Y	N	N	N
	Geology	DiGiMap625		Y	Y	Y	Y
		DiGiMap250		Y	Y	Y	Y
		DiGiMap50		Y	Y	Y	Y
	Relief	Aster 30m		Y	Y	Y	Y
		NEXMAP		N	N	N	Y
		Landform Panorama		Y	Y	Y	Y
		SMRT		Y	Y	Y	Y

## Stage 3 and 4 Combination of layers to provide ecosystem information

In previous work it became clear that, for any individual ecosystem service, there was rarely a single habitat attribute dataset that was readily available, appropriate to use, simple to map and fully representative of that service. Success of the project would rely on developing a means of bringing together and combining different types of datasets, in a consistent, transparent and scientifically rigorous way, to produce meaningful maps that allowed a spatial representation of the importance of habitats in delivering each ecosystem service. In some cases whilst directly attributable data was not available, a 'proxy' could be found that would approximate to the attribute to be mapped. An example was peaty soils in Scottish Borders. No soils dataset is available for Scotland (to this project), but an approximate distribution of peaty soil across the catchment can be estimated from the (Phase 1) vegetation which occurs on peaty soils or deep peat modelled together with landform.

## Stage 5 Development of rule-base

For each ecosystem service a rule-base was required that identified:

- The specific elements of each dataset considered important for mapping that service;
- The relative value to be assigned to each element to enable mapping, and
- Any weighting required when different datasets were to be combined.

The rule-base uses knowledge and understanding of habitat attributes to show the spatial distribution of ecosystem service delivery.

For the grassland and woodland ecosystems the ‘rules’ developed to generate the ecosystem service maps are included in the framework document. Table 9 below demonstrates how the rule base has been developed for climate regulation in Bridgend.

**Table 9 Rule base for the data modelled for Climate regulation in Bridgend**

<b>Millennium Ecosystem Assessment Framework Regulating</b>			
<b>Ecosystem Service Typology</b>	<b>Most significant effects</b>	<b>1<sup>o</sup> Factor</b>	<b>2<sup>o</sup> Factor</b>
<b>Climate Regulation</b> Carbon Storage in Soils	Largest influences are the soil type and how the vegetation is contributing to active peat formation	Peat soil High influence ⇕ Sandy soil low influence	Active peat forming vegetation high influence ⇕ Modified vegetation low influence
Carbon Storage in Vegetation	Largest effects are the amount of woody material in the vegetation and the management imposed on the land use.	Woodland high influence ⇕ Improved agricultural grassland low influence	Unmanaged high influence ⇕ Annual cropping low influence

## Stage 6 Data processing

The analysis was run spatially to establish a value for each raster pixel or vector area of land. It made use of a grid, which could be varied in size to accommodate different datasets whilst maintaining consistency of mapping. Presence or absence of the data in each grid square was noted. These data were produced automatically using ArcGIS software. The grid size was set to produce the most effective display of data and varied between 10m and 1km. Each dataset used provided a separate data layer for the service under consideration, which could be combined with others to produce the final map.

## Stage 7 Verify data values and produce maps and rule-base

The final stage of the process involved verifying the data values assigned and producing the subsequent maps. This was an iterative process, where the resultant maps were initially quality assessed by eye to evaluate their clarity and ease of understanding, and changes made to the assigned values or the mapping colour ramp where necessary to help improve both clarity and ease of understanding.

At least one map was produced for each of the services; these are provided in the Appendices.

## 5 Evaluation – Application of the framework approach

The development of the framework showed how habitat attribute data could be derived to help map and quantify the importance of habitats in delivering ecosystem services.

For mapping purposes, habitat attribute data has been used in two ways:

- To directly map services such as vegetation carbon storage
- To act as a proxy (or substitute) for other less readily available or detailed datasets (such as soils) where local knowledge and other contextual data enables a good understanding of the role of habitat data – such as, for example, the use of the extent of blanket bog to help delineate the extent of deep peat soils in the mapping of soil carbon storage.

The case studies described below show how different datasets could be used to map the distribution of those ecosystem services.

### 5.1 Scoring of tiers for Grassland, Woodland and Marine Habitats

Figures 3 to 5 show how the framework and the experience from the case study mapping identify tiers for each of the woodland, grassland and sub-tidal sediment habitats examined.

Broadleaved woodland, particularly semi-natural and ancient woodland has a key role in the provision of water quality and quantity regulation, carbon storage and cultural use, pollination and biodiversity. The knowledge and data tend to be good and these services are well mapped. In contrast, although scrub can play an important role in water quantity regulation, pollination and biodiversity, data on its extent is available only in part.

For the grassland ecosystems studied, although they provide an extremely important role in water quality regulation, carbon storage and biodiversity, knowledge about the functioning of the systems is not as advanced as that for the woodlands and there is less certainty about the quality and distribution of the habitats.

Subtidal sediments play an important role in food provision (fisheries and aquaculture) through ecological processes like secondary production, species diversification and food web dynamics. These subtidal areas are also important in terms of pollution regulation and environmental resilience. Although all four of these services are significant in ecosystem terms, knowledge about how the processes work is not as advanced as knowledge about how similar systems operate in the terrestrial environment. In addition data relating to the spatial and temporal extent of marine habitats and the pressures being exerted on them is not comprehensive in its extent, scale and coverage. It is also less readily available and is therefore more difficult to process and use than much of the terrestrial data.

The examples shown below demonstrate the value of the tier diagrams in describing the status of knowledge, and data in the light of the importance of the ecosystem service. These tier diagrams are a particularly useful tool to include in addition to the spatial maps of the services to highlight where knowledge is less certain and data may need to be used with caution or supplemented by further studies. Because of the importance of ecosystem concepts it will not be possible to wait until all the data and knowledge gaps have been filled before exploring the spatial extent of the services; the tier diagram provides a way of describing our certainty about the mapped information and its accuracy, allowing users to make informed choices about the data and how it's used. The full tier table is shown again in Table 10 below for reference.

Spatial framework for assessing evidence needs for operational ecosystem approaches

**Table 10 Tiers of the spatial framework**

Example Habitat and Ecosystem Service										
Tier Importance for the Ecosystem Service		Knowledge and scientific understanding of how the service operates								
		Good knowledge (i)			Some Knowledge (ii)			Little or no Knowledge (iii)		
1	The habitat has a High Importance/Risk for the ecosystem service	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)
2	The habitat has a Moderate Importance/Risk for the ecosystem service	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)
3	The habitat has a Low Importance/Risk for the ecosystem service	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)	Data Good (a)	Data Some available (b)	Data Poor (c)

Spatial framework for assessing evidence needs for operational ecosystem approaches

**Broadleaf Woodland**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	H	H	1ia
Regulating Water Quantity	H	H	H	1ia
Carbon Storage	H	H	H	1ia
Cultural	H	H	H	1ia
<i>Agricultural Goods</i>				
Forestry Goods	M	H	H	2ia
Pollination	H	M	M	1iib
Biodiversity	H	H	H	1ia

**Coniferous Woodland**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	H	M	1ib
Regulating Water Quantity	H	H	H	1ia
Carbon Storage	H	H	H	1ia
Cultural	H	H	H	1ia
<i>Agricultural Goods</i>				
Forestry Goods	H	H	H	1ia
Pollination	L	M	M	3iib/3iic
Biodiversity	L	H	M	3ib

**Mixed Woodland**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	H	H	1ia
Regulating Water Quantity	H	H	H	1ia
Carbon Storage	H	H	H	1ia
Cultural	H	H	H	1ia
<i>Agricultural Goods</i>				
Forestry Goods	M	H	H	2ia/3ia
Pollination	M	M	M	2iib/2iic/3iib/3iic
Biodiversity	M	H	H	2ia/2ib/3ia/3ib

**Scrub**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	M	M	L	2iic
Regulating Water Quantity	H	M	M	1iib
Carbon Storage	M	M	M	2iib/2iic
Cultural	L	M	L	3iic
<i>Agricultural Goods</i>				
Forestry Goods	L	L	L	3iic
Pollination	H	H	M	1ib/1iib
Biodiversity	H	M	M	1iib

**Importance + Risk of habitat on provision of service**

H	Highly Important and High Risk
M	Moderately Important and Moderate Risk
L	Slightly Important and Slight Risk

**Knowledge**

H	Extensive Knowledge Through Previous Research in UK
M	Inferred knowledge from similar non UK habitats
L	Further research required - evident knowledge gap

**Data**

H	Lots of data readily available
M	Data restricted by license, availability or completeness
L	Known data gap

**Figure 3 Woodland Habitat Framework Tiers**

Spatial framework for assessing evidence needs for operational ecosystem approaches

**Acid Grassland**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	M	M	1iib
Regulating Water Quantity	M	M	M	2iib
Carbon Storage	H	H	M	1ib
Cultural	H	M	M	1iib
Agricultural Goods	H	H	M	1ib
Forestry Goods				
Pollination	M	L	M	2iiib
Biodiversity	H	L	M	1iiib

**Agriculturally Improved Grassland**

Regulating Water Quality	H -ve*	H	H	-1ia/-1ib
Regulating Water Quantity	M	H	M	2iib
Carbon Storage	H -ve*	H	M	-1ib/-2ib
Cultural	H	H	M	1ib
Agricultural Goods	H	H	H	1ia/-1ib
Forestry Goods				
Pollination	H -ve*	H	M	-1ib
Biodiversity	H -ve*	H	M	-1ib

**Calcareous Grassland**

Regulating Water Quality	H	M	M	1iib/2iib
Regulating Water Quantity	M	M	M	2iib
Carbon Storage	H	M	M	1iib
Cultural	H	H	M	1ib
Agricultural Goods	L	L	L	3iiic
Forestry Goods				
Pollination	H	H	M	1ib
Biodiversity	H	H	M	1ib

**Importance + Risk of habitat on provision of service**

H	Highly Important and High Risk
M	Moderately Important and Moderate Risk
L	Slightly Important and Slight Risk
H -ve*	Highly Negatively Important and High Risk

\*assumption that the land is intensively managed, i.e. not in an agri-environment scheme as short term leys may not be in an agri-environment scheme

**Knowledge**

H	Extensive Knowledge Through Previous Research in UK
M	Inferred knowledge from similar non UK habitats
L	Further research required - evident knowledge gap

**Data**

H	Lots of data readily available
M	Data restricted by license, availability or completeness
L	Known data gap

**Gardens: i) Shrubs and Trees**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	H	M	1ib
Regulating Water Quantity	H	H	M	1ib
Carbon Storage	H	H	H	1ia
Cultural	H	H	H	1ia
Agricultural Goods				
Forestry Goods				
Pollination	H	H	M	1ib
Biodiversity	H	H	M	1ib

**Gardens: ii) Mown Lawn**

Regulating Water Quality	H	H	M	1ib
Regulating Water Quantity	H	H	M	1ib
Carbon Storage	H	M	M	1iib
Cultural	H	H	H	1ia
Agricultural Goods				
Forestry Goods				
Pollination	H	M	M	1iib
Biodiversity	H	M	M	1iib

**Gardens: iii) Sealed Garden**

Regulating Water Quality	H -ve	M	M	-1iib
Regulating Water Quantity	H -ve	M	M	-1iib
Carbon Storage	H -ve	M	M	-1iib
Cultural	H -ve	M	M	-1iib
Agricultural Goods				
Forestry Goods				
Pollination	H -ve	M	L	-1iic
Biodiversity	H -ve	M	L	-1iic

**Figure 4 Grassland Habitat Framework Tiers**

Spatial framework for assessing evidence needs for operational ecosystem approaches

**Marshy Grassland**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	H	M	1ib
Regulating Water Quantity	H	H	M	1ib
Carbon Storage	M	H	M	2ib
Cultural	L	L	L	3iiic
Agricultural Goods	M	H	L	2ic
<i>Forestry Goods</i>				
Pollination	H	H	L	1ic
Biodiversity	H	H	L	1ic

**Neutral Grassland**

Services	Importance + Risk	Knowledge	Data	Tier*
Regulating Water Quality	H	M	L	1iic
Regulating Water Quantity	M	M	M	2iib
Carbon Storage	H	M	H	1iia
Cultural	H	H	H	1ia
Agricultural Goods	M	H	L	2ic
<i>Forestry Goods</i>				
Pollination	H	H	M	1ib/1ic
Biodiversity	H	H	M	1ib/1ic

**Importance + Risk of habitat on provision of service**

H	Highly Important and High Risk
M	Moderately Important and Moderate Risk
L	Slightly Important and Slight Risk
H-ve*	Highly Negatively Important and High Risk

**Knowledge**

H	Extensive Knowledge Through Previous Research in UK
M	Inferred knowledge from similar non UK habitats
L	Further research required - evident knowledge gap

**Data**

H	Lots of data readily available
M	Data restricted by license, availability or completeness
L	Known data gap

\*assumption that the land is intensively managed, i.e. not in an agri-environment scheme as short term leys may not be in an agri-environment scheme

**Figure 4 (Continued) Grassland Habitat Framework Tiers**

### Subtidal Sediments

**Services**

Services	Importance + Risk	Knowledge	Data	Tier*
Pollution regulation	H	M	L	1ic
Environmental resilience	H	M	L	1ic
Carbon Sequestration and capture	H	M	L	1ic
Fisheries	H	H	M	1ib
Aquaculture	H	H	M	1ib
Renewable Energy	H	M	M	1iib

**Importance + Risk of habitat on provision of service**

H	Highly Important and High Risk
M	Moderately Important and Moderate Risk
L	Slightly Important and Slight Risk

**Knowledge**

H	Extensive Knowledge Through Previous Research in UK
M	Inferred knowledge from similar non UK habitats
L	Further research required - evident knowledge gap

**Data**

H	Lots of data readily available
M	Data restricted by license, availability or completeness
L	Known data gap

Figure 5 Subtidal Sediments Habitat Framework Tier

## 5.2 Evaluation of individual ecosystem services

### 5.2.1 Carbon storage in soil

The studied habitats are very important for delivering soil carbon storage. The balance between inputs of organic matter mainly from vegetation, and losses due to decomposition, leaching and erosion, determines the magnitude of UK land carbon reserves. The potential for carbon sequestration through land management governs whether ecosystems can be maintained as stocks of carbon or sources of the greenhouse gases carbon dioxide and methane (Ostle *et al*, 2009). Ecosystem service understanding is that soil carbon is highest in peaty soils, lowest in light loamy and sandy soils. The rule-based weights soils accordingly.

Maps for the case study areas are shown in Appendix 2 maps 1–3. The Scottish Borders and Norfolk area maps (Figure 6) essentially reflect landscape differences.

In the Scottish Borders the tops of the hills have the peaty soils (reflected by using Phase 1 data as a proxy for soil as no soil dataset is available to this project for Scotland) – Norfolk shows peaty soils in the valley bottoms around the rivers and Broads (based on the 1:250,000 soil map).

Bridgend shows a range from peaty upland soils to coastal sand dunes – but at a lower resolution, using Phase 1 habitat data.

Overall soil maps (at 1:250,000) provide good data on soil distribution, but are fairly coarse. Where soil data is absent, land cover (Phase 1) can be used as a good proxy (on the basis that, for example, blanket bog occurs only on deep peat soils). A rule-based set up based on land cover can be enhanced by including other data – for example a buffer of 1 km on flat ground has been set up in the Scottish Borders around water bodies, on the understanding that peat is more likely to form on the fringes of water bodies – this is borne out by the soils data from Norfolk, where the peaty soils are adjacent to streams.

