Natural England Research Report NERR056

# Assessing the potential for mapping ecosystem services in England based on existing habitats

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# Assessing the potential for mapping ecosystem services in England based on existing habitats

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# Project details

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This report describes a new approach to mapping ecosystem services at the England scale. The approach used follows the National Ecosystem Assessment (*UK National Ecosystem Assessment, 2011*). The maps and methodology described in this report use (as base data) the Centre of Ecology and Hydrology's (CEH) Landcover Map 2007 (LCM2007) to describe the potential for areas to deliver individual ecosystem services.

The purpose of this report is to describe how we have followed the NEA assessment of the ability of habitats to deliver ecosystem services, using LCM2007, to create England level ecosystem service maps.

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# Executive Summary

This report assesses the first England level maps for ten ecosystem services, using a simple methodology derived from the National Ecosystem Assessment (NEA 2011) and based on habitat maps as a proxy for service provision.

With interest in adoption of the ecosystem approach in England, there is an increasing demand for maps showing the provision of ecosystem services. A number of mapping methods have been developed nationally and locally. The local initiatives mapping ecosystem services have been summarised through work commissioned by Natural England from the BESS[1] directorate at York University. Details have been made available through the **Mapping Ecosystem Services Gateway**[2].

The more complex mapping initiatives employ modelling to predict ecosystem service provision and require considerable staff time (several months in some cases) to input datasets and calibrate models. The simpler approaches use existing map data as proxies for ecosystem services provision. Although these more simple methods require less time to produce maps, they may not achieve the level of accuracy of the more complex modelling.

Natural England is keen to explore the usefulness and perceived level of accuracy of simple approaches to ecosystem services mapping, which do not require lengthy data collection, entry or processing, and could potentially be made accessible to partnerships and others wishing to adopt the ecosystem approach. This report assesses a Natural England ecosystem services mapping project with a simple methodology, using existing habitat data as a proxy for ecosystem services provision.

The methodology is based on translation of work contained within the NEA synthesis report (see Section 2). Each map has been produced using the full resolution data from the Centre for Ecology and Hydrology (CEH) Land Cover Map 2007.

The maps are presented in Section 3 of this report with sub-sections containing a short analysis of each map. The maps largely follow the classification of ecosystem services described within the National Ecosystem Assessment (NEA, 2011). Not all services are mapped due to the weak evidence base linking habitats to some services (principally regulating services). We have made no attempt to map marine ecosystem services at this time.

The effectiveness and limitations of this approach, at an England level, are assessed. The advantages of this approach are that it is quick and simple to use and provides maps at the England level of habitats that are important in the provision of ecosystem services. Limitations include the lack of consideration of flows and demand for ecosystem services and the location of beneficiaries. The habitat data used does not provide an indication of habitat condition, consequently the condition of ecosystem service provision cannot be inferred.

With selection of a simple methodology, it was clear from the outset that we would not be able to map condition, flow or demand for ecosystem services. However analysis of the maps by practitioners has indicated the significance of these factors in being able to meaningfully depict ecosystem services in map form.

A case study of the South Downs is included, considering the usefulness of these maps for local projects. Full resolution (25m$^2$ pixels) Land Cover Map 2007 data is used, so the maps can be cut to local project boundaries. However, through the South Downs work, and testing the local maps with a range of Natural England staff, it has been concluded that this approach is not currently appropriate

[1] Biodiversity, Ecosystem Service & Sustainability

[2] **www.nerc-bess.net/ne-ess/**

for use at a local scale. The limitations are amplified at this finer resolution and broader patterns of service provision, evident at a national scale, are not discernable locally.

Many of the existing projects which map ecosystem services are based on the use of habitats as a proxy. While this project has shown that habitat data can be used to map ecosystem services at the England level, there are limitations to the approach. Additional datasets are required for each service, to supplement the habitat maps and provide a more accurate and meaningful depiction of ecosystem services. For a simple and easy to use mapping method, that could be made available to partnerships and others with limited resources, further work is needed to identify how, and which, data sets could potentially be used in conjunction with the habitat data.

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# 1 Introduction

## Background

1.1 Ecosystem services are the benefits derived by people from the natural environment. These services underpin basic human health and survival as well as supporting the economy and social wellbeing.

1.2 The Ecosystem Approach represents a fundamental shift in the way we think about and manage the natural environment. It introduces an holistic and integrated approach that is more people and place focused. The essence of the ecosystem approach – management of whole ecosystems and their benefits – is to recognise the breadth of multiple benefits that the natural environment provides to people.

1.3 The ecosystem approach was adopted in 1995 by the Convention on Biological Diversity (CBD) as its principal strategy for implementation. The full set of principles adopted by the CBD are listed in **Appendix 1**.

1.4 These principles are also reflected in the England Biodiversity Strategy (*Defra, 2011*) which also promotes the need to create coherent ecological networks as promoted in the 'Making space for nature' report (*Lawton et al, report to Defra, 2010*).

## Why map ecosystem services?

1.5 For Natural England, there is a clear need to map ecosystem services to help it deliver an ecosystem approach and its responsibilities under the Natural Environment White Paper and Biodiversity 2020.

1.6 Other tools and frameworks already exist to undertake complex ecosystem service mapping exercises for specific purposes. These can require significant resources and take significant time to complete.

1.7 Examples of such initiatives include:

- The Joint Nature Conservancy Council (JNCC) who have recently published the second phase of their Spatial framework for assessing evidence needs for operational ecosystem approaches (*JNCC, 2012 and 2013*). They are also leading England's input to the European Ecosystem Service mapping project (MAES).
- A tool developed by Durham Wildlife Trust, EcoServ, (*Bellamy & Winn, 2012*) is currently being trialled in several Wildlife Trust areas and proving very successful.
- Polyscape is a GIS Mapping framework developed by a collaboration of universities and research bodies.
- InVEST (integrated valuation of environmental services and trade-offs) is a major tool developed by Stanford University in the United States through support from the Natural Capital Project, 2007.
- Other local tools and mapping initiatives are displayed on the **web portal** created by BESS.

1.8 The increasing number of mapping initiatives is a reflection of the increasing need for us to identify where stocks of ecosystem services are located. In particular there appears to be a general shift to delivering environmental outcomes through an ecosystem approach which in turn requires a rethink of the existing evidence base.

1.9 The National Planning Policy Framework (*DCLG, 2012*) contains specific aims on conserving and enhancing the natural environment and 'recognising the wider benefits of ecosystem services'[3]. ecosystem service maps will be of significant interest to Planning Authorities and the development sector. Local Enterprise Partnerships (LEPs) will also have an interest in identifying how the natural environment can make a very positive contribution to local economies and to people.

1.10 In summary, there is an increasing desire for information on ecosystem service stocks, where they are and how they relate to other environmental, social and economic interests. This demand comes from a variety of sources but, despite a number of excellent mapping initiatives across the country, there are still significant challenges in producing ecosystem service maps that can be used strategically (for long term decision making) and locally (for practical, on the ground action).

## The challenge of mapping ecosystem services

1.11 Mapping ecosystem service provision presents significant challenges, with some services more readily mapped than others.

1.12 The work commissioned from BESS identified that of 52 mapping projects analysed, 18 had a focus on climate regulation and just 3 on Noise Regulation. Other than climate, the regulating services were poorly served and there were only 6 projects that had a focus on cultural services (and even then, only on small aspects of those).

1.13 Direct data on the provision of ecosystem services is limited. This means we often have to use proxy information to represent services rather than actual data on the individual services themselves. When using proxy data to map ecosystem services it is important to clearly identify the limitations of so doing.