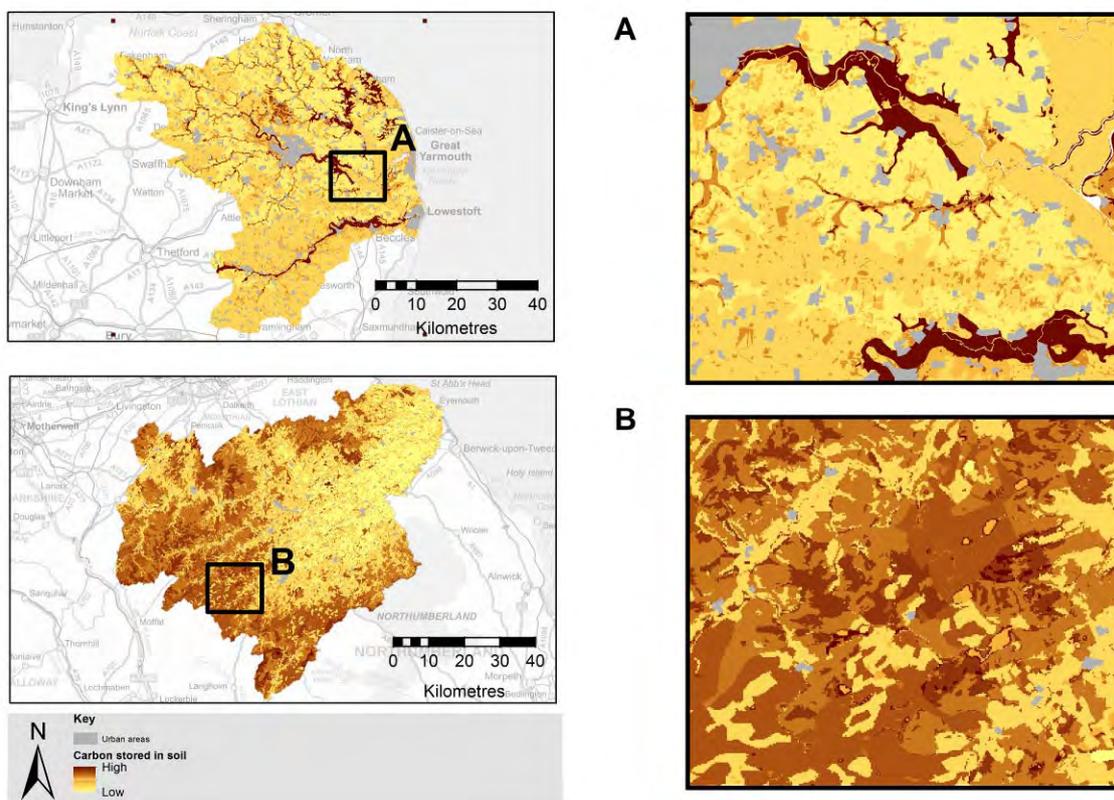


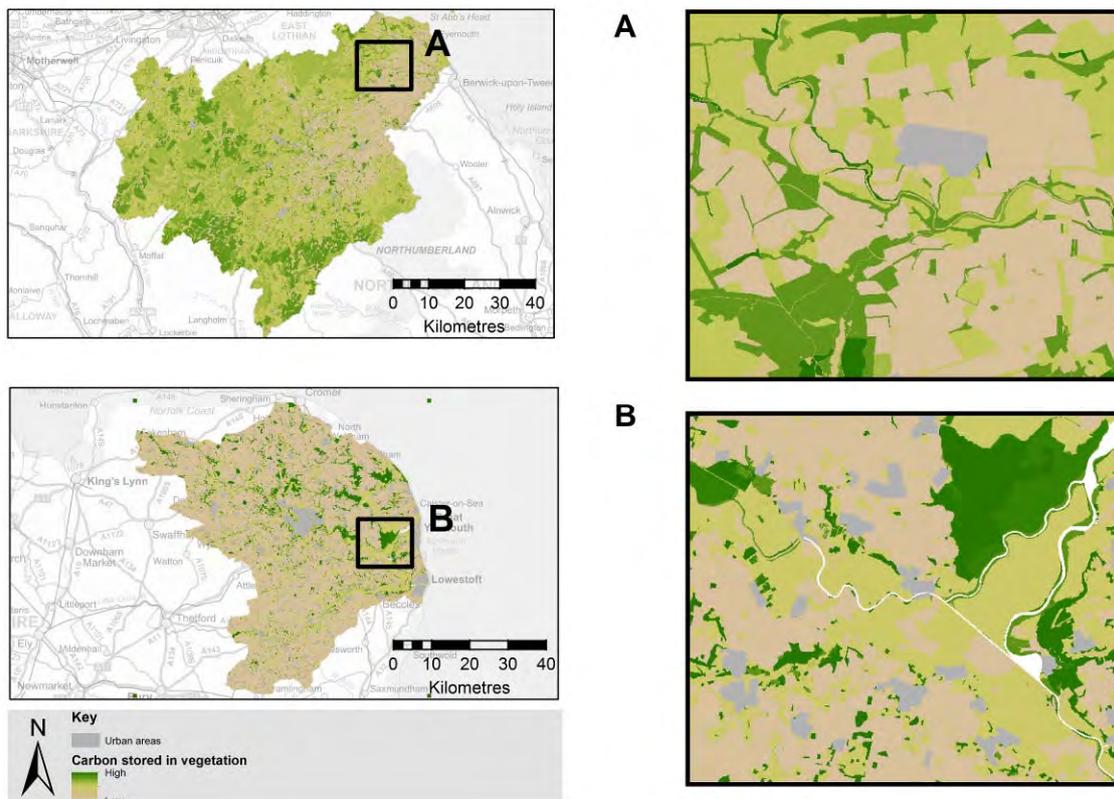
Figure 6 (a) Soil carbon storage, Norfolk (b) Soil carbon storage, Scottish Borders

## 5.2.2 Carbon storage in vegetation

The studied habitats are very important for delivering vegetation carbon storage. Ecosystem service understanding is that stored carbon is highest in bogs and mires, lower in woodland and grasslands and actually depleted in arable crops (through harvesting). The rule-based weights vegetation types accordingly.

Maps for the case study areas are shown in Appendix 2 maps 4-6.

The maps in Figure 7 illustrate the effect of data resolution and scale. Brown areas are arable land, where vegetation carbon is depleted. Green areas are woodland and reedbeds. At the top (a) the Scottish Borders map uses very high resolution, Phase 1 data, accurate to field boundaries. At the bottom (b) the Norfolk map uses Land Cover Map 2007 (supplemented by some local very high resolution data).



**Figure 7(a) Vegetation carbon storage, Scottish Borders; (b) Vegetation carbon storage, Norfolk**

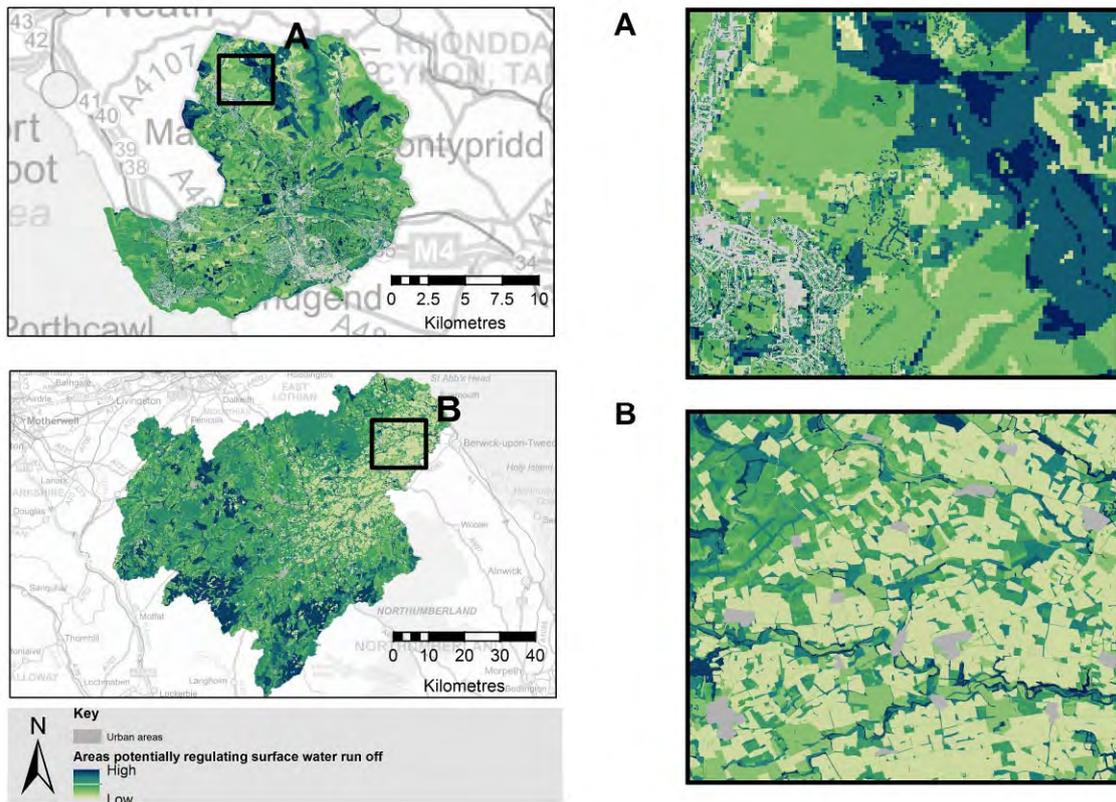
## 5.2.3 Water regulation

The studied habitats are very important for influencing water regulation. Ecosystem service understanding is that, in particular, surface water flows are regulated well by woodland and rougher land cover types; less so by grassland and not at all by sealed surfaces. Water regulation is least effective on steep slopes. The rule-based takes account of land cover, slope and known areas of flood risk.

Maps for the case study areas are shown in Appendix 2 maps 7-9.

Figures 8 and 9 illustrate the effect of data resolution. Within Figure 9 the maps of Scottish borders and Bridgend map uses very high resolution, land cover data. This land cover data set includes hedges and ribbon woodlands, which can have a strong influence on regulating





**Figure 9(a) Comparison of water regulation in Bridgend and (b) Scottish Borders**

One of the strengths of the framework approach to ecosystem service mapping is the ability of one high resolution data set to enhance the data of lower resolution; this technique is called ‘image fusion’. It allows the combining of multiple raster layers into composite products, through which more information than that of individual input images can be revealed. This is similar to a technique in the remote sensing world called ‘pan sharpening’ wherein the fused output contains the spectral values from the lower resolution input image and spatial features of the higher resolution input image.

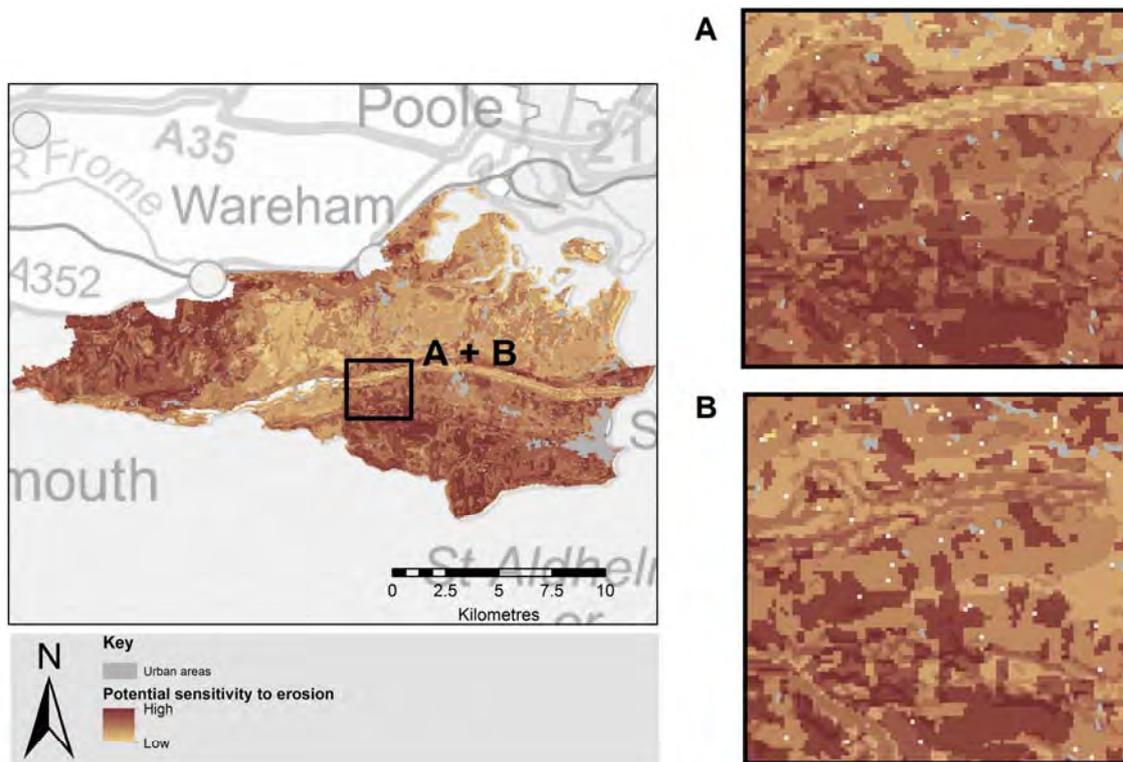
The example maps from Bridgend (Figure 9) show the value of looking in more detail at features such as urban gardens. The garden layer for Bridgend was derived from information from OS MasterMap combined with information gathered from colour infrared (CIR) aerial photography. Here, gardens likely to contain shrubs and bushes were identified and given a higher value than grassy or sealed surface gardens. This sort of model can help illustrate the contribution individual households can make towards preserving and enhancing our environment.

### 5.2.4 Soil erosion risk

The studied habitats are very important for influencing soil erosion risk. Ecosystem service understanding is that soil erosion risk is greatest on fine silty and sandy soils on steep slopes, and where agricultural crops produce bare ground at critical times of the year. It is least on organic clay soils, where flat and/or continuously vegetated. The rule-base takes account of land cover, slope, soil type and, in the case of Purbeck, Agricultural Land Classification (ALC) data.

Maps for the case study areas are shown in Appendix 2 maps 10–11ii.

These maps in Figure 10 illustrate the effect of adding additional datasets and of the resolution and certainty of the data. Both maps show the same part of Purbeck. The north of the area is essentially poor agricultural quality sandy soils (largely woodland and heathland), the south good loamy agricultural soils. The left-hand map, and Map (a) use the Natmap Vector soil dataset and ALC data. This is an extremely comprehensive data set with information about the organic matter present in each soil type as well as an exact description of its particle size distribution. As such detailed rules can be attributed to it. This dataset can therefore be regarded with a high degree of certainty. Map (b) map uses the Natmap Soilscape dataset alone. This is a strategic data set which just gives main soil class. As such the data can be viewed with less certainty.



**Figure 10(a) Soil erosion risk (Natmap Vector & ALC), Purbeck (b) Soil erosion risk (Natmap Soilscape & ALC), Purbeck**

The overall policy message would be the same for both sets of data but the scale of use and certainty are inherently different. The power of taking a pragmatic approach and using the framework is therefore demonstrated in that both types of data can be used for strategic county or countryside decision, but at a local level, the higher the spatial and detailed quality of the data the more meaningful the interpretation and uses to which it can be made.

### 5.2.5 Forestry goods

Certain of the studied habitats are very important for delivering forestry goods. Ecosystem service understanding is that the supply of forestry goods (essentially timber) is greatest in woodland areas and insignificant elsewhere. The rule-bases simply use land cover mapping of woodland. Forest goods become important in areas such as Bridgend and Scottish Borders. Woodland has, of course, other ecosystem service roles, especially for carbon

storage and flood alleviation. Where woodlands have a very strong flood protection role (and especially on steep slopes), extra care on felling and replanting will be necessary to preserve the integrity of the soil and water provision through the ecosystem.

Maps for the case study areas are shown in Appendix 2 maps 12 and 13.

### **5.2.6 Agricultural goods**

Certain of the studied habitats are very important for delivering agricultural goods. Ecosystem service understanding is that the supply of agricultural goods is greatest in intensively managed arable and horticultural areas, ranging through intensive and less intensively managed grasslands to least important in woodlands and other non-agricultural areas. The rule-base assesses land cover, although in Bridgend Land Parcel Information System (IACS) data was available from the Welsh Government, which gave a much more detailed picture of cropping than other land cover assessments.

The level of detail of assessing agricultural production is also affected by other land uses such as hedgerows, shelter belts and tall individual trees, which influence productivity by providing shelter and a pollination resource. Where data is available on these additional land uses (as in Bridgend), then they can be mapped and used in the assessment.

Maps for the case study areas are shown in Appendix 2 maps 14–16.

### **5.2.7 Landscape aesthetics**

The studied habitats are very important for delivering landscape aesthetics, although the ecosystem service understanding is less consistent here. The maps try to map the value placed on the landscape by society. Two approaches are shown:

For Bridgend, the map is based on CCW's Landmap visual and sensory layer, where areas have been mapped based on the judged international, national, regional and local significance of the land.

For Purbeck, the map is based on a rule-base where all semi-natural (habitat) areas are seen as important, but of increased importance where they lie within a designated area, and adjusted to reflect the two landscape character areas in Dorset.

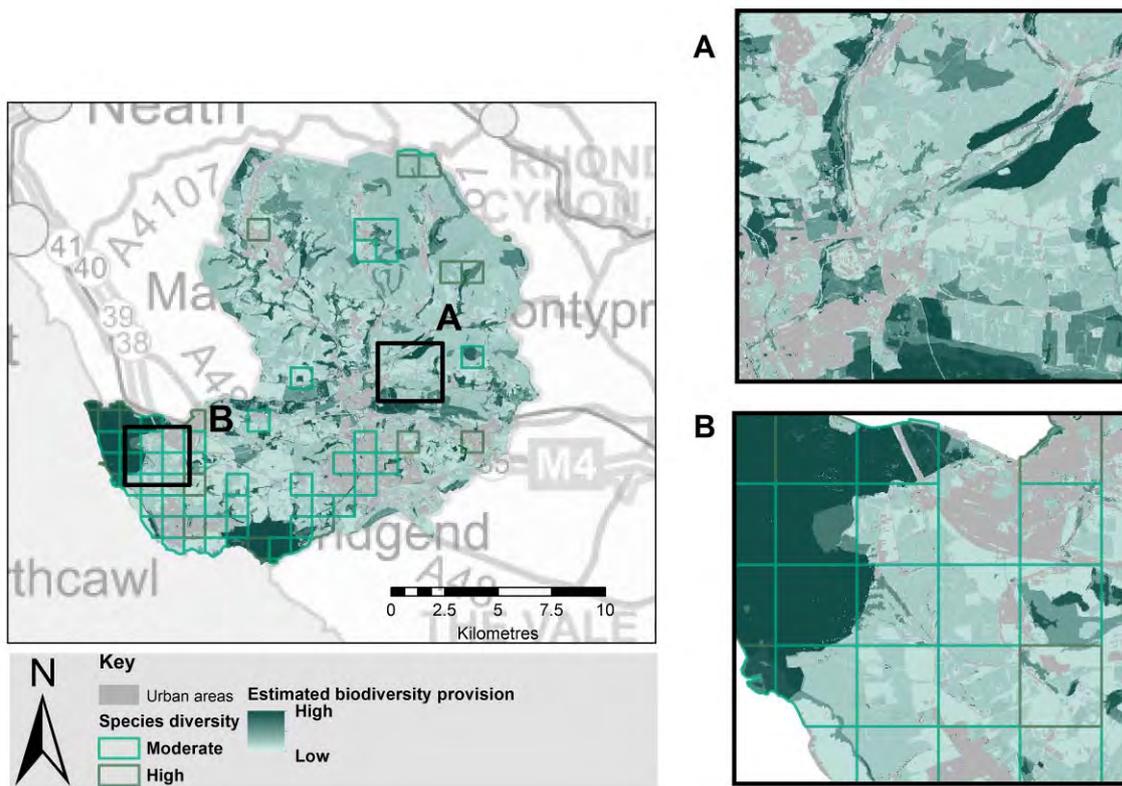
In a way both maps show a similar theme – the coastal areas are highly important, undulating and upland agricultural landscapes are moderately important, and the urban fringe is least important – although the resolution of the data for the two study areas is very different.

Maps for the case study areas are shown in Appendix 2 maps 17 and 18.

### **5.2.8 Biodiversity**

Biodiversity differs from the other services illustrated and as it is considered as a supporting service, and therefore has wide ranging characteristics. Describing the most significant of these is challenging. However, if the attempt is not made to describe biodiversity features its significance could be lost as no maps would be available and therefore users of the other spatial datasets could overlook this issue.

Maps for the case study areas are shown in Appendix 2 map 19.



**Figure 11 Biodiversity in Bridgend**

The biodiversity mapping (Figure 11) considers: naturalness of existing habitat, habitat networks and connectivity, opportunities for enhancement of the habitat and species diversity. Naturalness is scored using four categories:

- A habitat in a protected site is considered most likely to be natural and scores highest;
- Outside protected sites, a habitat with a high proportion of its area in the specific location scores moderately high (i.e. if the county holds most of the national resource for a habitat);
- Other habitats outside protected sites score moderately low;
- Intensively managed agricultural land scores low;

The diversity scores examine presence of species with national importance / red data book species scoring high, BAP species as moderate and locally significant species as low. It would be advantageous to build in the mapping of habitat vulnerability utilizing the scores from the Nature Conservation Review (NCR) Ratcliffe (1997 / 2011) method looking at size and rarity; however this project did not have time to take this aspect forward.

## 5.3 The Challenges of mapping ecosystem function in the marine environment

This section considers the application of the framework approach to a marine habitat (see Section 3). The marine environment provides a wide range of ecosystem services, on a much larger scale than most terrestrial environments. The seas of the United Kingdom extend to some 867,400km<sup>2</sup>, which is more than three and a half times its land area; there is also 11,000 miles of diverse coastline. The seabed is composed of a rich variety of substrata and is influenced by both colder Arctic and warmer Mediterranean waters. This results in a diverse range of marine seabed habitats supporting over 8,500 species (UKMMAS, 2010) and 11,921 algae species (MSBIAS, 2012).

This part of the project specifically to tested whether the mapping of ecosystem services approach set out in the report could be tested on a case study in the marine environment, rather than give a comprehensive description of all ecosystem services and habitats within the marine environment. Because of the exploratory nature of this section of the work, one habitat of considerable importance to the UK marine environment was chosen as the case study; this was shallow sub-tidal sediments, including sandbanks. The Dogger Bank area was chosen to act as the focal point for the mapping and modelling stage.

The subtidal sediments of Dogger Bank are significant in terms of the following ecosystem services (Natural England, 2012), reinterpreted into CBD definitions to follow the terrestrial framework from Fletcher *et al* (2012):

- **Supporting services** e.g. biodiversity,
- **Regulating services** e.g. carbon sequestration, pollution regulation, water purification and erosion control,
- **Provisioning services** e.g. Larval/gamete and fish supply, fertiliser/feed supply and renewable energy.

In order to provide a comparison with the terrestrial data, the provisioning service of larval/gamete and fish supply was chosen as a focus for this case study, as the sand eel species are such an important component of these habitats (Jensen *et al*, 2011; van Mikael, 2010).

The following section of the report considers the knowledge that exists about the functioning of ecosystem services in the marine environment. How far this knowledge can be translated into mappable features is considered in relation to the data available for marine mapping within the context of the Dogger Bank provisioning services case study. The significance of each component of this ecosystem service, and therefore the risk of actions which would damage the service are illustrated within the case study example via a rule base (Section 5.3.3).

### 5.3.1 Knowledge

The rationale introduced in Section 2.1 seeks to identify attributes of habitats which are important for, and influence the role of, those habitats in delivering ecosystem services. This rationale fits the marine environment as well as the terrestrial environment; however there are some important and significant differences which are highlighted below. The influence of any oceanographic zone on the ecosystem services it delivers is intrinsically related to the four main fundamental features previously identified; what the habitat is, what the habitat has formed on, where in the land/sea scape it occurs and how it is managed:

**1. What it is:** In the marine environment habitats occur in two different settings. On the sea bed, habitats can be long lived features which can develop over a large number of years. Conversely water column communities are temporally transient, often forming for a matter of hours and then reforming elsewhere as the tides and current change. The water column holds a significant proportion of the biodiversity, far more than the atmosphere does on land. This is because water is much denser than air and many marine flora and fauna live their whole lives suspended in the water column. Within this section we have concentrated on habitats related to the seabed. However, there will need to be a future exercise to map the pelagic environment. This could be done using data about currents, wave forms and processes to map zones of water column habitats which are of significance for ecosystem services.

**2. What it is on:** The geology and sediment have as profound a relationship to the habitats that form within and upon them in the marine environment as has geology and soil on land. However the interaction between the sediment and the energy of the water column is also of primary importance in the marine environment. In most terrestrial examples soils subjected to high winds support similar species to sheltered examples, often however the habitats will have a different phenotypic appearance with lower growth forms common. In the marine environment the difference is much more fundamental. For example high energy sandy sediments support more biodiversity because of the increase of nutrient cycling and oxygen availability than those found in lower energy environments (JNCC, 2008). Conversely coarse gravel in a high energy environment has conditions which are so harsh that few habitats are supported (JNCC, 2008). In the rule base example worked below the geology and sediment has been augmented by the energy environment to give a clearer picture.

**3. Where it is:** The UK marine environment is characterised by complex coastal zones and an extensive continental shelf area, which transitions into the continental slope area leading to the deep sea. These zones experience a wide range of environmental parameters which influence the ecological character of the water column and seabed. The differences in the water column are also of significance when considering where the habitat and ecosystem services are present. The water column has specific physical, chemical and biological characteristics which vary depending on changes in depth, salinity, temperature, viscosity, density and light attenuation (UKMMAS, 2010). These characteristics are important because they are often synergistic and are difficult to disentangle from each other. This fluidity means that pelagic habitats are much more difficult to map temporally and spatially. For many habitats and species, an understanding of both the benthic and pelagic environment is required.

Species such as sand eels, which are considered in more detail in the ecosystem services spatial framework document, use both the sea bed and the water column at different times of their life cycle. Species in the water column can move considerable distances and therefore mapping areas of significance in this respect will be extremely challenging. With the advent of the GMES sentinel programme, Sentinel 1 and Sentinel 3 satellites will record data on ocean features including currents and wave patterns. These datasets together with advances in geo-informatic techniques will significantly enhance our ability to map ecosystem service features relating to the pelagic zone in the future.

**4. How it is managed:** The pressures and threats causing change in the marine environment include anthropogenic induced change, both from management practices on land and sea sources. Increasing economic market pressures are putting pressure on UK sea shelf and coastal habitats. Large areas of subtidal sediments have been affected by the physical impact of activities such as trawl fishing, aggregate extraction, coastal defences and building offshore wind farms which damage the benthic biota and their communities (Austen *et al.*, 2011), affecting and simplifying the services they contribute towards. Pressure from wind farm development is expected to continue in the future, particularly on shallow

sandbank areas. Future pressure and threats in the southern North Sea are likely to include an increase in tele-communications, mineral extraction and recreation (UKMMAS, 2010). Such activities can cause habitat damage and loss, increased siltation, increased sediment re-suspension, underwater noise, de-oxygenation and increased litter loads (UKMMAS, 2010). Figure 12 shows a diagrammatic representation of the different facets of the marine environment in terms of ecosystem services data relationships.

**Major ecosystem services and risks:** Oceans are the sink and source of our fresh water, having a strong role in water purification; they account for over half the world's CO<sub>2</sub> sinks, so have a strong role in climate and carbon regulation; and food resources extracted from ocean stocks represent important industrial and societal interests. Marine ecosystem services are being affected by sea temperature rise and are experiencing increased levels of ocean acidity. Marine invertebrates are essential for the microbial processing and irrigating of nutrients in the sediment. Without recycling, most of the nutrients would be lost from the ecosystem to the seabed.

The marine environment is also strongly affected by pollutants entering the system from land based issues. The effects caused by hazardous substances entering the marine environment have been reduced through the improvements in sewage treatment works and more efficient regulatory control to reduce the discharge of industrial effluent, but much has still to be done. One of the major gaps in knowledge is in our understanding of the functioning of the marine environment in relation to these risks and to the wider issue of biodiversity.

Studies have shown the profound effects of subtle changes in water conditions (Jonsson & Jonsson, 2010; The Royal Society, 2005; UKMMAS, 2010). There are critical values and thresholds beyond which major ecosystem and functionally change will occur, but in general these are poorly understood. Many are under investigation at the moment, but research tends to concentrate on certain species or pollutants. Mapping of all relevant ecosystem services will help bring the importance of the whole environment to the attention of policy makers and should assist in the identification of critical pathways, relationships and issues.

In terms of the biodiversity of the marine ecosystem there is much less understanding of marine function and biodiversity features, than there is in the terrestrial environment where food webs and habitat dynamics and their relationship to nutrient cycling is understood at a broad scale and for some habitats at a very detailed level. Within the marine environment many significant foodwebs are not fully understood particularly with regard to the energy flows and the links between the pelagic and benthic environment, plus there is only a very small proportion of the seabed which has been surveyed in UK waters. The majority of our seabed maps are predictive and modelled only e.g. UK SeaMap. Therefore, we do not even fully understand habitat distribution in UK waters. The data gaps are explain in Section 5.3.2 below in more detail.

Some particular knowledge gaps became apparent as the sand bank example was worked through within the Dogger Bank area. These are also highlighted in Charting Progress 2 (UKMMAS, 2010):

- Gaps in understanding of the functioning of the marine environment and its relationship to biodiversity, especially the complex interactions between biotic elements and the physical characteristics as mentioned above.
- Foodwebs for significant species are not fully understood, the energy flows and the links between the pelagic and benthic environments for these species need more understanding.
- Links between current human activities and pressures and marine environment. Many impacts are quite localised and further understanding is needed on the

cumulative impact of several activities and/or pressures in one area and the ability of a species or habitat to recover once a pressure is removed.

- Our understanding of fish species e.g. salmon and eel and causes of decline in their recruitment which potentially could have an effect on the provision of ecosystem services relating to food.
- How marine species will respond to increases in sea temperature and the affects this will have on the services they provide.
- Little is known about the extent and nature of environmental pressures that will arise from increasing human activity in renewable energy, coastal defence or gas storage.

In the diagram (Figure 12) we have summarised the relationships between the four aspects of knowledge (data types) about the marine environment and the ecosystem services.

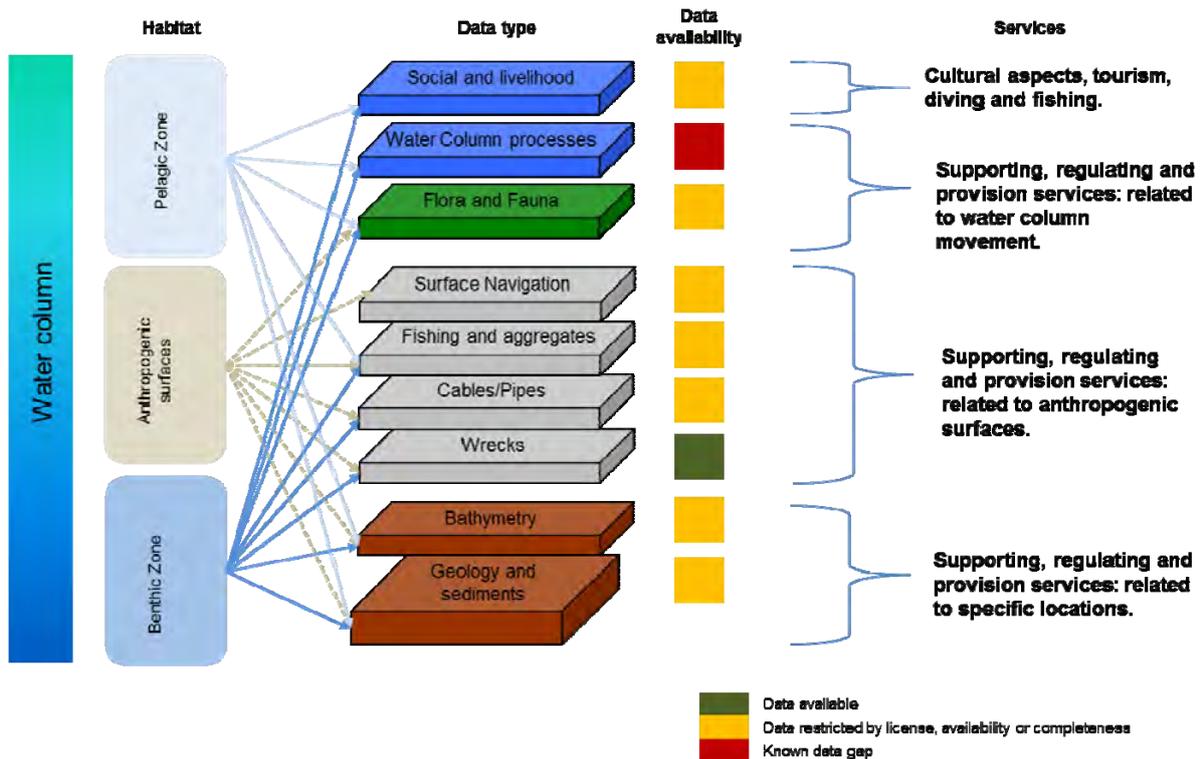


Figure 12 The marine environment and ecosystem service features obtained from existing datasets (following CBD definitions, see section 3.2)

### 5.3.2 Data

The data available for the characterisation of the marine environment, typically sample based, modelled or acquired through remote observation is very expensive to collect, due to nature of data collection methods and the technology required. Mapping and data tends to therefore be either be at a coarse level, or limited to very specific features, at a much finer more detailed level. In addition, the degree of manipulation varies depending on the quality of the data. Understanding of marine ecosystem functions, their interactions with human activities, and the availability of data supporting an ecosystem assessment are generally limited.

Mapping of human activities and ecosystem components is possible for the assessment of separate impacts on habitats and related benthic communities within the marine environment but is dependent on the extent of our understanding and the availability of

suitable data. This approach is less easily applied to assess complex cumulative effects and mobile species and presents a challenge in regards to the movement of the water column.

This work has identified many data gaps for ecosystem service assessment in the mapping of the ecosystem service productivity on Dogger Bank. These include:

- Species distribution e.g. data on meiofauna (nematode), benthic and pelagic species.
- There is a lack of data on benthic habitats in particular.
- Quantity and quality of meteorological data available.
- Small proportion of the seabed has been surveyed, with habitat maps currently only covering 10% of the UK continental shelf area. Much of the seabed data is predictive and modelled and therefore do not fully acknowledge the spatial distribution of habitats in UK waters.
- There is a need to improve the accuracy, resolution and scope of habitat maps by making the existing data more widely available and/or undertaking more surveys.
- Better models are needed which integrate and predict the interactions between biological and physical components, and human pressures at different scales.

Experience from the terrestrial case study examples suggests that other data gaps will become apparent as other ecosystem services are examined and other habitats modelled.

### 5.3.3 Mapping rationale

The map rule base and framework within this study includes the ecosystem service 'Production' > Fisheries' and examines the role of sand eel as being indicative of general production of fish stocks related to a habitat of significant importance within the southern North Sea and Dogger Bank area. The requirements of sand eel species are therefore highlighted in the information below. The following two tables set out the rationale for choosing this species as a comparator to terrestrial production.

Table 11 below sets out the thinking behind the rule base for a terrestrial food provision service and a marine one. It highlights some of the difference and similarities.

**Table 11 Comparison of rule base options between land based and marine services**

<b>Land-based provisioning service - food</b> <b>Example service – beef and sheep production</b>	<b>Marine-based provisioning service - food</b> <b>Example service – sand eel / fish production</b>
<p>There are datasets which record the number of animals held against registered holdings. However these are very broad scale and cannot simply be disaggregated because:</p> <ul style="list-style-type: none"> <li>• We do not know if those animals are mainly present in that area, or where it is just the farm address.</li> <li>• We also do not know how the animals move about between lowland and upland as the seasonality of sheep / beef production is quite marked.</li> </ul>	<p>We have fish catch data from the whole of the North Sea, but do not have catch information related to just the Dogger Bank or even a small part of it.</p> <p>Fish catch data are more problematic than agricultural data as they are much more difficult to track:</p> <ul style="list-style-type: none"> <li>• The species are more mobile than terrestrial species and have different mobility at different stages of their life cycle</li> <li>• Modern fisheries vessels have a very large catch area</li> <li>• The picture is further complicated by the role of the factory ships which can offload catches whilst at sea and land them under a</li> </ul>

<p>Therefore we have had to model the carrying capacity of the land, rather than having an absolute number already available to us in a data base.</p>	<p>different flag in a different location. Therefore, as with the situation on land we need to model the potential for fisheries or production rather than directly fish numbers.</p>
<p>Land carrying capacity is related to the inherent productivity of the land (its soil type, habitat (natural or sown) and location in the landscape) and to the management regime imposed upon it, that is the fertiliser input and the grazing regime.</p> <p>The geology, soil, landform and habitat types can be gained from direct datasets. We have no direct information on management, in some instances the landscape context, sizes of field and productivity of the habitat can be used to give a proxy of management where there is good knowledge about the types of systems practiced in the area and their manifestations in the landscape.</p>	<p>Sand eel / fish production is related to the sediment type, the energy of the waves in relation to its depth and salinity. In addition, the number of different habitats in an area as providing different niches will enhance overall diversity.</p> <p>In this example we have considered the habitat distribution of sand eels and where habitats are suitable? This can be used to indicate high productivity of fish for food. This is because a large and healthy sand eel population is important in its own right as it is fished for fertilizer and feed products; also sand eel species are significant in terms of other fish which predate them such as haddock and whiting which are also commercially important fish stock. Other predators which feed on sand eels include Minke whale, Puffins and Kittiwake, these species add considerably to the biodiversity of the area.</p> <p>We have direct data on sediment, bedform, wave energy, depth and sand eel nursery and spawning grounds. We have some data on fishing effort, where management practices can be to a certain extent inferred from shipping lane information, but this is tentative. It does not equate to the information available or modelled in the terrestrial environment. Within the terrestrial environment the amount of modification to a habitat can be ascertained from data sets on land use. Within the marine environment we have some information of non-biogenic structures. As structures such as wrecks offer hard bottom substrates they can assist the development of communities that are often rich in terms of diversity (BEWREMABI, nd).</p>

Table 12 shows the thinking behind the different aspects of the rule base and the datasets that have been scored and modelled to give a representation of the food production potential from sand eels in the southern part of the North Sea. This thinking could be further enhanced and developed to build in data that relates to other species of fish and their requirements, these could then be added into the model to enhance its representation of the provision of a food service overall.