1.14 Mapping of ecosystem services needs to strike a balance between the resource and time demands of the mapping process and being able to make the maps available and affordable for local projects. On the one hand there is the desire for accuracy, which leads to complex modelling and data/resource intensive initiatives. On the other, is the need to communicate information to a lay audience.

1.15 There is a particular problem with mapping cultural services. If these are the experiences that people *individually* derive from nature it is almost impossible to map. An area which gives one group of people much benefit may provide nothing to another group. Some people may only receive cultural benefits from areas most people may prefer to avoid. Mapping a subject which is so subjective is extremely challenging.

## Aims of this project

1.16 The title of our project is, '*Assessing the potential for mapping ecosystem services in England based on existing habitats*'.

1.17 The core aim of the project is to assess whether our simple method for mapping ecosystem services, based on existing habitat data, can be used to produce robust maps for practitioners adopting the ecosystem approach. Natural England is keen to explore the potential to develop such maps that can be made readily and freely available (through the MAGIC[4] portal, for example) to our customers, partners and the general public.

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[3] Paragraph 109, page 25

[4] **www.magic.gov.uk**

1.18 We consider that robust ecosystem services maps for practitioners should include the following characteristics:

- cover the whole of England;
- be widely available;
- be relevant at all spatial scales;
- have supporting data that enables further analysis; and
- be visually easy to understand and effective for communication/visualisation.

1.19 Our focus, therefore, is very much on the "*need to communicate information to a lay audience*" (see paragraph 1.14) and on simplicity, as these areas appear to be those least addressed among the various other initiatives described earlier. There is also no need to duplicate or replicate the admirable work already undertaken by those initiatives.

# 2 Mapping methodology

## Methodology

2.1 Natural England's Ecosystem Service mapping is based on an interpretation of information published by the UK National Ecosystem Assessment (*NEA, 2011*). Specifically, we have interpreted the information contained in Figure 5 (page 11) of the NEA synthesis report. This table is reproduced as Figure 1 below with kind permission of the NEA.

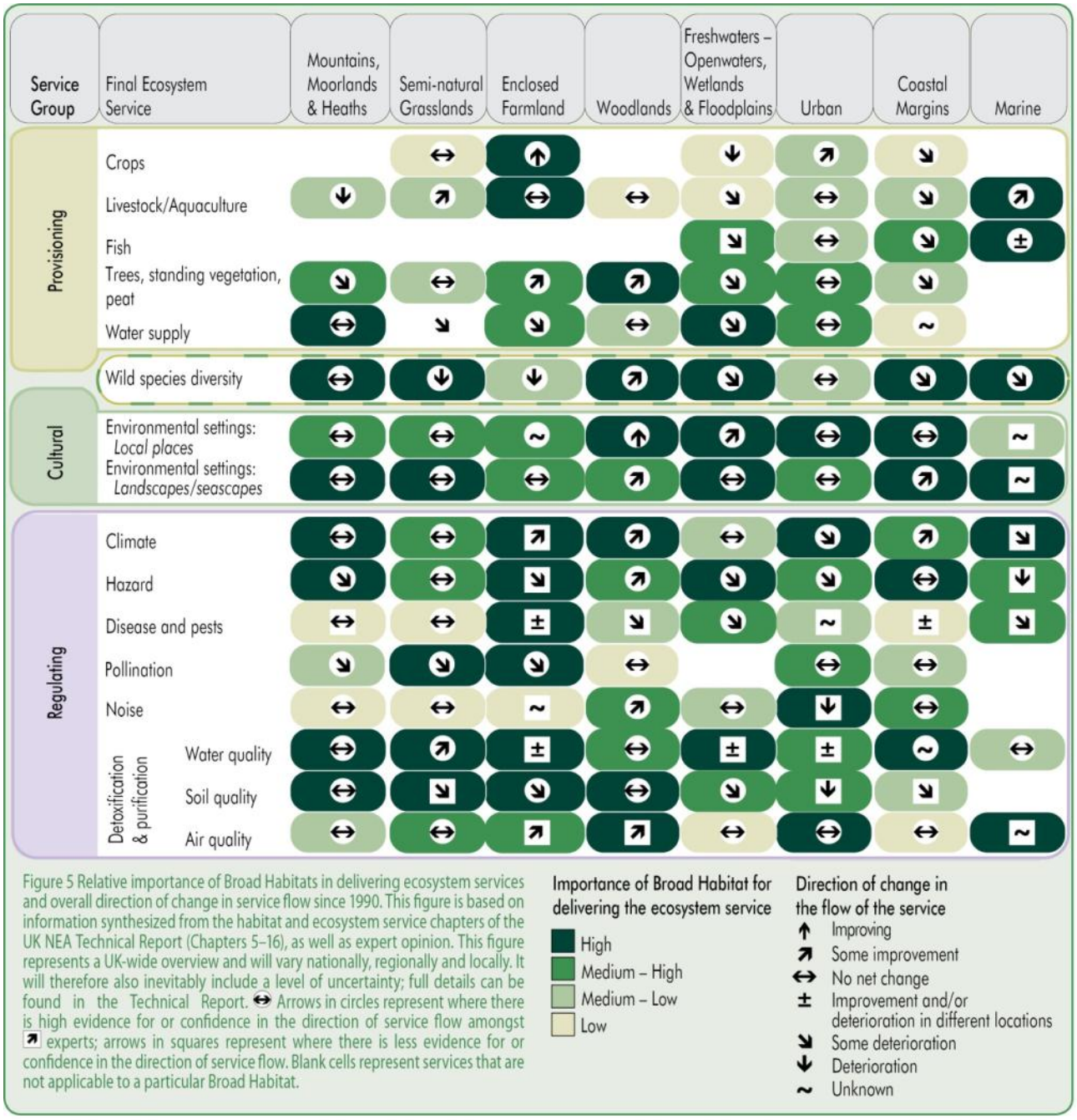


Figure 5 Relative importance of Broad Habitats in delivering ecosystem services and overall direction of change in service flow since 1990. This figure is based on information synthesized from the habitat and ecosystem service chapters of the UK NEA Technical Report (Chapters 5–16), as well as expert opinion. This figure represents a UK-wide overview and will vary nationally, regionally and locally. It will therefore also inevitably include a level of uncertainty; full details can be found in the Technical Report. ↔ Arrows in circles represent where there is high evidence for or confidence in the direction of service flow amongst ↗ experts; arrows in squares represent where there is less evidence for or confidence in the direction of service flow. Blank cells represent services that are not applicable to a particular Broad Habitat.

**Figure 1** Extract from the NEA Synthesis report

2.2 This table was developed through expert opinion based on the NEA analysis of ecosystem service provision by broad habitats. It is a pictorial synthesis of the huge volume of information contained in the full NEA report.

2.3 Our maps use habitats as proxies for the *potential* of a particular area to deliver a particular ecosystem service. These are based on existing habitat type – and without any reference to the quality of that habitat in any given area. We have simply mapped where particular habitats exist and which therefore have the potential to deliver an ecosystem service. The key principles driving the development of our maps were simplicity, ease of interpretation and usefulness as effective communication and visualisation tools.

2.4 The information we have interpreted from the table – and then mapped – is the assessment of the *importance* of broad habitat for delivering the ecosystem service. The table reflects this by using different intensities of colour for each habitat to service link. For example, Mountains, Moorland and Heath habitats are highly important for delivering the water supply service so the box is a deep shade of green. Those habitats are not important for the Noise (regulation) service, so the box is a very pale green. Where there is no link between a habitat and service (for example, Fish in this example) the box is left blank (white).