The key aspects which influence the delivery of ecosystem services are the four fundamental features and the evaluation criteria described earlier in this section as shown in Table 12 below.

**Table 12 Showing aspects related to the development of the marine rule base**

<b>Aspects influencing ecosystem service provision.</b>	<b>Features relating to fish productivity, to be included in the rule-base.</b>	<b>Possible datasets to be used in the rule-base.</b>
<b>What the habitat is</b>	Sediment type	Predictive Habitat Model (Level 3 or Level 4 EUNIS description information)
<b>What the habitat is formed on</b>	Seabed sediments	DEM at 1 sec 1:250,000 seabed sediments
<b>Where the habitat is</b>	Water column features (e.g. energy level and major tidal currents) Light level Preference for an oxygenated environment	High energy information  Biological Zones Predicted habitat model 'Comb energy' information Depth area or DEM information
<b>How the habitat is managed</b>	Wrecks  Pipelines Cables Pile driving activities for wind farm construction Dredging, fishing and transport routes	SO_Wrecks data set (UKHO)  Offshore installations (UKHO) Offshore installations (UKHO) Offshore wind farm sites (Crown Estates) All passage routes (potentially includes dredgers)

### **5.3.4 Evaluation of ecosystem services in a marine habitat**

The marine spatial framework included in Appendix 1 explores the ecosystem services provided by sub tidal sediments. Natural England (2012) identified that sub tidal sediments (EUNIS codes A5.1 to A5.4) are important for various marine ecosystem processes which contribute towards the delivery of the following ecosystem services: aquaculture, fisheries, environmental resilience and regulation of pollution. The spatial framework aims to identify applicable ecosystem attributes that underpin the ecosystem service which through the integration of knowledge and data can be modelled and mapped.

On this basis, a map showing production pertaining to sand eels on the Dogger Bank was unable to be finalised. During the project, it was identified that there are significant gaps in knowledge and data availability which did not provide sufficient information to accurately reflect the ecological processes underpinning production pertaining to sand eels. As the mapping is an iterative and expert led process it will be possible to add additional data, as it becomes available, into this framework to complete the mapping.

### **5.3.5 Marine ecosystem service mapping summary**

The case study work has shown that the ecosystem services spatial framework approach has potential for assessing marine ecosystem services. Currently there is a lack of readily available data and well understood methods for deriving proxies to fill the missing information gaps. However, the evidence base is still advancing through various research consortiums e.g. European Marine Ecosystem Observatory (EMECO), literature and reports with data sharing becoming more available through archive centres like MEDIN. This should mean that both knowledge and data for marine ecosystem services will be enhanced rapidly in the future.

For marine ecosystem services this project has shown:

- The extent of knowledge of the functioning of ecosystem services in the marine environment is not as advanced as that in the terrestrial environment. Knowledge

currently available suggests the marine environment plays an equally significant if not more significant role in overall ecosystem services as the terrestrial systems and therefore these knowledge gaps need to be filled with some urgency if we are to understand the system adequately.

- The extent of data on the marine environment and the quality is also not as robust as that in the terrestrial environment. There is enough to begin the mapping process, however several iterations will be necessary before the modelling is representative of productivity in terms of sand eels in the Dogger Bank case study.

Gaps in both data and knowledge mean that mapping of ecosystem services in the marine environment is inevitably coarse and lacks detail. In the terrestrial environment gaps in data can often be filled by using proxy datasets that provide an approximation of the extent of a missing or inconsistent dataset (for example using the Phase 1 habitat data and topography features to model soil carbon in Scottish Borders). In the marine environment proxy datasets are not sufficiently advanced to help fill these gaps in the same way.

Advancing the capabilities of ecosystem service mapping is an important step in developing an approach to assess and understand ecosystem service provision in the marine environment. Progress has been made towards this, through the availability and widespread application of datasets and improved models as highlighted by the Charting Progress 2 report (UKMMAS, 2010). However, although such progress is being made, marine environments and their associated processes remain much less understood.

To advance this understanding there needs to be increased research, knowledge sharing and open data policies to underpin the widest understanding of the role of marine environments in ecosystem service provision

## 6 Forward Look – progressing the spatial framework approach

The framework approach provides a logical and transparent process for evaluating the role of habitats in delivering ecosystem services which can be extended to other habitats and other ecosystem services.

### Knowledge and understanding

Understanding of the relationships between terrestrial habitats and ecosystem services is generally good for most regulating, provisioning and supporting services, although less so for cultural services. Understanding for marine habitats is generally poor.

### Terminology

Similar terminology is used in literature to explain both terrestrial and marine concepts but on occasion the same term may have different meanings depending on its context e.g. carrying capacity

### Data

The project has shown the wide range of terrestrial datasets currently available for evaluating regulating, provisioning and supporting services, although data availability is generally poorer for cultural services. The differences that exist in quality, resolution and scale are further illustrated by the case study mapping.

There is a need for more consistent and compatible data across wider areas of the terrestrial landscape to support decision-making at a variety of spatial scales. Consideration of fitness-for-purpose is also important; high quality data is not always required, especially for strategic purposes, but for more local practical planning purposes high quality high resolution data provides a more effective tool.

For marine habitats the provision of more data generally is a key requirement. Data that does exist is not readily available, is costly and can often be in a complex raw format.

A consequence of higher quality and higher resolution data is that mapping calculations become more computer-intensive and this must be taken account of in any wider mapping undertaken.

### Mapping

Each case study has been mapped independently. There has been no attempt to make value judgements between areas. A major issue in wider mapping is in ensuring data scoring and weighting compatibility across wider areas, especially where data is inconsistent or incomplete.

Mapping is dependent on rule-bases. Rule-bases can be designed to achieve consistency and compatibility across wide areas, providing there is good understanding of the relationship between the habitat attributes being mapped and ecosystem service delivery.

### Transferability

Next steps include:

- Application to other habitats

The process should be applicable to other habitats, whilst accepting that understanding and data is much less developed for marine habitats.

- Application to other ecosystem services

The process should be applicable to other ecosystem services. Again, as the services examined become less well understood, the mapping becomes more difficult. It may be possible to generate a library of generalised habitat attributes for different habitats to use as a proxy baseline where directly applicable data doesn't exist.

- Extension to wider UK mapping

The case studies are small regional areas. Extending the mapping to larger, possibly national areas, will involve consideration of the following factors:

- The data availability, in terms of both coverage and resolution.
- The rule-base used is key to mapping, using existing knowledge to identify how to score attribute contributions and relative weightings to be used in a transparent way. For example, the rule-base can be used to weight data differently across the UK, which will be vitally important in taking account of regional differences in climate (with say, a rainfall gradient from west to east, and a temperature gradient from north to south – which will go some way to explaining and weighting differences in ecosystem service delivery across the UK).
- The mapping process often requires the combination of data at different scales and resolutions.
- The mapping process and colour ramp used is important in providing maps that are clear and understandable.

In a practical application of the mapping to local development issues there is a need to identify not just the importance of habitats but also the synergies and trade-offs necessary to achieve the optimal land use strategy. Synergies identify where habitats are mutually beneficial with other land uses (such as recreation and cultural use). Trade-offs identify where habitats and other uses are mutually exclusive (such as with urban type development)

## **The framework**

Key to an evaluation of the application of the framework are the three main criteria on which the tier table is based:

- a) The overall importance of the habitat for that service.
- b) The general state of knowledge about the relationship between the habitat and the service.
- c) The quality and availability of the data that exists to help quantify and map the service.

Key conclusions arising from the framework are:

- A framework is an appropriate means of showing how habitats contribute to ecosystem service delivery.
- It provides a logical and transparent process that can be developed as the understanding and data about habitats improves in future.
- The framework format is transferable to other habitats and other ecosystem services.
- In terms of specific habitats, the terrestrial habitats evaluated (woodlands and grasslands) are those for which generally good understanding and datasets exist (except for cultural services, the understanding of which is not as fully developed)

- In contrast, marine habitats (of which sandbanks were evaluated) are much less developed in terms of understanding and availability of datasets

### **The case studies**

Key conclusions from the case studies are:

- The data available, in terms of both coverage and resolution, is key to the possibility and reliability of mapping
- Where direct data are not available, proxy data can often be used effectively and habitat attribute data can often provide this proxy.
- A rule-base is key to mapping, using existing knowledge to identify scores and relative weightings to be used in a transparent way and to show the spatial distribution of ecosystem service delivery. The scores and weightings are based on current understanding of the habitat attributes, and applied to the datasets that exist.
- The mapping process often requires the combination of data at different scales and resolutions. The scale of the data is important in judging how the maps can be used. Low resolution data is often acceptable for strategic mapping purposes but high resolution or very high resolution data is required for effective local planning purposes.
- The mapping process and colour ramp used is important in providing maps that are clear and understandable

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**AGRICULTURALLY IMPROVED GRASSLAND**

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## **Appendix 1 – Framework, guidance documents and other outputs**

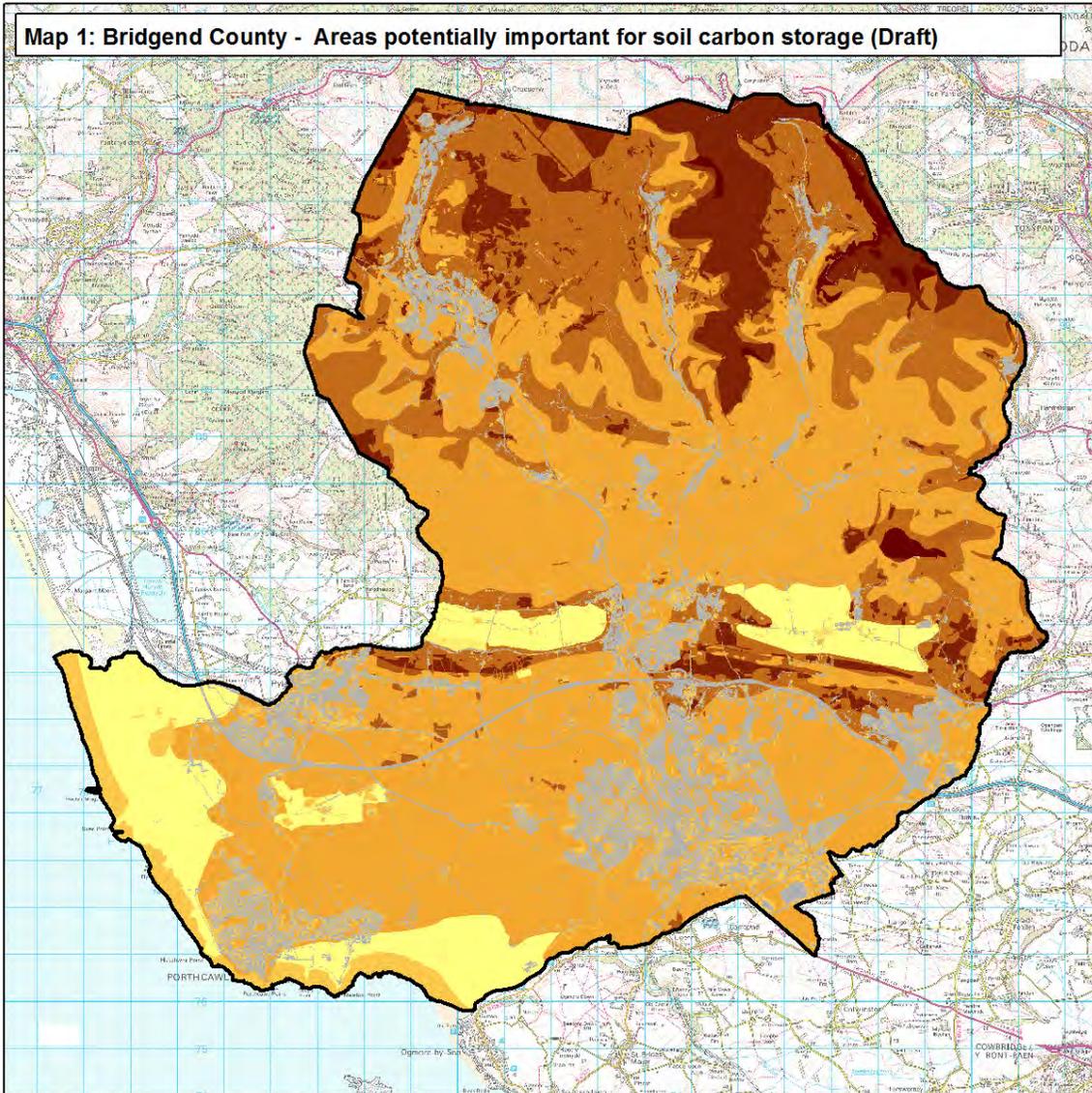
In addition to this report and attached maps, other documents and maps produced as a part of the spatial framework project output include:

1. Framework data tables, which set out, for each ecosystem service, all the habitat attribute data identified and used. These are available as .xls files
2. Framework tier tables – which set out the resultant tier into which each habitat falls for each ecosystem service. These form part of the framework data tables.
3. Handbook and user manual – which sets out a user guide to the framework data tables, defining and explaining all the data used. This is available as a separate document.

## Appendix 2 – Ecosystem Service Maps

Map	Case study area and ecosystem service	
1	Areas potentially important for soil carbon storage	Bridgend County
2	Areas potentially important for soil carbon storage	Scottish Borders
3	Areas potentially important for soil carbon storage	Norfolk Broads Catchment
4	Areas potentially important for vegetation carbon storage	Bridgend County
5	Areas potentially important for vegetation carbon storage	Scottish Borders
6	Areas potentially important for vegetation carbon storage	Norfolk Broads Catchment
7	Areas potentially important for regulating surface water run off	Bridgend County
8	Areas potentially important for regulating surface water run off	Scottish Borders
9	Areas potentially important for regulating water availability	Norfolk Broads Catchment
10	Areas potentially sensitive to erosion	Bridgend County
11i	Areas sensitive to erosion <i>The model includes NATMAP Vector data</i>	Purbeck (AONB)
11ii	Areas sensitive to erosion <i>The model includes NATMAP Soilscales data</i>	Purbeck (AONB)
12	Areas potentially important for timber provision	Bridgend County
13	Areas potentially important for timber provision	Scottish Borders
14	Areas potentially important for agricultural goods provision	Bridgend County
15	Areas potentially important for agricultural goods provision	Scottish Borders
16	Areas potentially important for agricultural goods provision	Purbeck (AONB)
17	Landscape aesthetics	Bridgend County
18	Landscape aesthetics	Purbeck (AONB)
19	Estimated biodiversity provision: relative importance, connectivity and diversity	Bridgend County

Map 1: Bridgend County - Areas potentially important for soil carbon storage (Draft)



**Key**

 Bridgend County Boundary

 Urban areas

**Carbon stored in soils**

 High

 Low

Acknowledgements to CCW for their kind permission in allowing the inclusion of the SCCAN ecosystem services layers for this piece of work.

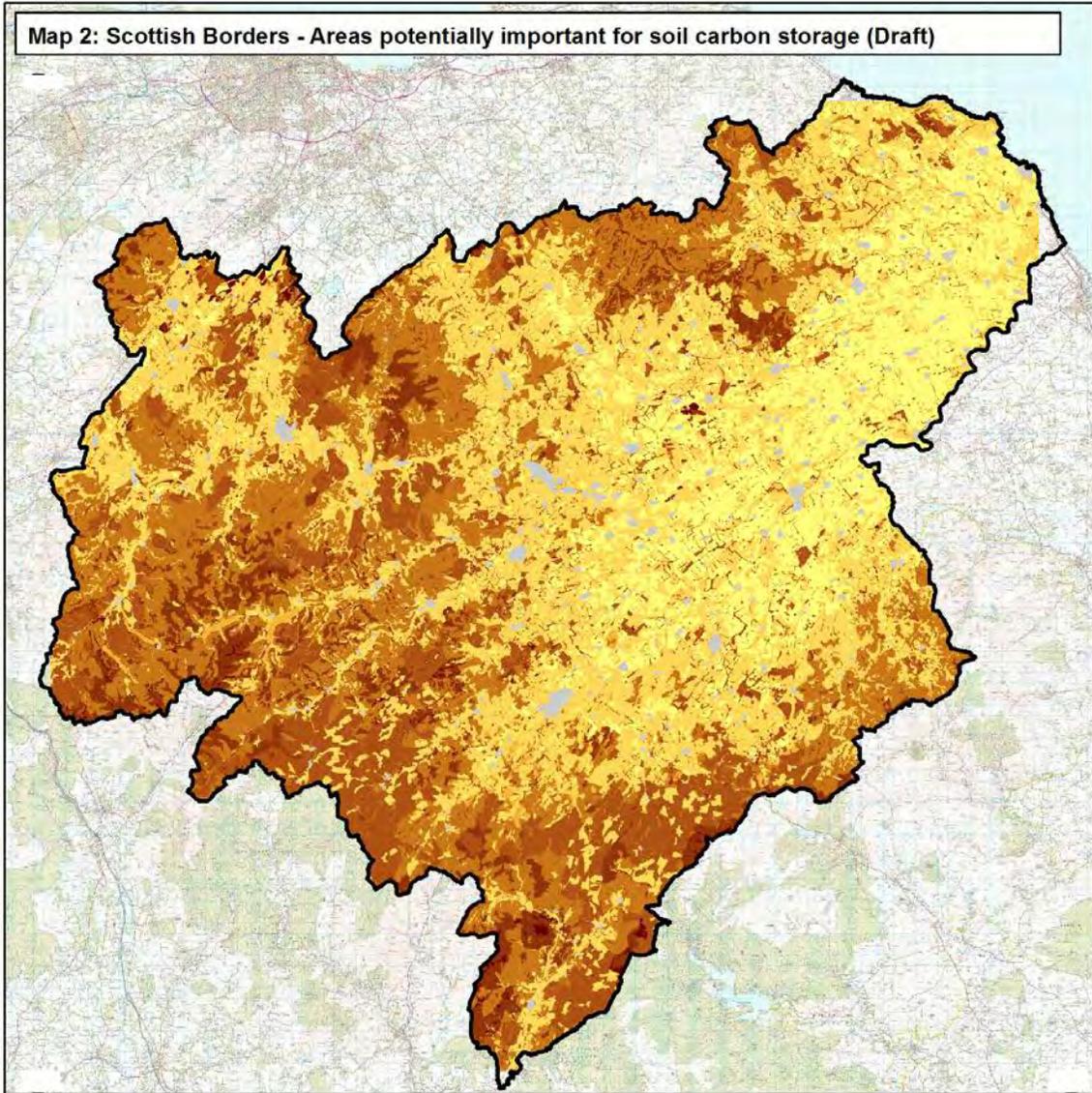


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Map 2: Scottish Borders - Areas potentially important for soil carbon storage (Draft)



**Key**

 Scottish Borders Council Boundary

 Urban areas

**Carbon stored in soil**

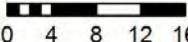
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Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

Acknowledgements to the Scottish Borders Council for providing data to include in the ecosystem services mapping.

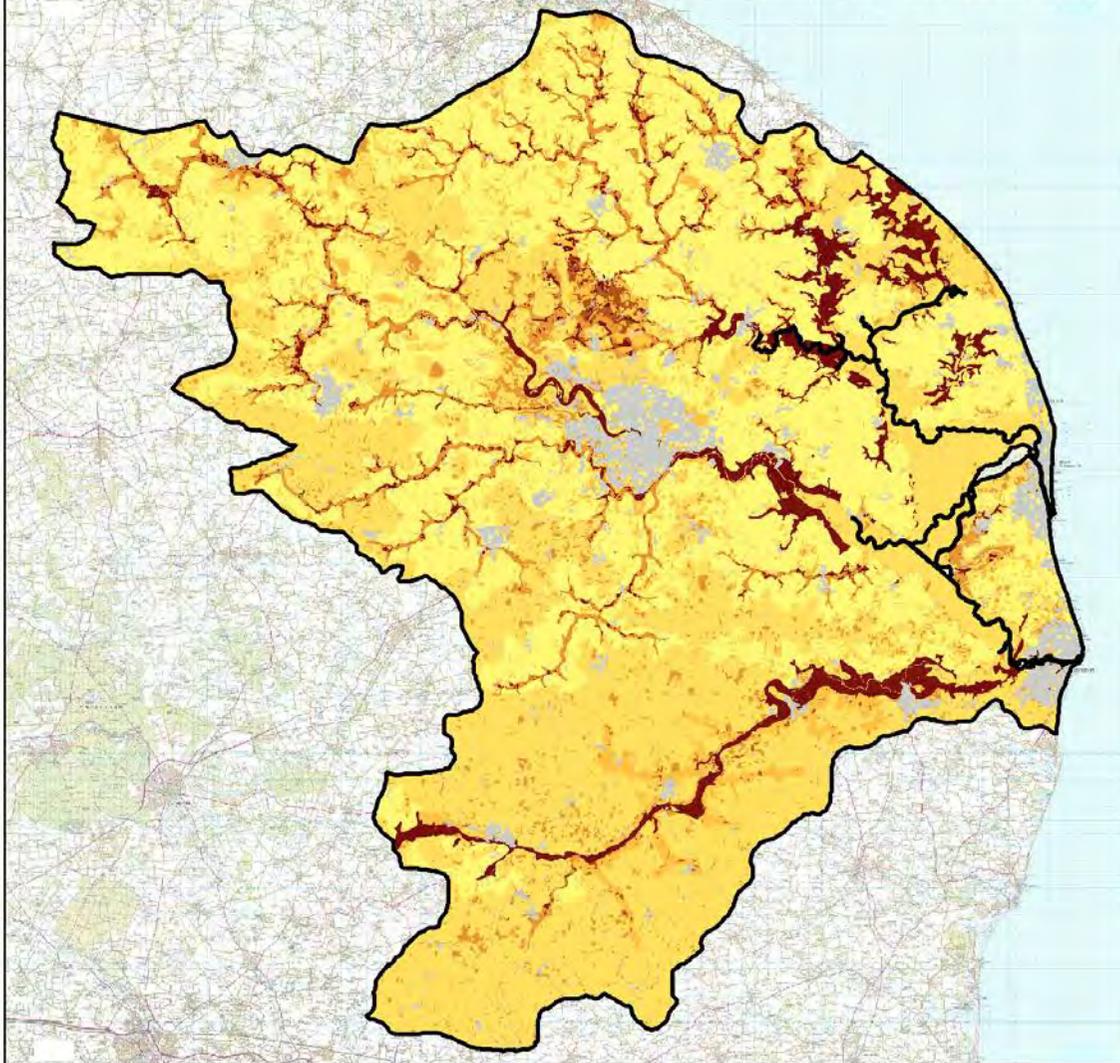


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Map 3: Norfolk Broads Catchment - Areas potentially important for soil carbon storage (Draft)



**Key**

 Norfolk Broads Catchment Boundary

 Urban areas

**Carbon stored in soils**

 High

 Low

Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

**Acknowledgements to:**

Norfolk Broads Authority, Norfolk Biodiversity Information Service, Norfolk County Council, Norfolk Wildlife Trust and [www.uklakes.net](http://www.uklakes.net) for providing data to include in the ecosystem services mapping.

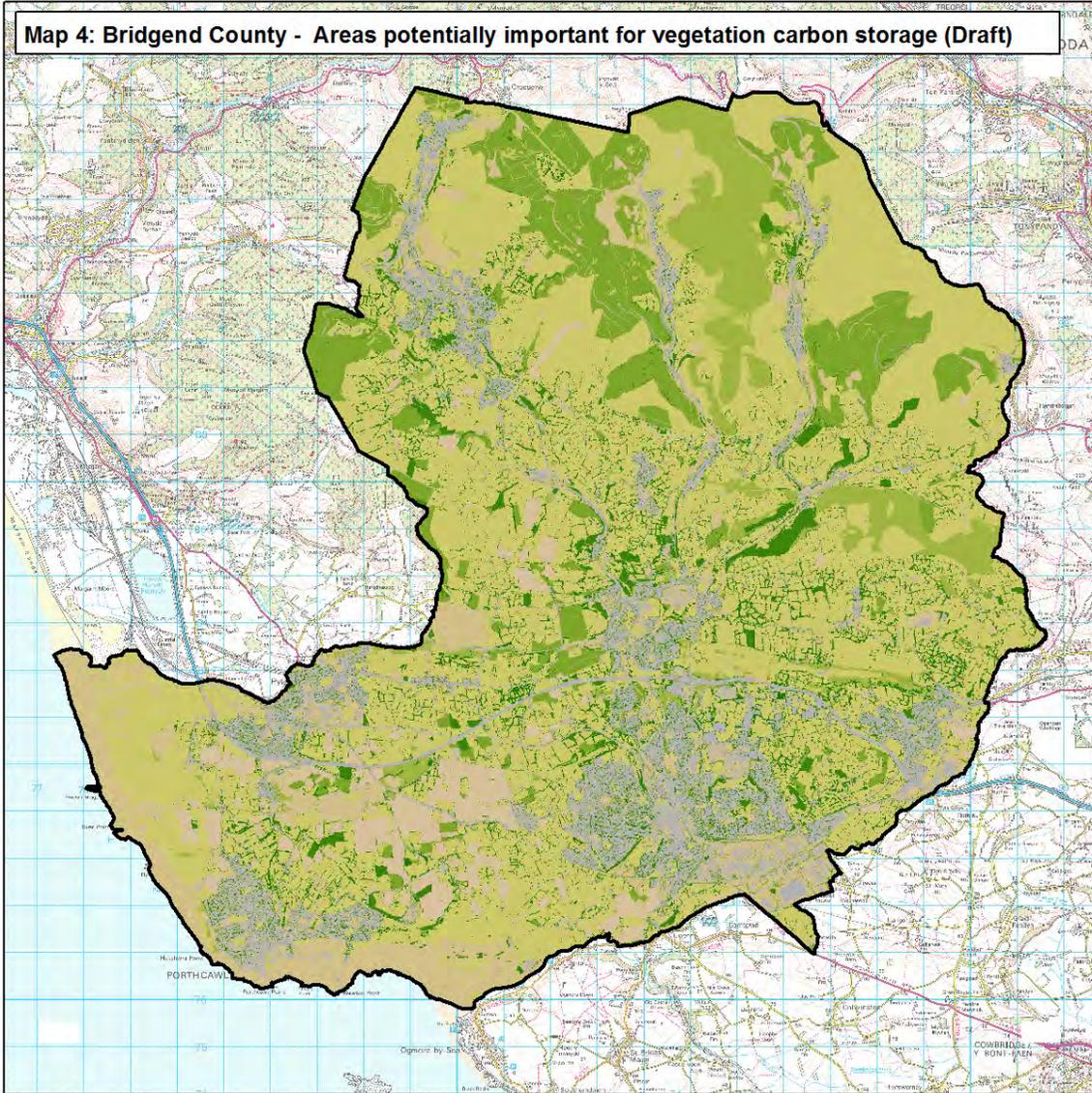


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Map 4: Bridgend County - Areas potentially important for vegetation carbon storage (Draft)



**Key**

 Bridgend County Boundary

 Urban areas

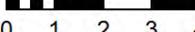
**Carbon stored in vegetation**

 High

 Low

Acknowledgements to CCW for their kind permission in allowing the inclusion of the SCCAN ecosystem services layers for this piece of work.

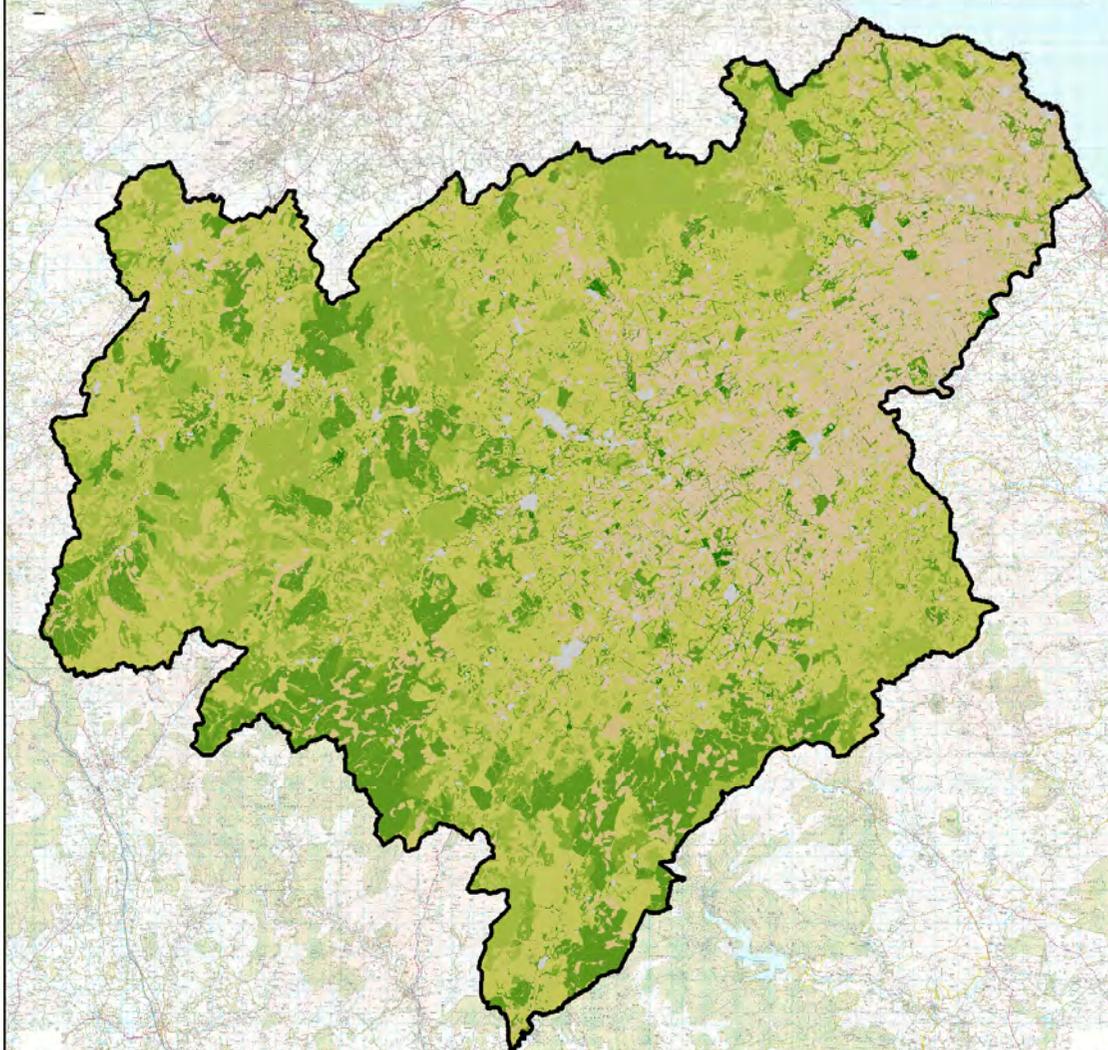


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Map 5: Scottish Borders - Areas potentially important for vegetation carbon storage (Draft)



**Key**

 Scottish Borders Council Boundary

 Urban areas

**Carbon stored in vegetation**

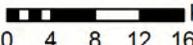
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Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

Acknowledgements to the Scottish Borders Council for providing data to include in the ecosystem services mapping.

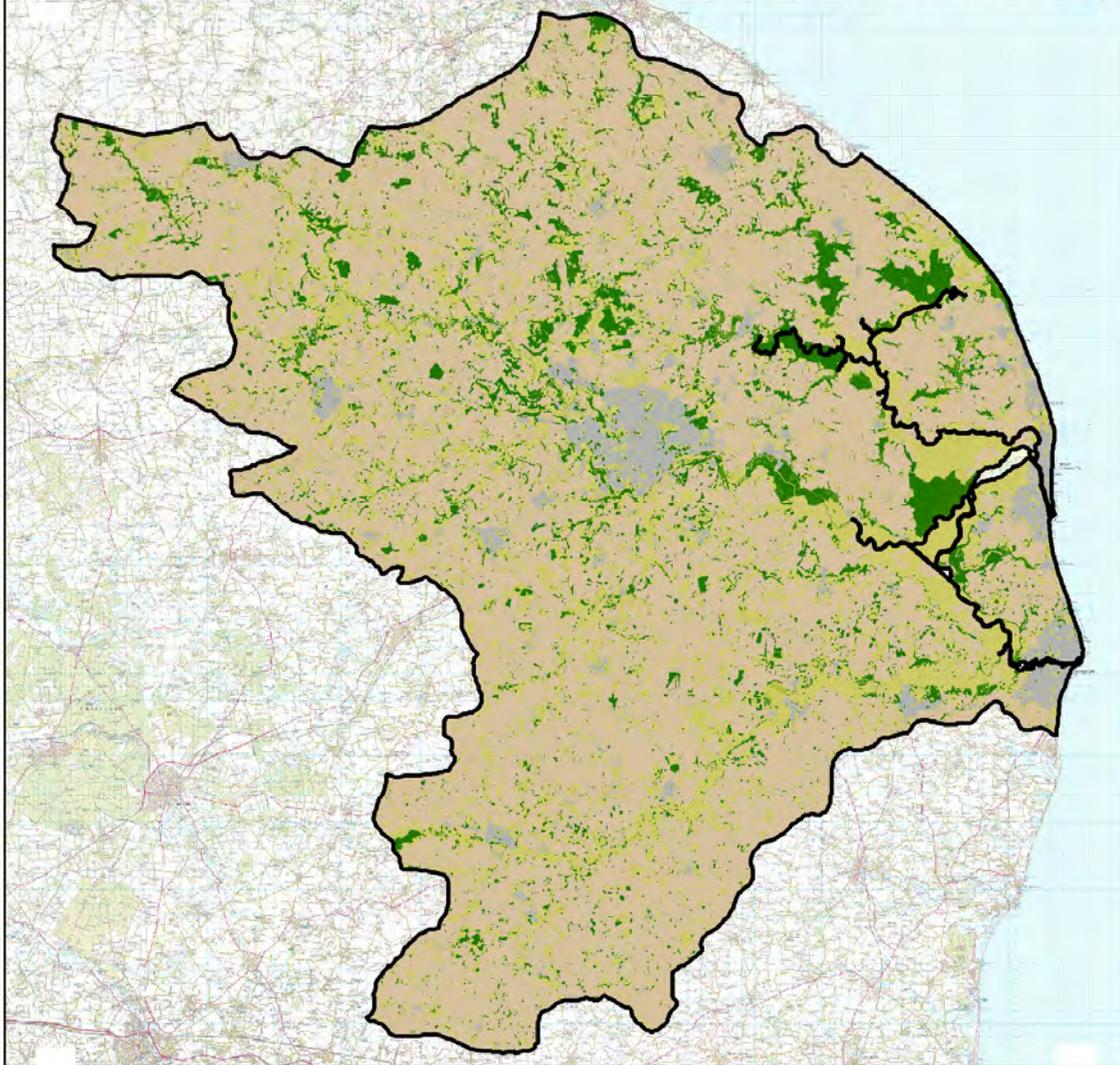


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Map 6: Norfolk Broads Catchment - Areas potentially important for vegetation carbon storage (Draft)



**Key**

 Norfolk Broads Catchment Boundary

 Urban areas

**Carbon stored in vegetation**

 High

 Low

Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

**Acknowledgements to:**

Norfolk Broads Authority, Norfolk Biodiversity Information Service, Norfolk County Council, Norfolk Wildlife Trust and [www.uklakes.net](http://www.uklakes.net) for providing data to include in the ecosystem services mapping.