2.5 The direction of change information and confidence levels in the evidence base behind any particular assessments of habitat to service provision, have been excluded from our interpretation. To facilitate the production of the maps we have made several changes to the way in which we have interpreted the table and these are described below.

2.6 The habitat data used is the Centre of Ecology and Hydrology's (CEH) Land Cover map 2007 (LCM2007) and all our maps reflect this. The table makes links between service provision and the 8 Broad Habitats contained within LCM2007. We found that using the broad habitats limited the scope of the maps so we expanded our interpretation to link the 19 LCM2007 *sub*-habitats to the individual services. Doing this enabled us to re-assess 'importance' in terms of the more specific habitats and therefore the scoring. See below:

- We were concerned about the potential overlap between some habitats and the services they provided. We have therefore merged Crops, Livestock & Fish services into a 'food provision' service. We have also changed the scope of some services so that trees, standing vegetation and peat now becomes 'Timber Production', based on woodland habitats only.
- We have also moved the Fen, Marsh and Swamp sub-habitat from its parent (semi-natural grassland) and placed it with the freshwater habitat types (which changes the way its importance for each service is assessed).
- This widening of approach does raise some issues. The 'rock' habitats are generally assigned the same score as the broad habitat, although this is not visible at the national scale.
- We have not mapped all ecosystem services. The evidence base for the link between habitats and some services is not clear cut (especially within the regulating group) so we felt there was little point in attempting to map them. The services not mapped are Hazard regulation, Disease and Pests & Noise regulation.
- Finally, while we *have* created a Cultural Ecosystem Service (CES) map based on habitat (to be compatible with the others), we have also developed a completely different assessment which is not based on habitat for reasons described in a specific section on CES below.

2.7 All the maps published in this report were created using ESRI ArcGIS software (version 9.1). We initially had concerns that using LCM2007 at an England level would put our GIS under severe pressure in terms of processing time. In trialling various approaches we found that using LCM2007 at full resolution, although taking a little longer than other options, did not cause undue processing problems so all our maps to date have been produced in this way.

2.8 Land Cover Map 2007 is a parcel-based classification of UK land cover. It uses 19 habitat classes to map the UK which are based on the UK Biodiversity Action (BAP) Broad habitats. LCM2007 is created by classifying summer-winter composite images captured by satellite sensors with 20-30m pixels (*CEH, 2011*). Each pixel represents a unique habitat type which is important in terms of displaying the data contained in Figure 1 on a map. We have simplified the

information from the table for mapping purposes and have allocated each habitat a score for each service mapped as follows:

- Habitat has high importance for the service – Score = 3
- Habitat is of medium importance for the service – Score = 2
- Habitat is of low importance[5] for the service – Score = 1
- Habitat has no importance for the service – Score = 0

2.9 The habitat scoring for each service is shown in the analysis for each map in Section 3 of this report.

2.10 In creating an individual service map we have attributed the various habitat scores to each 25m pixel and displayed the results using an appropriate colour ramp at the England level.

## Cultural services

2.11 We have taken a completely different approach to mapping Cultural Ecosystem Services (CES). CES are complex and the challenge of mapping them at large scales is well known. The use of habitats as proxies for mapping CES is perhaps less appropriate than it is for other services, but we have prepared a CES map that follows the NEA approach for the sake of completeness and for comparison with the other maps. The habitat based map also acts as a useful baseline for the testing of other approaches.

2.12 For the second map and with reference to the NEA Cultural Ecosystem Services chapter (*NEA, 2011*), we have identified a number of commonly used datasets which represent areas of the country where people experience at least one aspect of CES (and for which the evidence base is strong).

The datasets used can be clearly seen in the legend of the map (Figure 11). They represent a blend of designated and protected sites, as well as those which provide a degree of accessibility to the general public.

2.13 These datasets have been plotted against a 1km grid and our map shows the number of datasets present in each grid square. Again, a suitable colour ramp has been used to show the areas which appear to offer the greatest opportunity to experience CES.

2.14 A detailed analysis of the CES map is provided in Section 3, but there are some different limitations to the habitat based approach taken for the other maps. First, there is no pretention that the 1km grid approach will have a use at smaller spatial scales. Secondly, there is no account taken of actual numbers of people experiencing cultural services. A square which appears to be a hotspot for CES (ie contains several datasets) may receive very few visitors and another square with just 1 dataset (a 'coldspot') may receive many times more visitors. A Country park near a large urban area might be a good example of this.

[5] This includes the medium-low and low categories in the NEA table.

# 3 Interpreting the ecosystem service maps

## Introduction

3.1 This section shows each of the ecosystem service maps produced using the methodology described in Section 2. The map for each service is accompanied by the habitat scoring table used to prepare it, a short analysis of each map and simple statistics showing the area and percentage of each class (high, medium and low potential).

A summary of the habitat scores for all services, including the deviations discussed in Section 2, is at **Appendix 2**.

3.2 The aim of our project was to produce maps at the England scale and to make them widely available with little or no restriction to their use. A further aim was that use of the maps and data would not require users to expend significant resources both human and financial. A focus at this end of the spectrum does come at a cost and the maps will not help on their own in assessing more complex issues such as flows of services, their beneficiaries and trade-offs between services. Other tools are available to undertake these. Our maps may help develop solutions, but are not the solution in themselves.

3.3 The variable condition of habitats across England is not identified by LCM2007. We have not, therefore, included a qualitative assessment within our mapping (because such information is largely lacking). The maps show areas that have the potential to deliver a service based on their underlying habitat, but whether those areas are actually delivering that service to its full potential depends on knowledge of its condition.

3.4 Additional data on the condition, flow and demand for ecosystem services is required to provide a more accurate depiction of ecosystem services spatially.

3.5 The way in which the habitat data has translated into ecosystem service maps is variable from service to service. Some maps look immediately more usable than others and an assessment of this is included in the analysis of each map. A particular issue is where many habitats have high potential to deliver a service. For example, 90% of England has at least medium potential to deliver the food provision service.

3.6 The main limitation of our approach (and the use of habitats as proxies for services) is that the maps may not cover all aspects of a particular service.

As an example, the water supply map only describes the potential for *surface* water supply, as this is all that is covered by habitat data. *Ground* water (or below ground water) supply is not covered by the map so we get neither the full picture for the water supply service, nor identification of areas of the country where ground water supply is of major importance.

3.7 Special care must be taken in interpreting the contribution made by urban habitats to ecosystem services. Clearly there is significant potential for urban parks, gardens and street trees to regulate both air quality and climate (among other things). In the LCM2007 dataset the urban broad habitat is made up of just one sub-habitat, Built up Areas and Gardens. The whole of an urban area is attributed to this habitat so it appears that the *entire* area has the potential to deliver services, not just the ‘green’ areas within urban boundaries. This, as well as an understanding of why particular habitats have been deemed important for services, are required to interpret the ‘urban offer’ correctly.

3.8 The individual maps will be published in JPEG format and available to download from this report's main publication page on the Natural England Internet Site. They are designed to be printed on A4 paper.

## Climate regulation

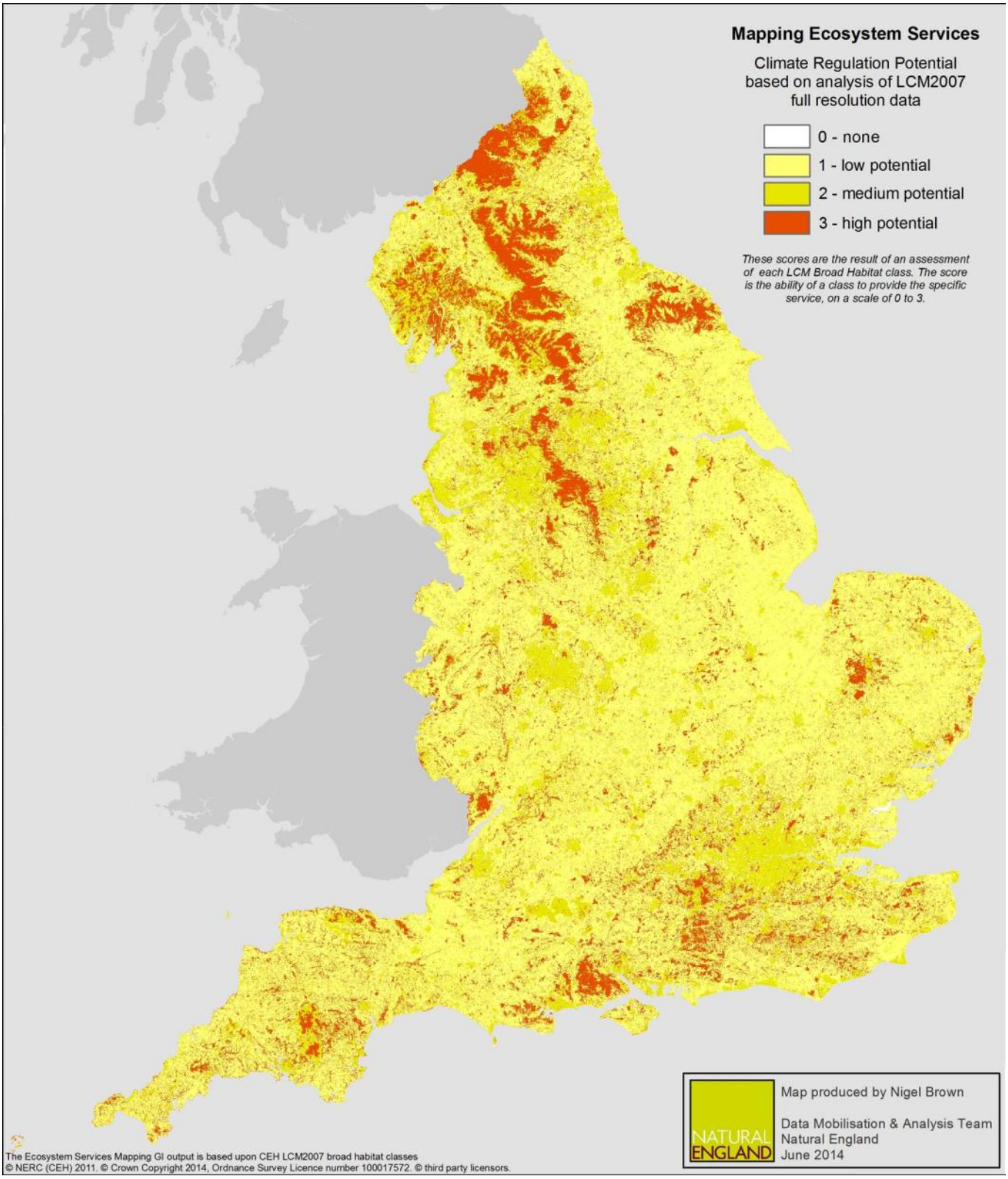


**Figure 2** Climate regulation potential

## Climate regulation map – Analysis

**Table 1** Climate regulation - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 2 |
| Littoral sediment | 2 |
| Supra-littoral rock | 2 |
| Supra-littoral sediment | 2 |
| Arable and horticulture | 1 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 1 |
| Fen, Marsh & Swamp | 2 |
| Bog | 3 |
| Dwarf shrub heath | 3 |
| Inland rock | 3 |
| Montane habitats | 3 |
| Acid grassland | 2 |
| Calcareous grassland | 2 |
| Rough low-productivity grassland | 2 |
| Built up areas and gardens | 2 |
| Broad leaved, mixed, & yew woodland | 3 |
| Coniferous woodland | 3 |

## Analysis

3.9 All habitat types are considered to have some potential for the climate regulation service.

3.10 The map has no 'white space' and is visually easy to interpret in terms of the relevant levels of importance. Upland & woodland habitats have the greatest importance for this service and there is a clear skew towards the north of England as having the greatest overall potential to regulate the climate. Heavily wooded areas of southern England (for example, Thetford and the New Forest) stand out as particular areas of importance.

The most important habitats cover 14.35% of England.

3.11 There is no differentiation between the relative importance within broad habitat types. Coniferous and deciduous woodland are all considered of equal importance and upland habitats are also considered as equal.

3.12 The map does not directly map the importance of soils for storing carbon nor the potential for all soils to provide a regulating service if in good condition. The habitats do reflect the importance of their soils for storing carbon.
Woodlands and peatlands, for example, are important for this service and have soils with high

carbon content. Some important areas for carbon and Greenhouse Gases, such as lowland peatlands, are missing from the map.

3.13 To provide a full picture of the climate regulation service at both national and local levels, it will be necessary to gather additional data, particularly on soils and the quality of habitats. It would also be possible to use some of the more scientific data available (for example, on long term monitoring sites) to provide better mapping at local scales.

3.14 While there are benefits in having just one climate regulation map (and for this exercise it is essential for reasons of consistency), some may find it confusing. Natural England experts have suggested that presenting the combined aspects of climate change (carbon storage, carbon sequestration and cooling effects) on one map might make it hard to inform practical decision making. An obvious next step will be to explore the development of maps for each of these aspects.

## Statistics

**Table 2** Climate regulation statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 1,871,552 | 14.35% | 2,081,626 | 15.96% | 9,088,950 | 69.69% | 13,042,128 | 100.00% |