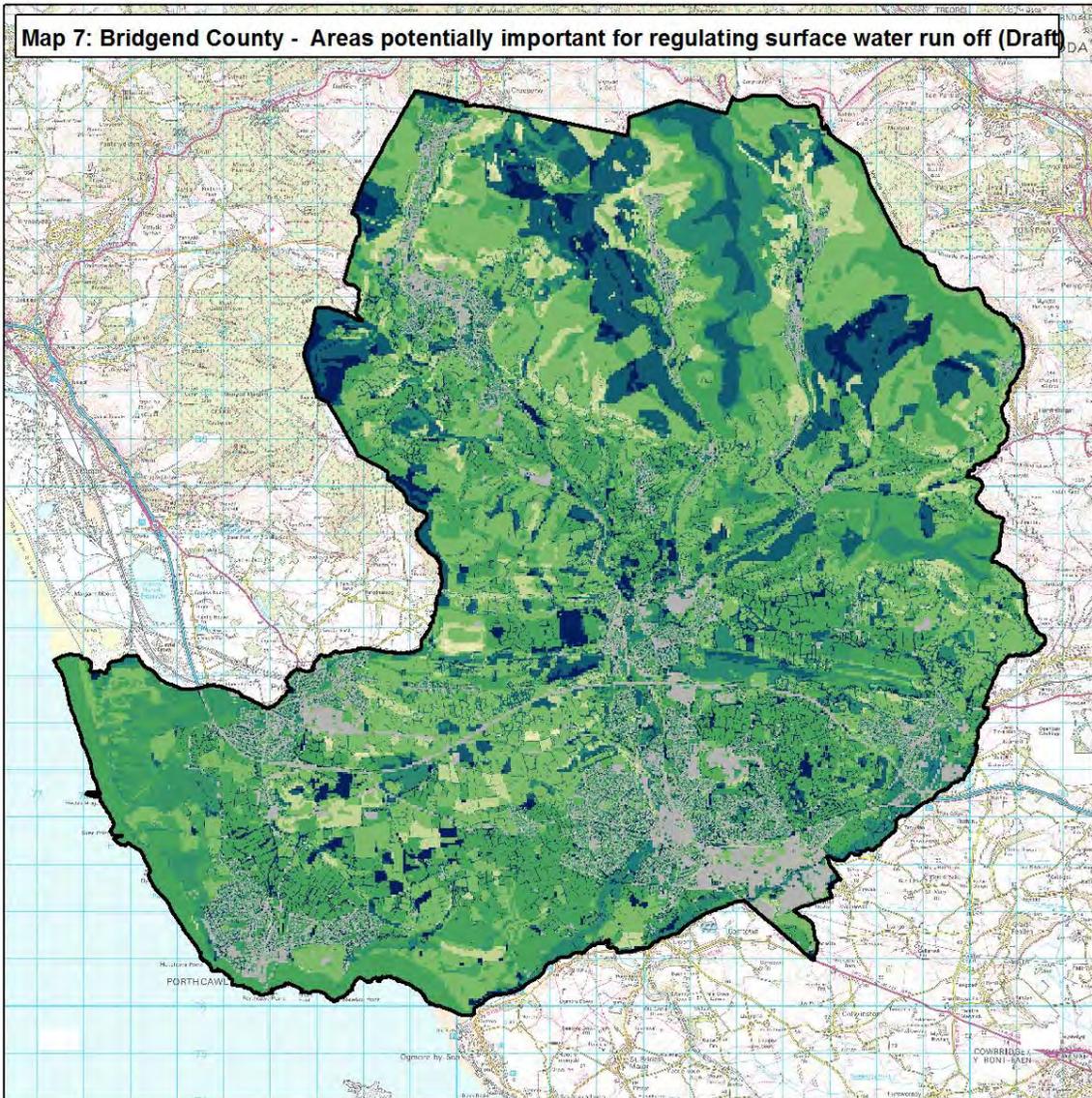


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Map 7: Bridgend County - Areas potentially important for regulating surface water run off (Draft)



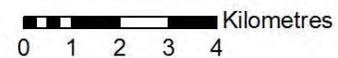
**Key**

-  Bridgend County Boundary
-  Urban areas

**Areas potentially regulating surface water run off**

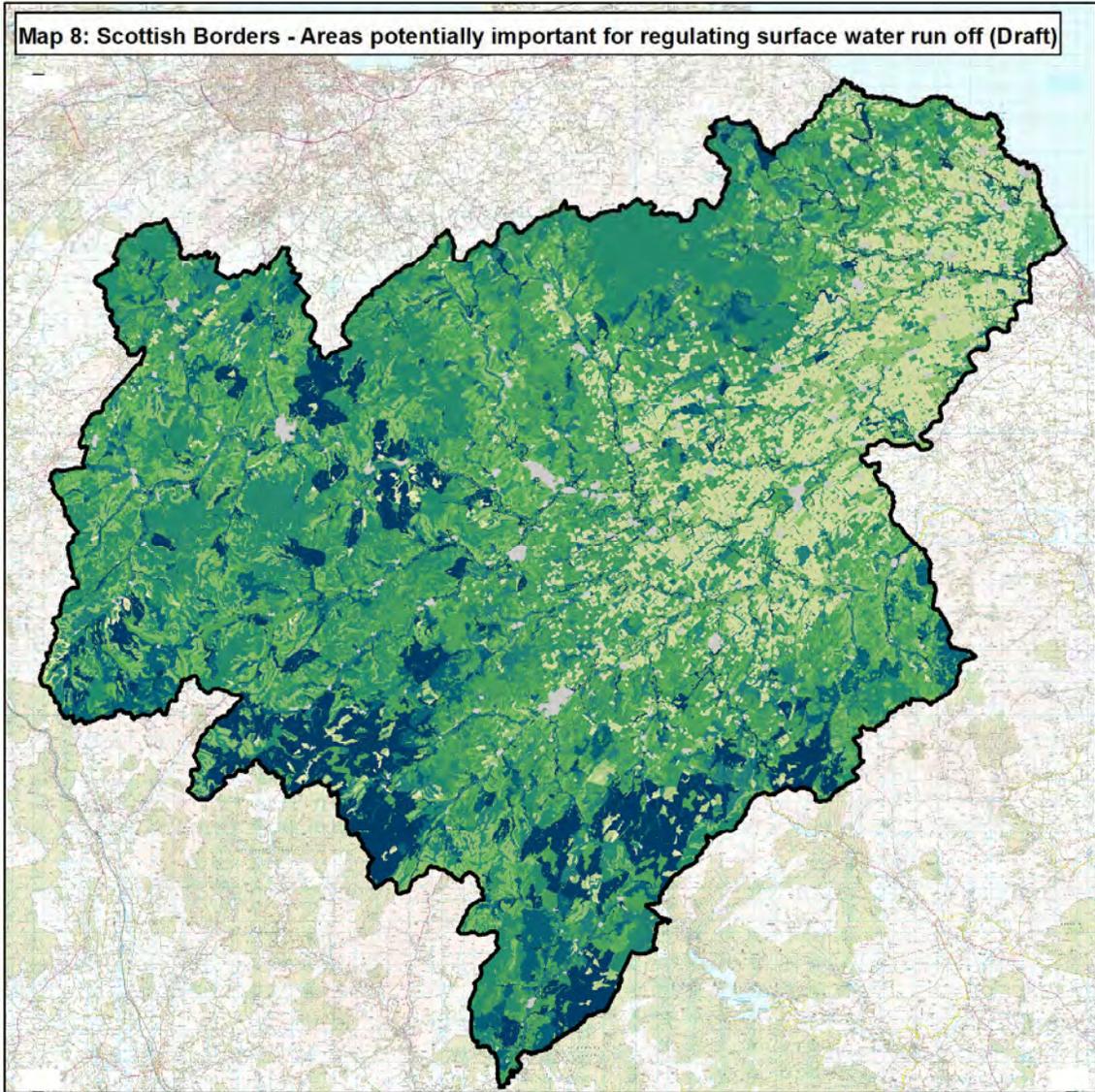
-  High
-  Low

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Map 8: Scottish Borders - Areas potentially important for regulating surface water run off (Draft)



**Key**

 Scottish Borders Council Boundary

 Urban areas

**Areas potentially regulating surface water run off**

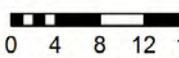
 High

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Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

Acknowledgements to the Scottish Borders Council for providing data to include in the ecosystem services mapping.

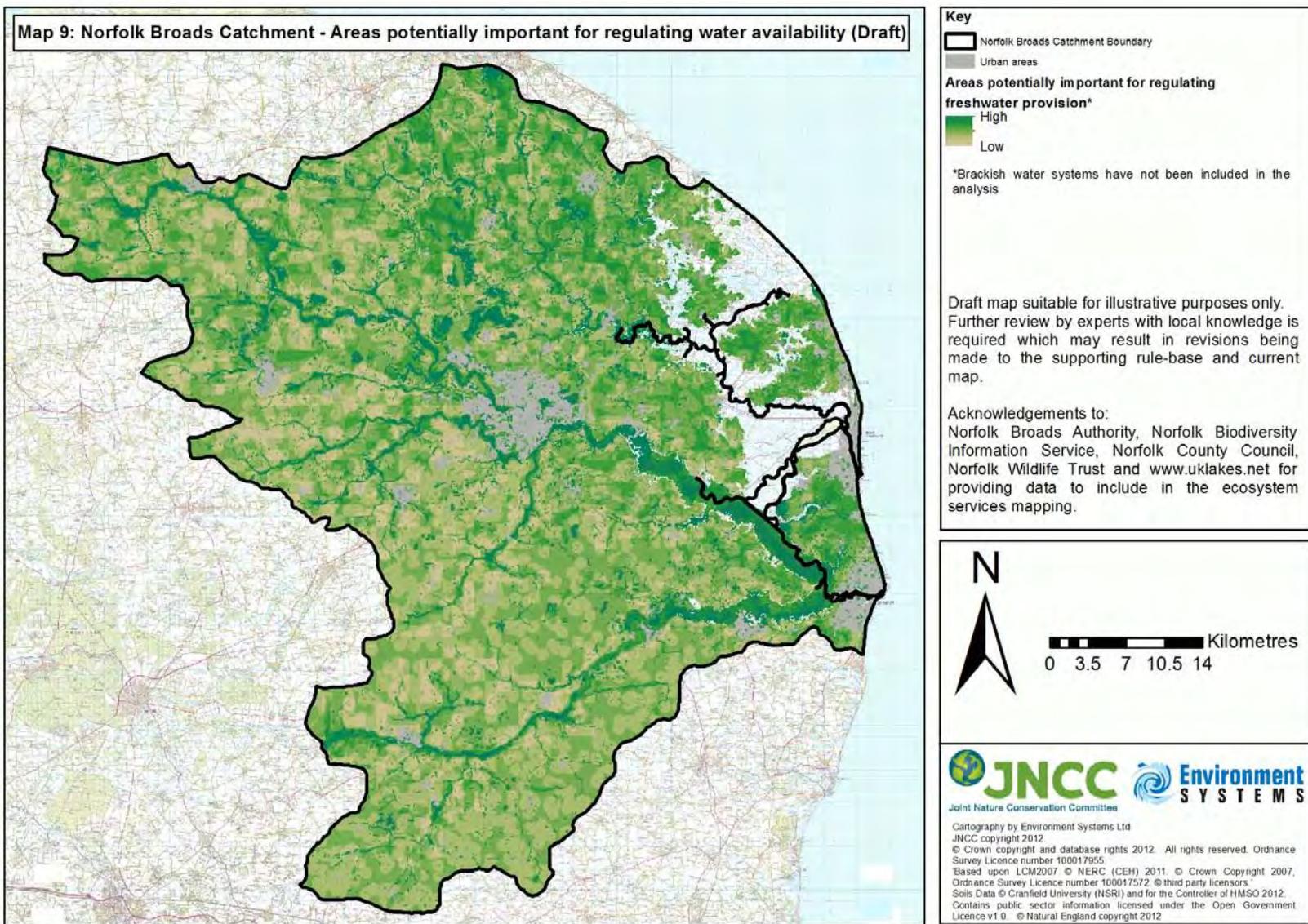


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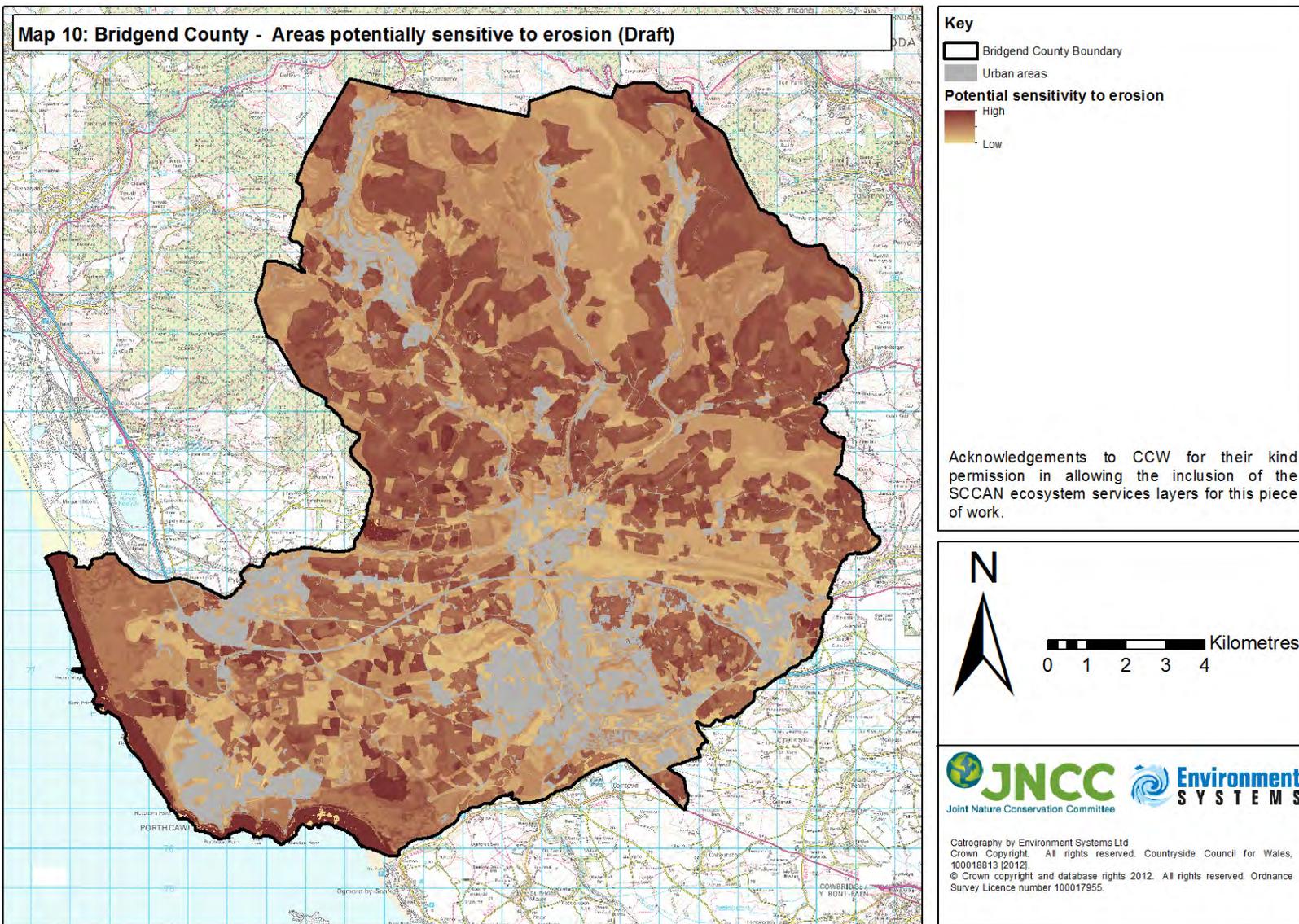