All figures in hectares

# Pollination (for crops)

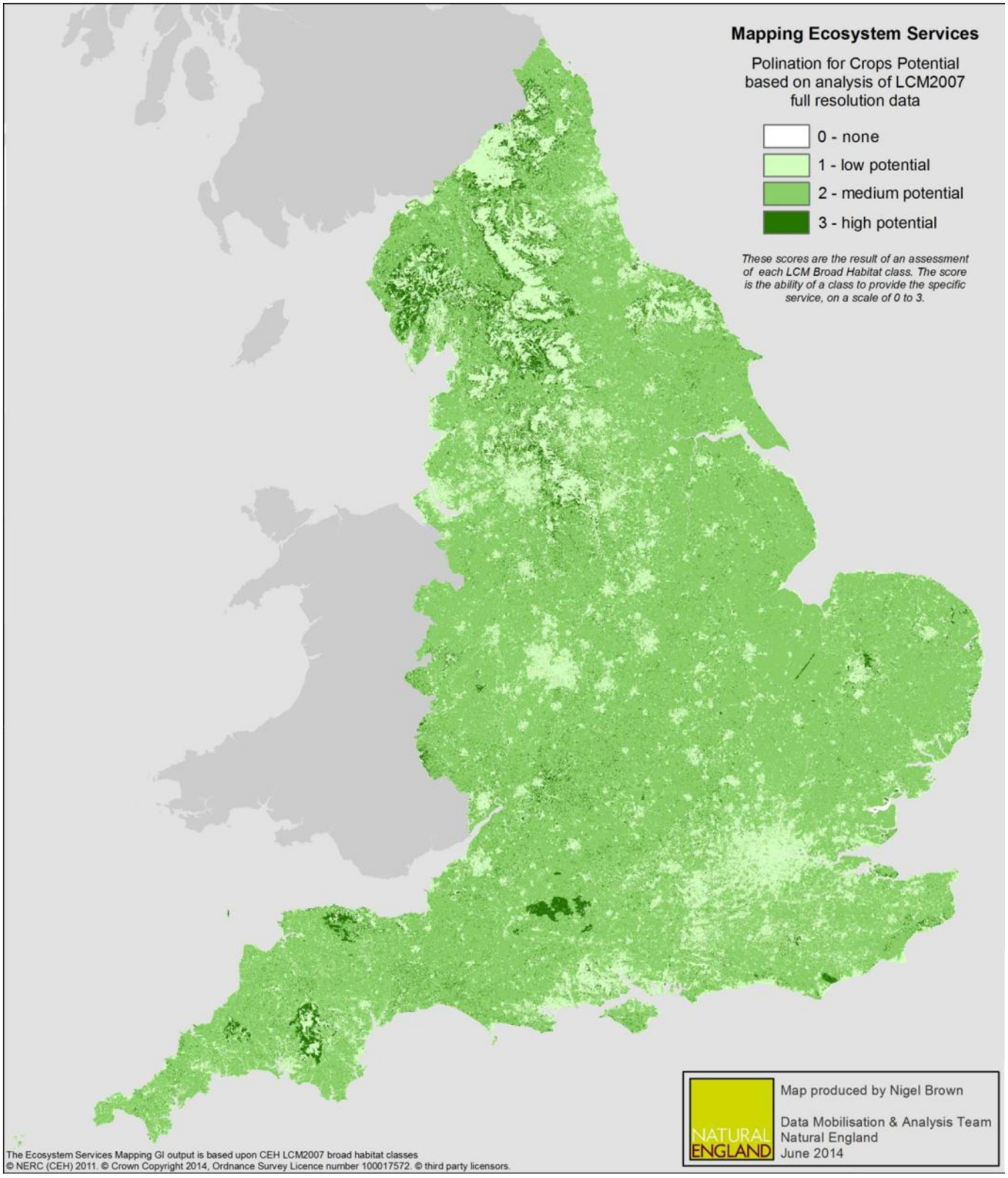


**Figure 3** Pollination (for crops) potential

## Pollination map – Analysis

**Table 3** Pollination - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 1 |
| Littoral sediment | 1 |
| Supra-littoral rock | 1 |
| Supra-littoral sediment | 1 |
| Arable and horticulture | 2 |
| Improved grassland | 2 |
| Neutral grassland | 2 |
| Freshwater | 1 |
| Fen, Marsh & Swamp | 3 |
| Bog | 1 |
| Dwarf shrub heath | 1 |
| Inland rock | 1 |
| Montane habitats | 1 |
| Acid grassland | 3 |
| Calcareous grassland | 3 |
| Rough low-productivity grassland | 3 |
| Built up areas and gardens | 1 |
| Broad leaved, mixed, & yew woodland | 1 |
| Coniferous woodland | 1 |

## Analysis

3.15 This is a difficult service to map effectively. Pollination services have many different beneficiaries. Our focus is the service given to agricultural crops. There has been no attempt to map the actual relationship between where crops requiring insect pollinators and the important habitats are located. This would be an obvious, but complex next step.

Based on the NEA definition, the important habitats displayed on the map are those that *can* provide a range of flower communities and, therefore, a diversity of wild pollinator communities. Whether those habitats are actually doing so is not part of this mapping process.

3.16 There are few habitats that have the highest potential for providing a pollinating service for crops. At an England level, only large areas of wetland and the fringes of our uplands (high value grasslands) stand out. The most important habitats cover only 7.17% of England. On the other hand, all other habitats have some potential for providing the service.

3.17 Another limitation to the ‘pure’ habitat approach to mapping this service is that clearly there will be significant pollination opportunities within the dominating habitat. Woodlands contain many

other pollinating species and there will be trees and hedgerows within low scoring habitats that will provide the service. Relevant species data, where available, would also be useful.

## Statistics

**Table 4** Pollination statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 935,041 | 7.17% | 9,011,705 | 69.09% | 3,092,933 | 23.71% | 13,039,679 | 99.98% |