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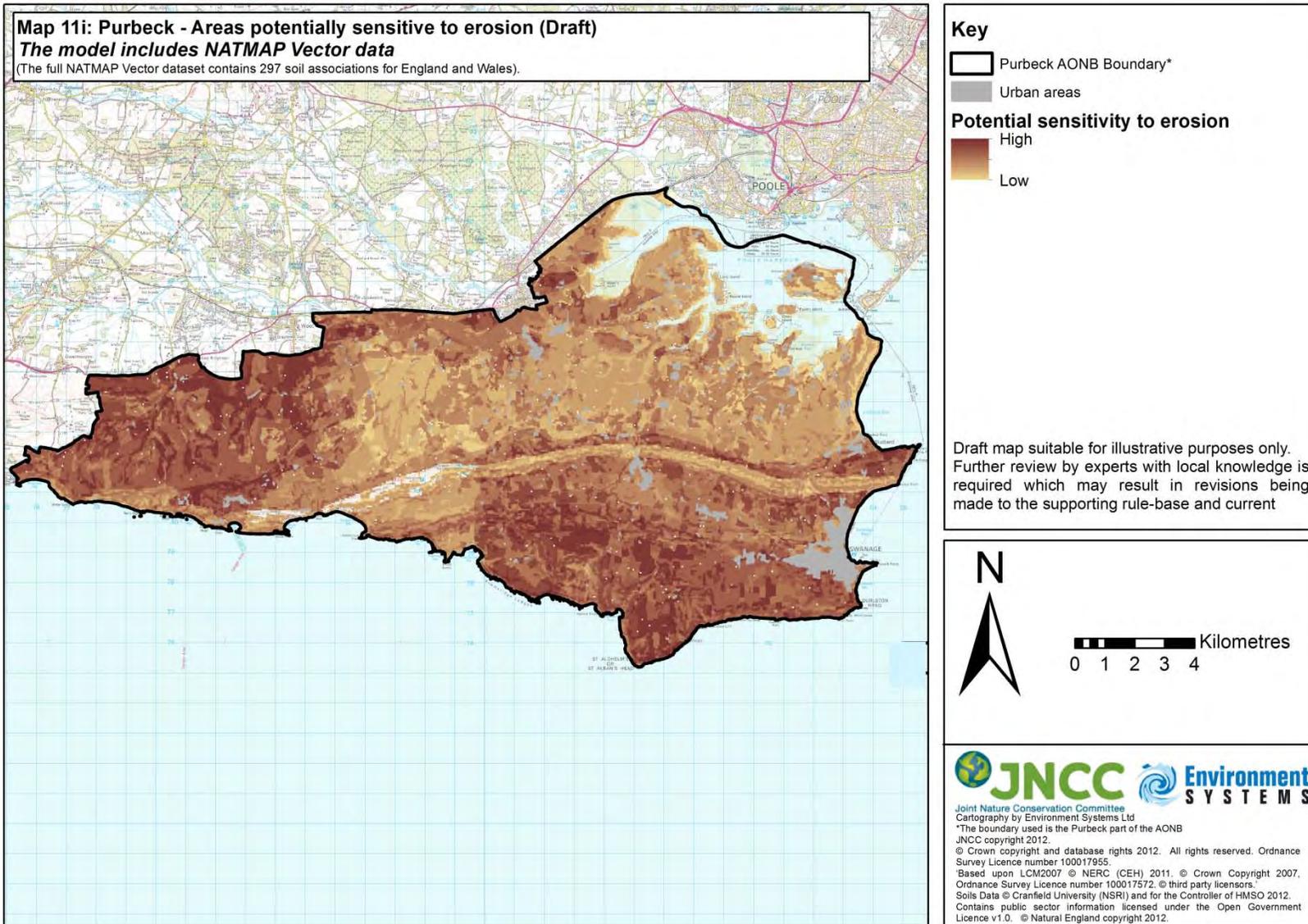
Spatial framework for assessing evidence needs for operational ecosystem approaches



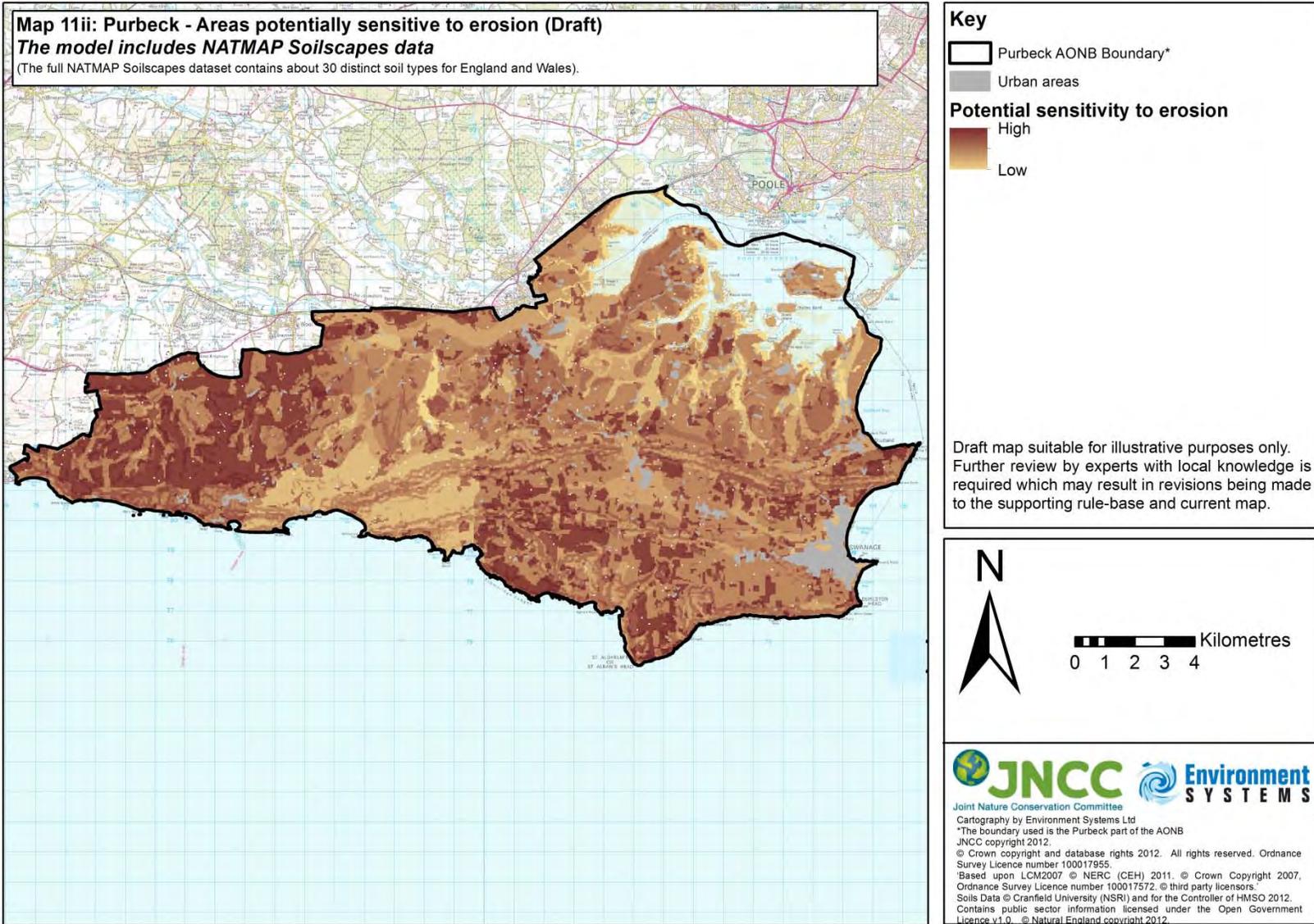
Spatial framework for assessing evidence needs for operational ecosystem approaches



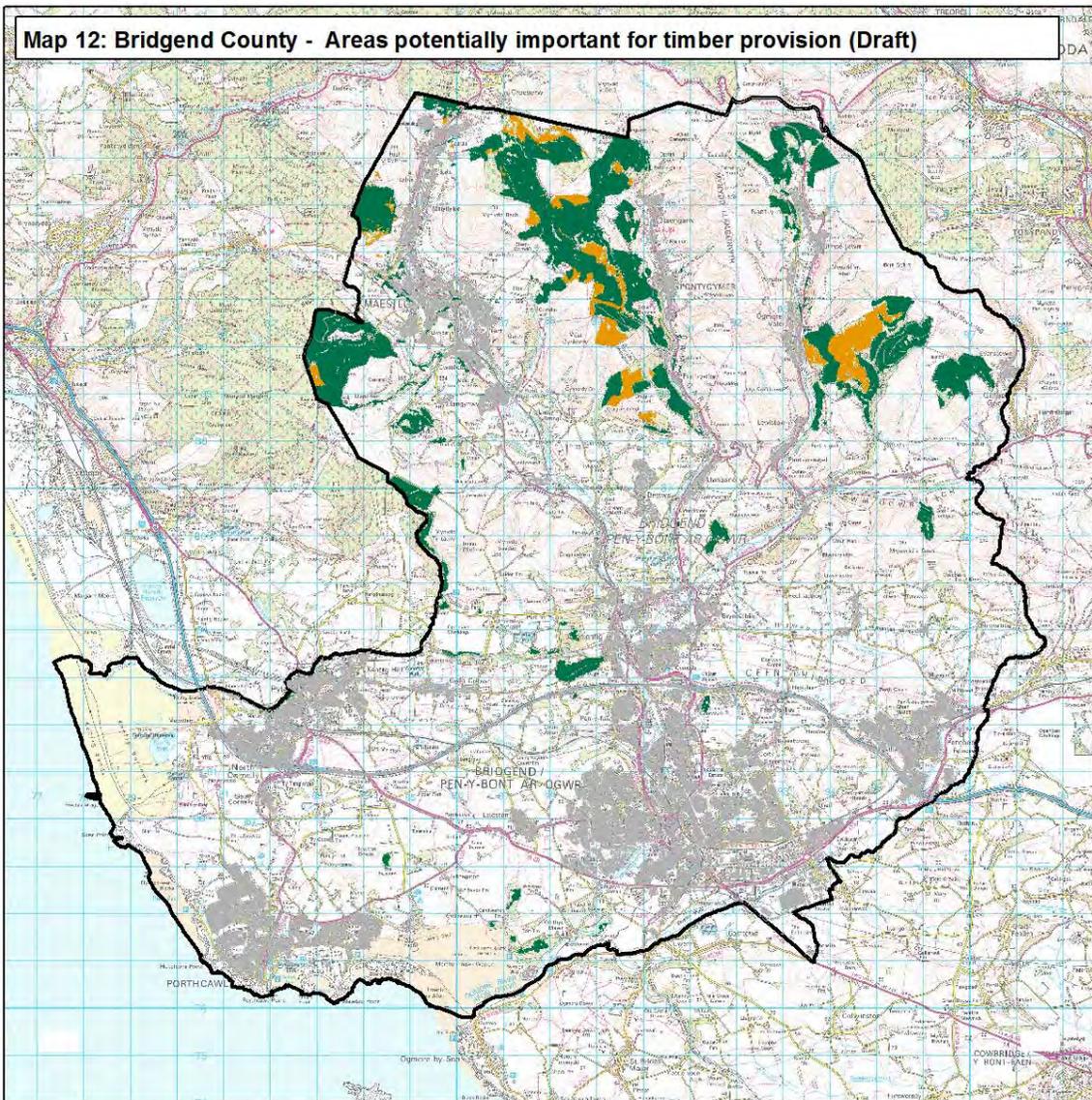
Spatial framework for assessing evidence needs for operational ecosystem approaches



Spatial framework for assessing evidence needs for operational ecosystem approaches



Map 12: Bridgend County - Areas potentially important for timber provision (Draft)



### Key

- Bridgend County Boundary
- Urban areas
- Timber provision**
- Felled
- Coniferous plantation

Acknowledgements to CCW for their kind permission in allowing the inclusion of the SCCAN ecosystem services layers for this piece of work.

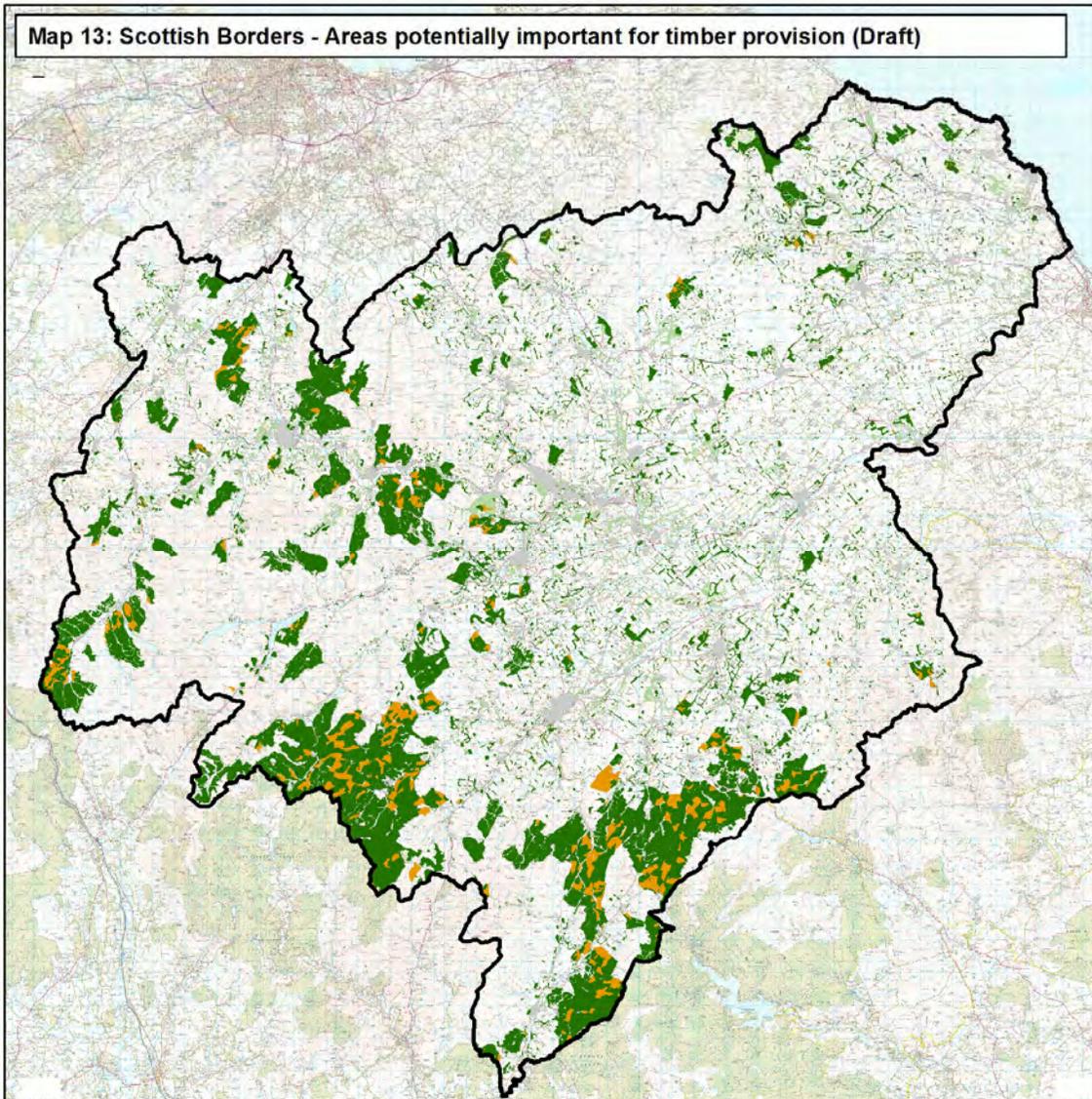


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Map 13: Scottish Borders - Areas potentially important for timber provision (Draft)



**Key**

 Scottish Borders Council Boundary

 Urban areas

**Timber Provision**

 Felled

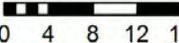
 Mixed Plantation

 Conifer

Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

Acknowledgements to the Scottish Borders Council for providing data to include in the ecosystem services mapping.



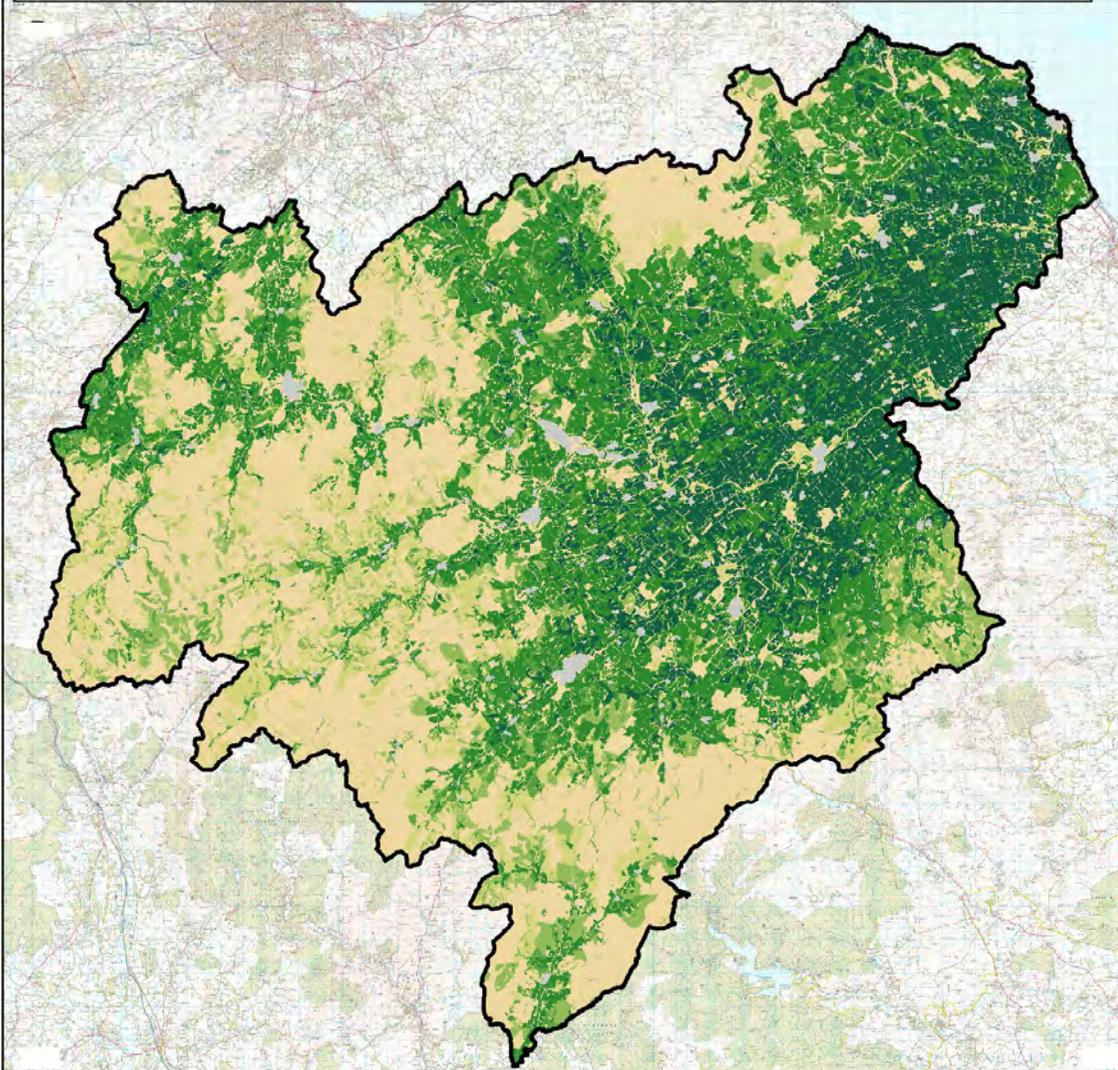
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Map 15: Scottish Borders - Areas potentially important for agricultural goods provision (Draft)



**Key**

-  Scottish Borders Council Boundary
-  Urban areas

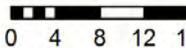
**Potentially productive agricultural areas**

-  High
-  Low

Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

Acknowledgements to the Scottish Borders Council for providing data to include in the ecosystem services mapping.