All figures in hectares

## Air quality regulation

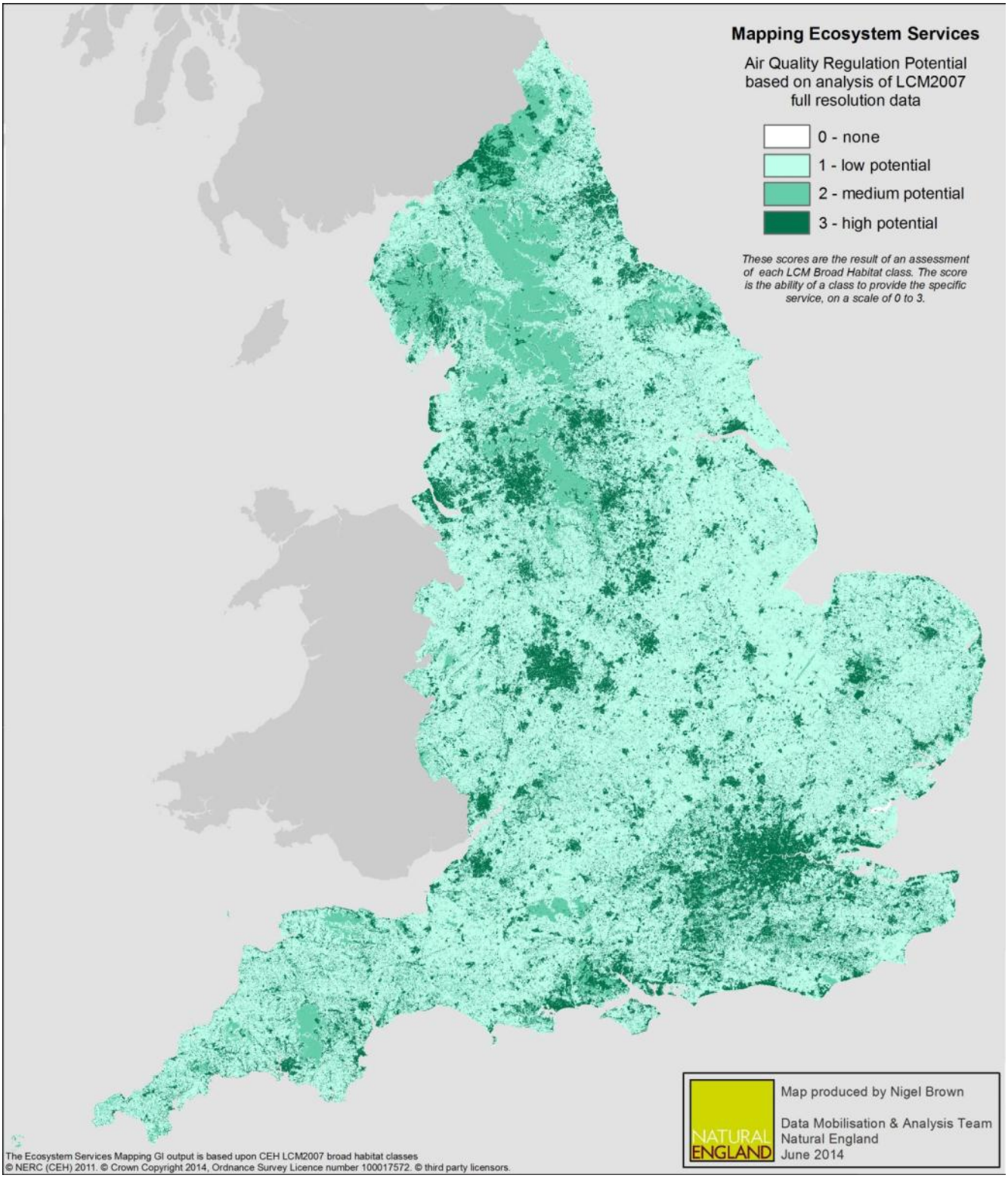


**Figure 4** Air quality regulation potential

## Air quality regulation map – Analysis

**Table 5** Air quality regulation - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 1 |
| Littoral sediment | 1 |
| Supra-littoral rock | 1 |
| Supra-littoral sediment | 1 |
| Arable and horticulture | 1 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 1 |
| Fen, Marsh & Swamp | 2 |
| Bog | 2 |
| Dwarf shrub heath | 1 |
| Inland rock | 1 |
| Montane habitats | 1 |
| Acid grassland | 1 |
| Calcareous grassland | 1 |
| Rough low-productivity grassland | 1 |
| Built up areas and gardens | 1 |
| Broad leaved, mixed, & yew woodland | 1 |
| Coniferous woodland | 2 |

## Analysis

3.18 The map shows that all areas of England have some potential to assist with air quality regulation. The habitats with the greatest potential are woodlands and built up areas and gardens which cover 18.40% of England.

3.19 There has been no attempt to map the relationship between the important habitats against areas of the country in greatest need of the service.

3.20 This is clearly a complex area and one where much more detailed analysis is required to make informed decisions.

## Statistics

**Table 6** Air quality regulation statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 2,400,153 | 18.40% | 1,571,485 | 12.05% | 9,068,041 | 69.53% | 13,039,679 | 99.98% |

All figures in hectares

## Soil function

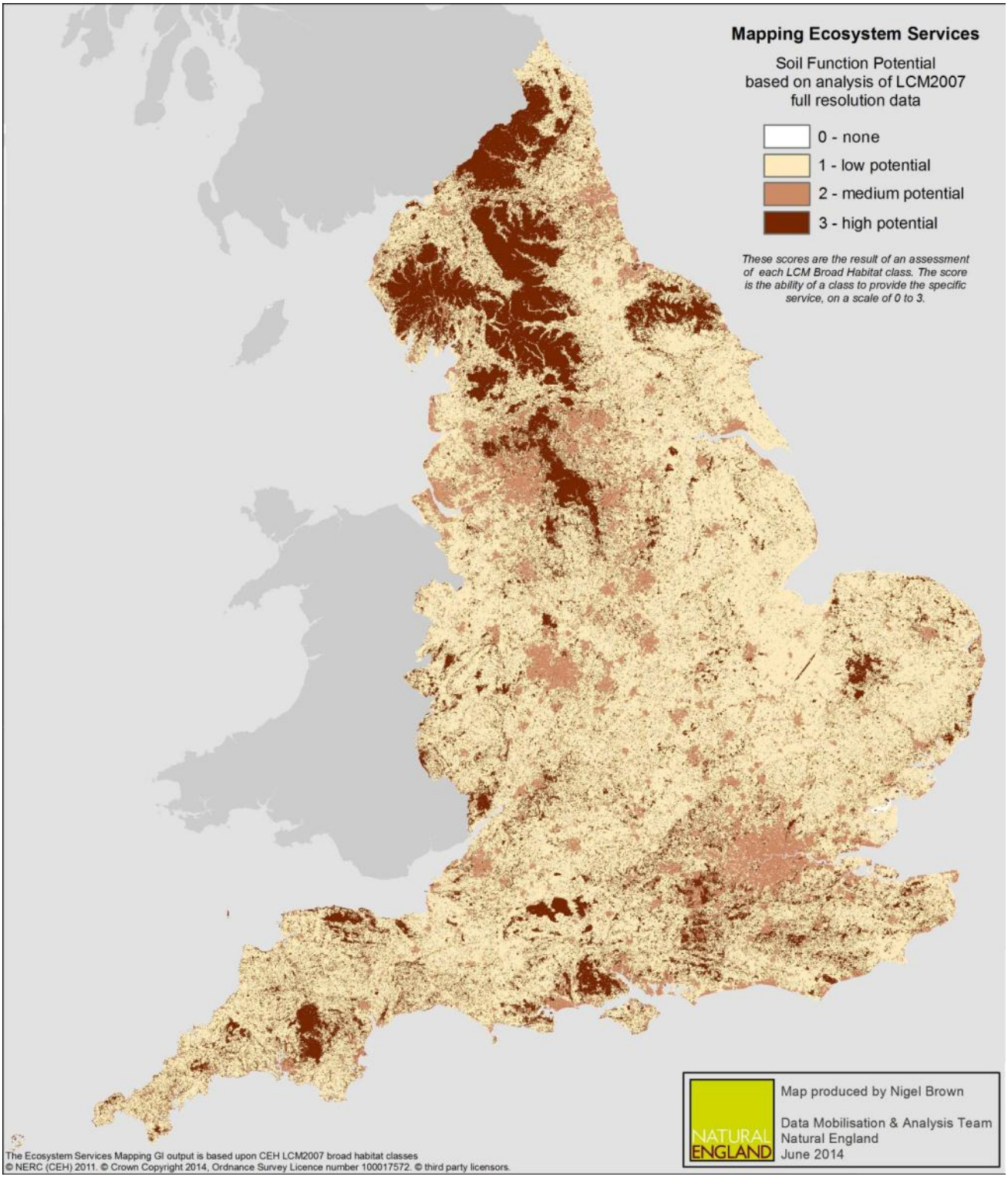


**Figure 5** Soil function potential

## Soil function map – Analysis

**Table 7** Soil function - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 1 |
| Littoral sediment | 1 |
| Supra-littoral rock | 1 |
| Supra-littoral sediment | 1 |
| Arable and horticulture | 1 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 2 |
| Fen, Marsh & Swamp | 3 |
| Bog | 3 |
| Dwarf shrub heath | 3 |
| Inland rock | 3 |
| Montane habitats | 3 |
| Acid grassland | 3 |
| Calcareous grassland | 3 |
| Rough low-productivity grassland | 3 |
| Built up areas and gardens | 2 |
| Broad leaved, mixed, & yew woodland | 3 |
| Coniferous woodland | 3 |

## Analysis

3.21 We have encapsulated all the services provided by soils by describing them as *soil function*.

3.22 This is a complex service to map and to understand. This map focuses on the factors that lead to good quality soils rather than the final services which good quality soils help to regulate. The ability of a soil to function will depend on both habitat and soil condition (which is not shown here). The ability of soils to provide these services will not be uniform across the breadth of the habitat. A total of 20.91% of England is covered by the high scoring habitats, which are largely natural or semi-natural in nature.

3.23 The map shows the general picture of where high value soils may exist, but further data is required to allow the quality of all soils to be identified to enable practical action for their maintenance and protection.

## Statistics

**Table 8** Soil function statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 2,726,900 | 20.91% | 1,244,738 | 9.54% | 9,068,041 | 69.53% | 13,039,679 | 99.98% |

All figures in hectares

## Water quality

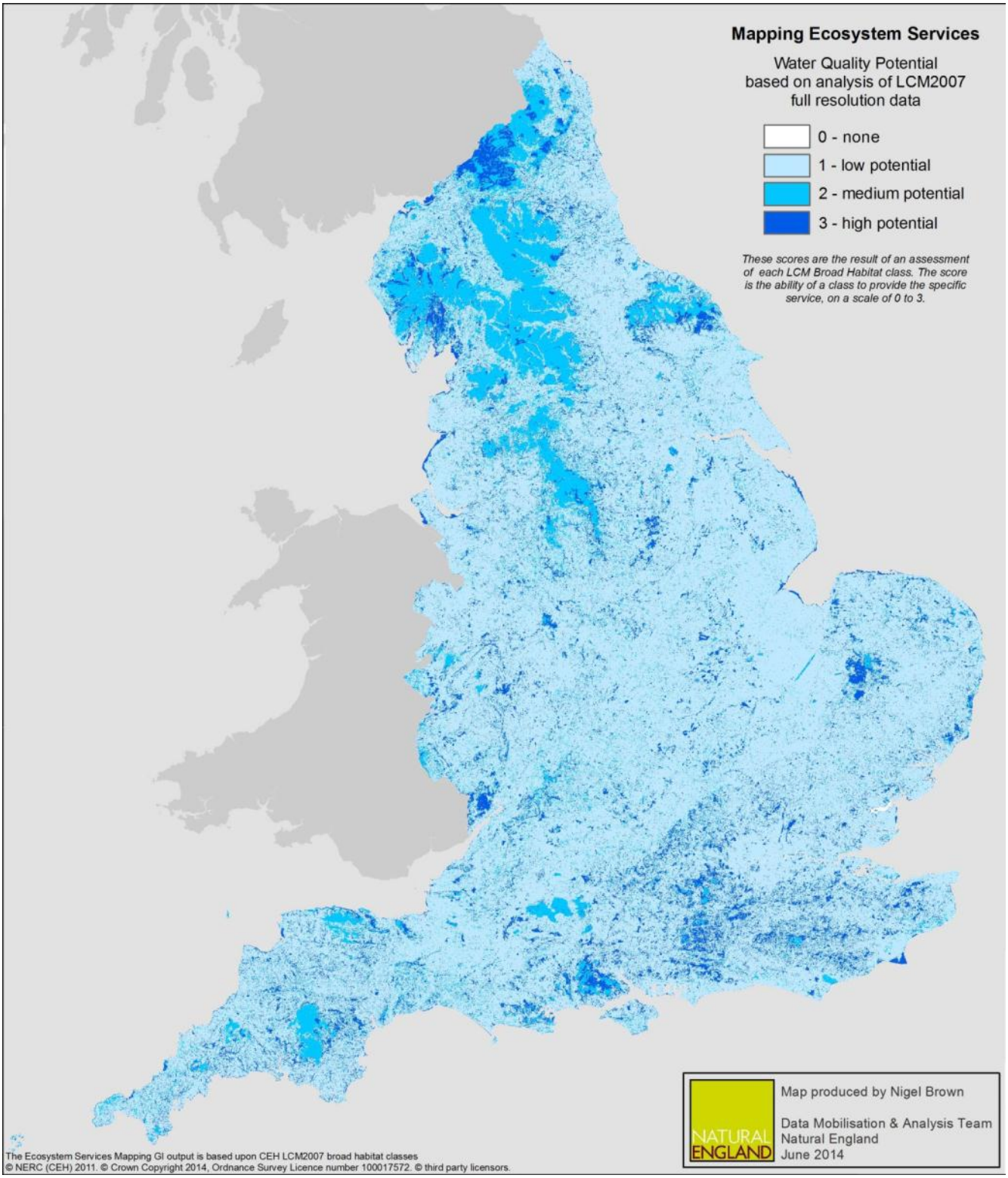


**Figure 6** Water quality potential

## Water quality map – Analysis

**Table 9** Water quality - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 3 |
| Littoral sediment | 3 |
| Supra-littoral rock | 3 |
| Supra-littoral sediment | 3 |
| Arable and horticulture | 1 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 3 |
| Fen, Marsh & Swamp | 2 |
| Bog | 2 |
| Dwarf shrub heath | 2 |
| Inland rock | 2 |
| Montane habitats | 2 |
| Acid grassland | 2 |
| Calcareous grassland | 2 |
| Rough low-productivity grassland | 2 |
| Built up areas and gardens | 1 |
| Broad leaved, mixed, & yew woodland | 3 |
| Coniferous woodland | 3 |

## Analysis

3.24 The map does *not* show the quality of water, rather the habitats (and their associated underlying soils) that could contribute to the regulation of water quality. On this basis, the most important habitats are freshwater, coastal and woodland habitats which cover 10.48% of England.

3.25 At one level this map can help target interventions that can provide water quality services by protecting the most important habitats. Additional data is required to target the most beneficial interventions which may not necessarily be for the highest priority habitats. Using this map in combination with data on actual water quality and monitoring under the Water Framework Directive could assist with this. (The NEA also recommends widening the monitoring of water quality so that more areas and scenarios are covered. Small water courses, for example, are often excluded).

3.26 While the maps shows where habitats in good condition can help regulate water quality, it does not show habitats that contribute to diffuse pollution, nor where water quality is impacted by diffuse or point sources of pollution.

## Statistics

**Table 10** Water quality statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 1,366,240 | 10.48% | 1,494,241 | 11.46% | 10,179,188 | 78.05% | 13,039,669 | 99.98% |