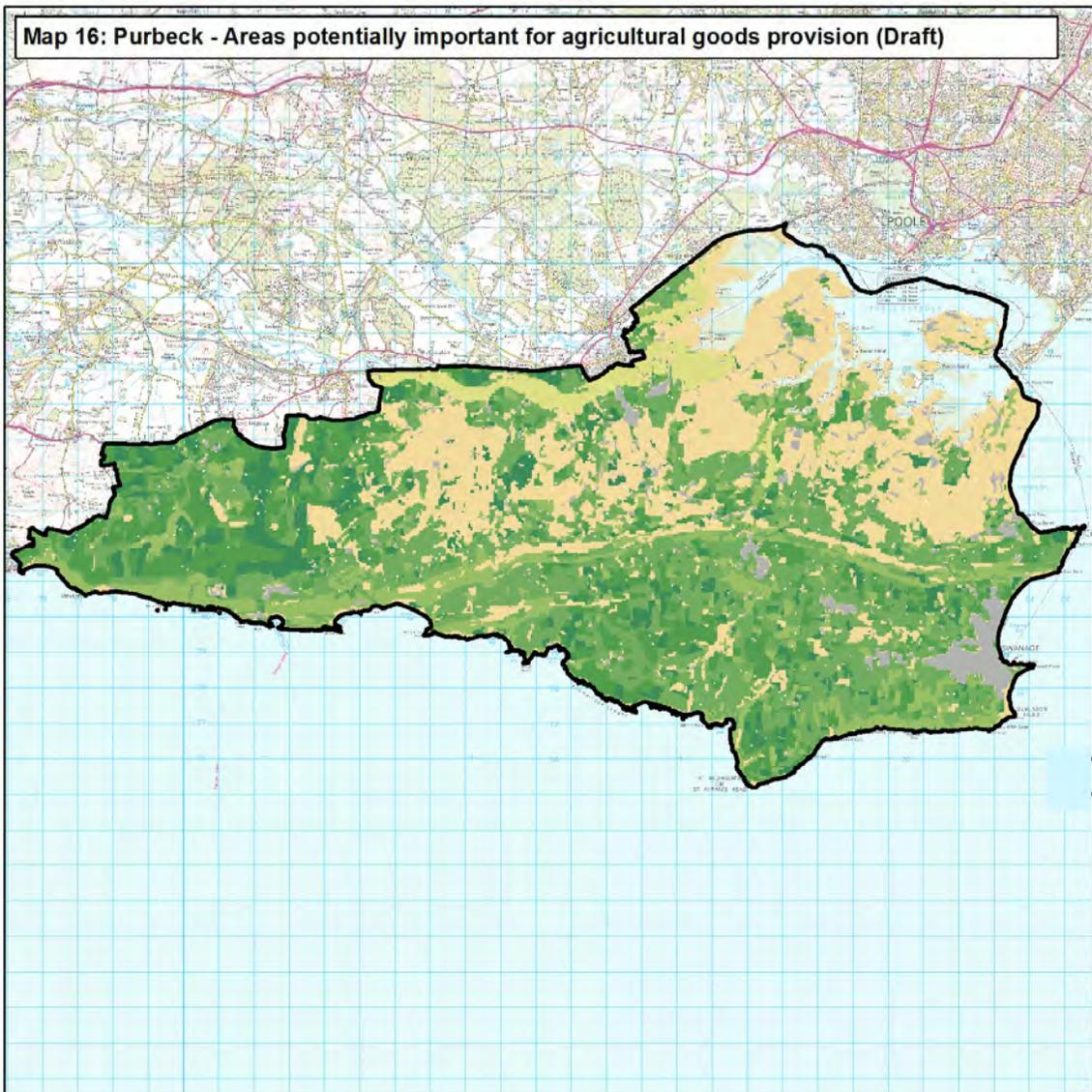


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Map 16: Purbeck - Areas potentially important for agricultural goods provision (Draft)



**Key**

Purbeck AONB Boundary\*

Urban areas

**Potentially productive agricultural areas**

High

Low

Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map

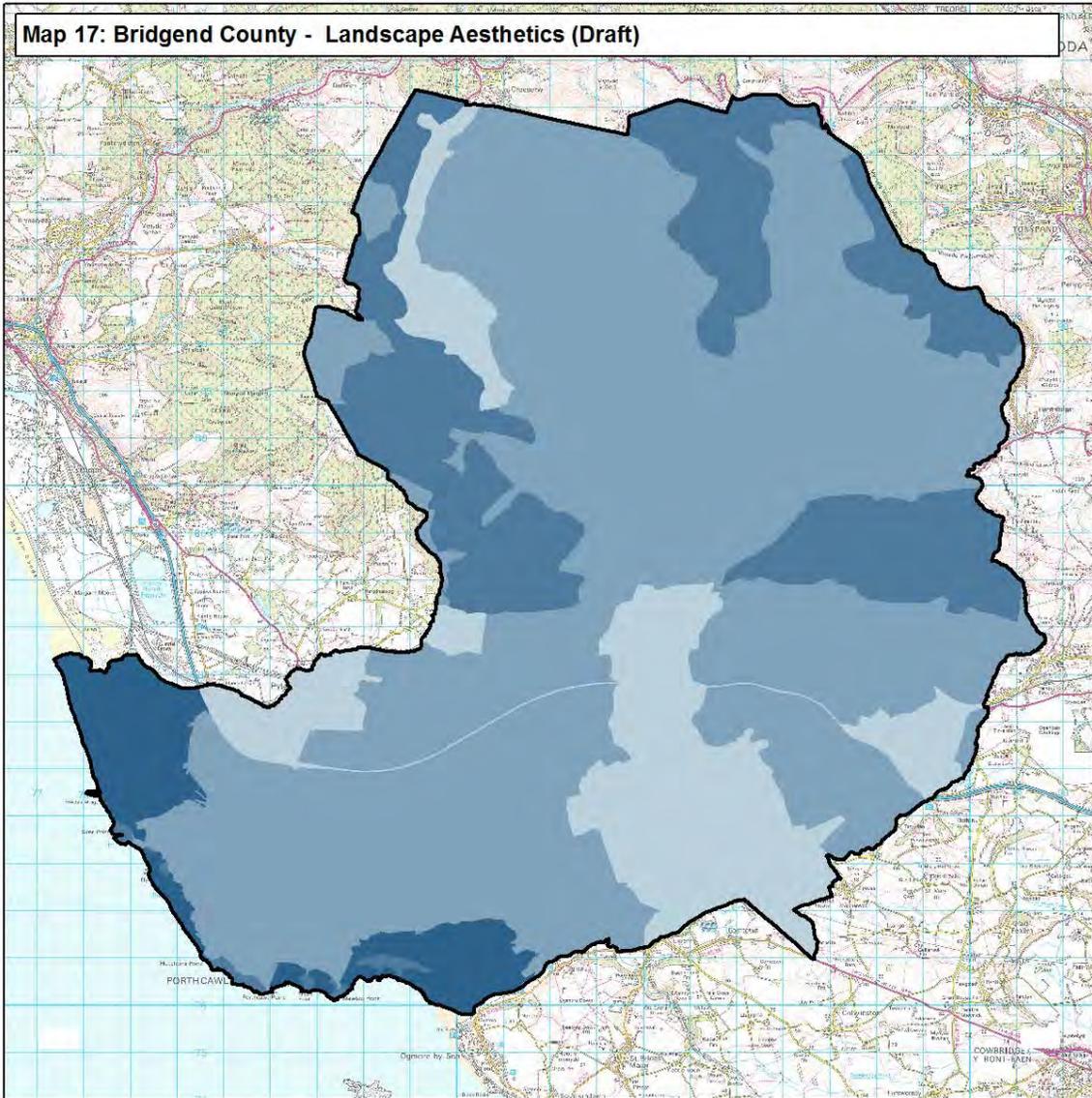


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Map 17: Bridgend County - Landscape Aesthetics (Draft)



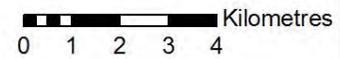
**Key**

-  Bridgend County
-  Urban areas

**Landscape aesthetics**

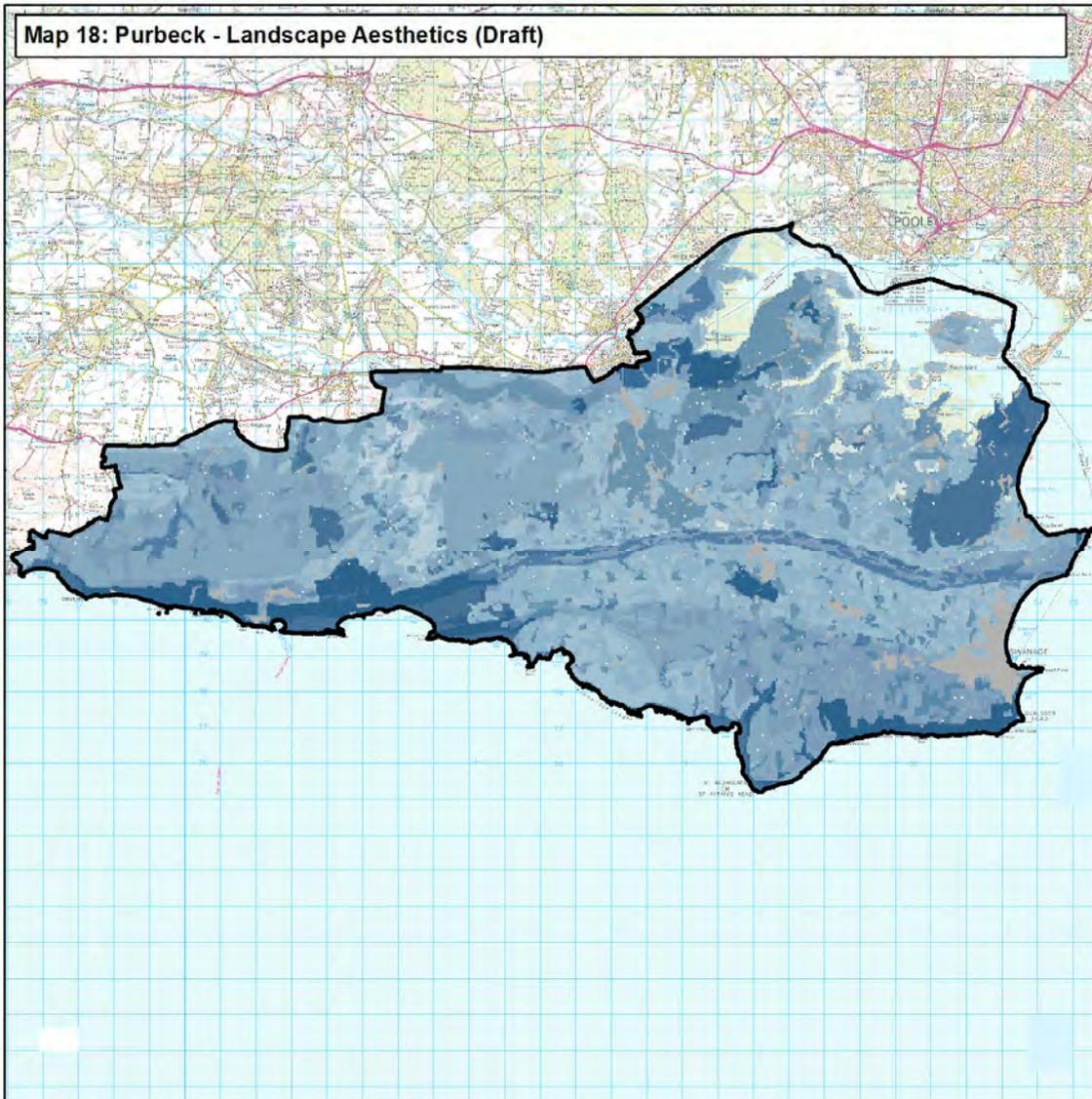
-  High
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Map 18: Purbeck - Landscape Aesthetics (Draft)



**Key**

-  Purbeck AONB Boundary\*
-  Urban areas

**Landscape aesthetics**

-  High
-  Low

Draft map suitable for illustrative purposes only. Further review by experts with local knowledge is required which may result in revisions being made to the supporting rule-base and current map.

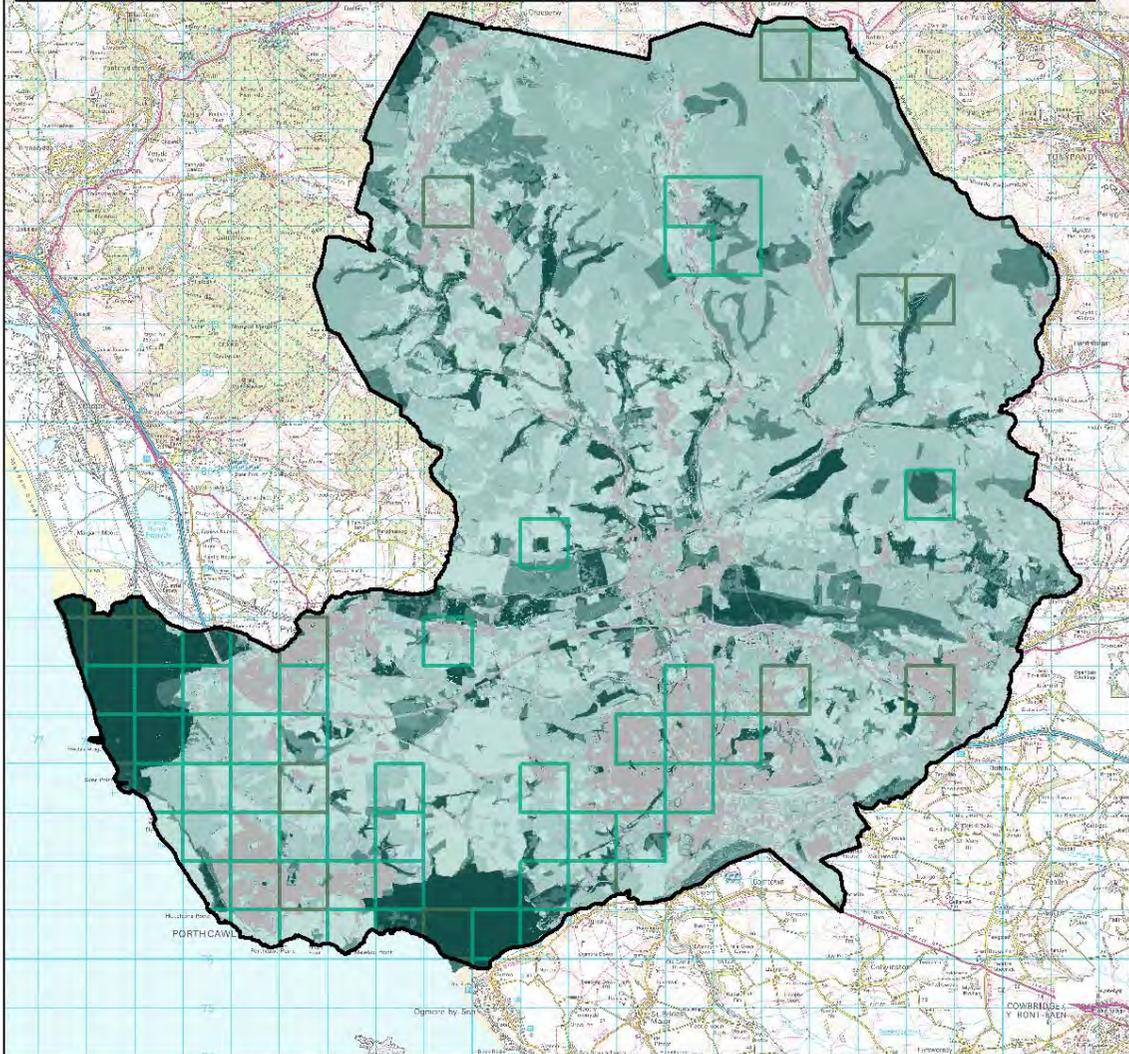


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**Map 19: Bridgend County - Estimated biodiversity provision: relative importance, connectivity and diversity (Draft)**



**Key**

-  Bridgend County Boundary
-  Urban areas

**Species diversity**

-  Moderate
-  High

**Estimated biodiversity provision\***

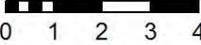
-  High
-  Low

Acknowledgements to CCW for their kind permission in allowing the inclusion of the SCCAN ecosystem services layers for this piece of work.

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Joint Nature Conservation Committee

\*Phase 1 data - provisional draft data layer. Final dataset available April 2012.  
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