All figures in hectares

## Water supply

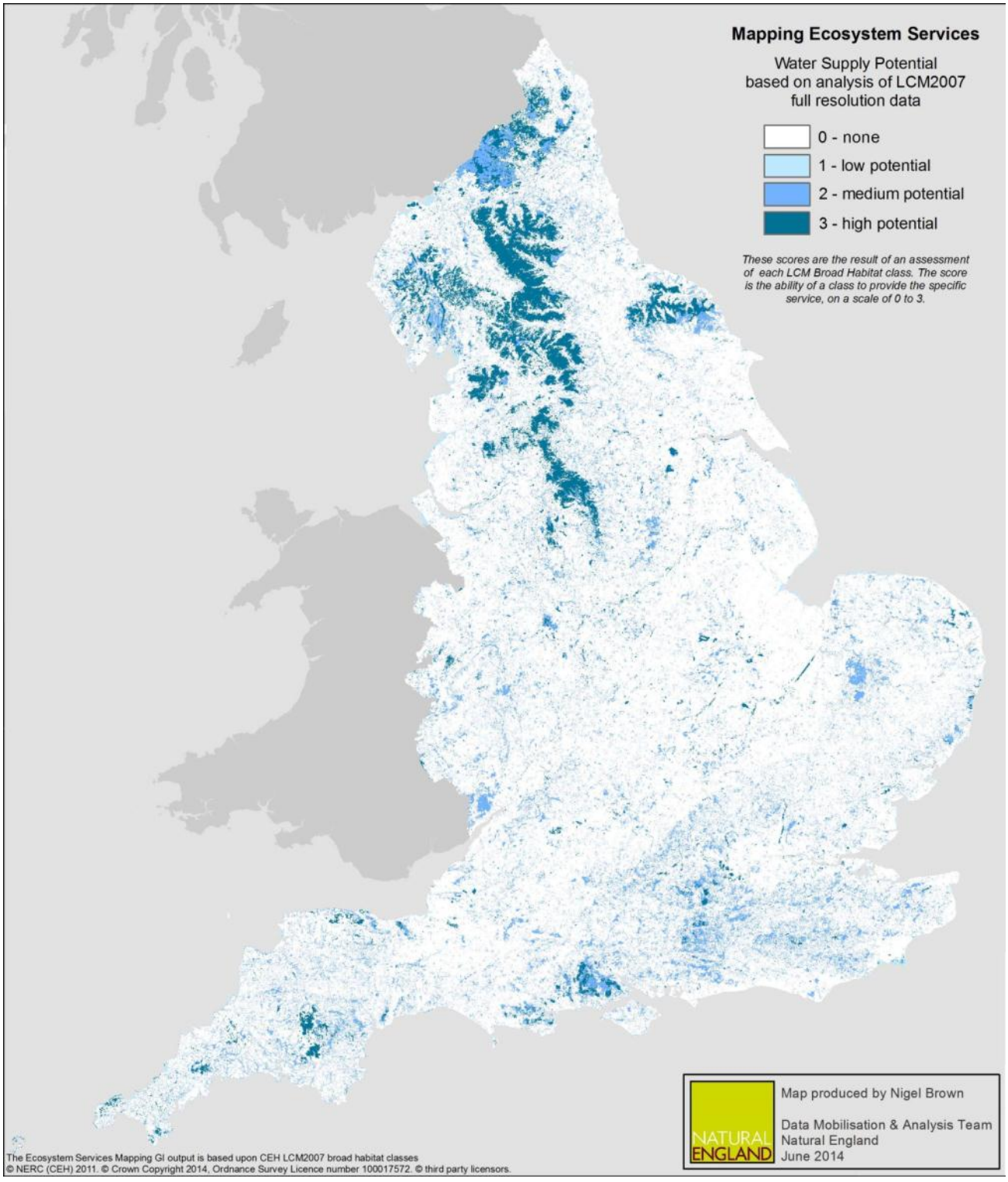


**Figure 7** Water supply potential

## Water supply map – Analysis

**Table 11** Water supply - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 1 |
| Littoral sediment | 1 |
| Supra-littoral rock | 1 |
| Supra-littoral sediment | 1 |
| Arable and horticulture | 0 |
| Improved grassland | 0 |
| Neutral grassland | 0 |
| Freshwater | 3 |
| Fen, Marsh & Swamp | 3 |
| Bog | 3 |
| Dwarf shrub heath | 3 |
| Inland rock | 3 |
| Montane habitats | 3 |
| Acid grassland | 0 |
| Calcareous grassland | 0 |
| Rough low-productivity grassland | 0 |
| Built up areas and gardens | 0 |
| Broad leaved, mixed, & yew woodland | 2 |
| Coniferous woodland | 2 |

## Analysis

3.27 Water supply is about the provision of volumes of water *independent* of its quality.

3.28 Apart from the freshwater and wetland habitats this map does *not* show habitats that actually provide water – rather those that are important for supporting or delivering the water supply service. In addition to freshwater and wetlands, the high potential habitats are the upland habitats and, together, just 5.47% of England contains these habitats.

3.29 Some habitats are assessed as having no potential to deliver/support the water supply service and this map contains more white space than any other.

3.30 The most important feature of this map is that it relates only to *surface* water. Ground water sources are excluded (as there is no link between source and habitat). The map will assist in identifying habitats that have importance for surface water supply, but will need to be used in conjunction with ground water data, where available, to give the complete picture.

3.31 Other data sources that would be useful additions to this map would include catchments. Contrary to popular belief the amount of water being extracted has decreased in the last two

decades (*NEA, 2011*) but pressures on supply still remain in many areas and there are the potential impacts of climate change to consider also.

3.32 For the water supply service we really need to know where the beneficiaries of the water supply are located in relation to where the supply is provided from. Water from the Lake District is supplied to Greater Manchester and other areas of north west England, for example.

## Statistics

**Table 12** Water supply statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 713,689 | 5.47% | 1,232,660 | 9.45% | 65,410 | 0.50% | 2,011,759 | 15.42% |

All figures in hectares

## Wood provision

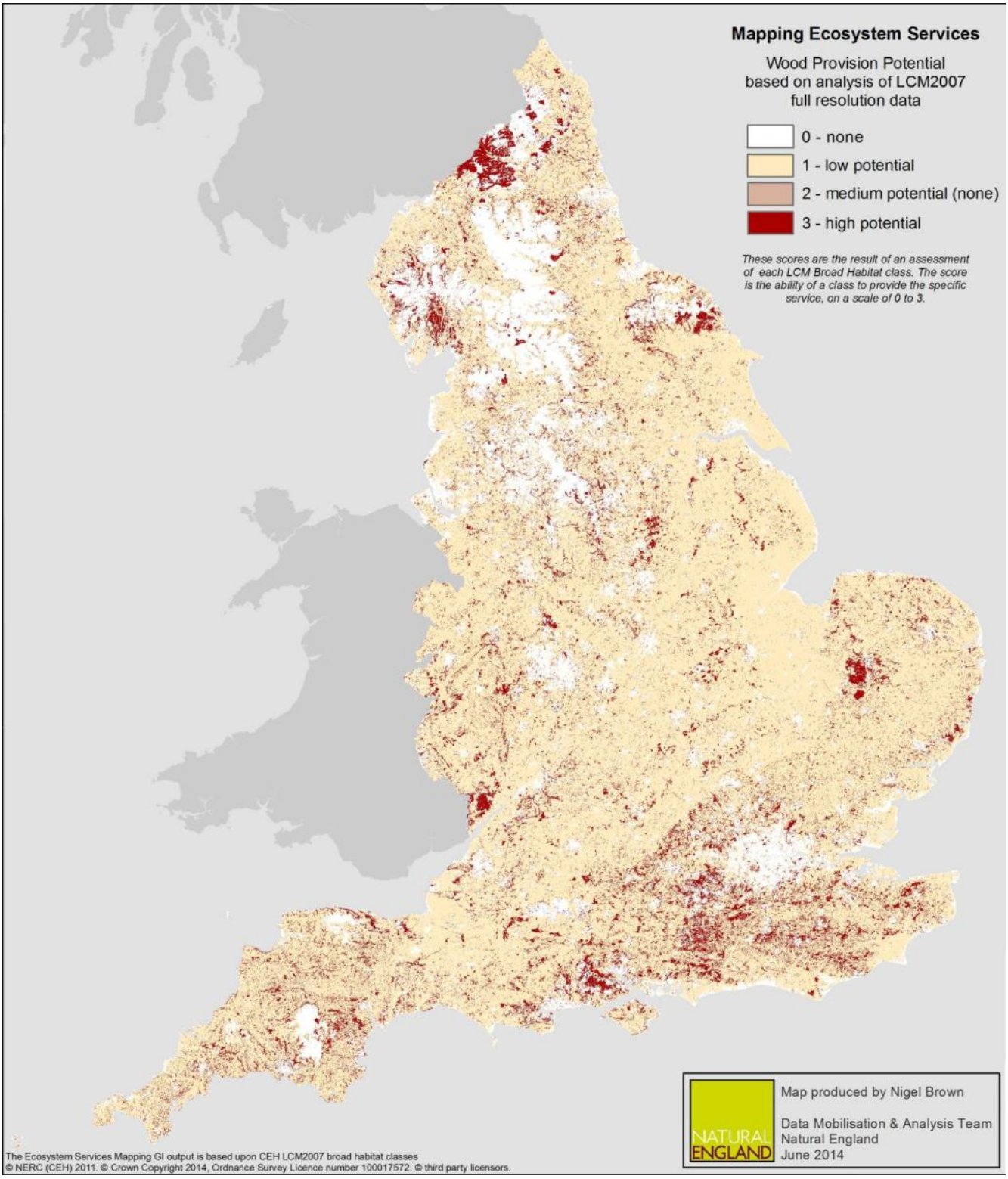


**Figure 8** Wood provision potential

## Wood provision map – Analysis

**Table 13** Wood provision - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 0 |
| Littoral sediment | 0 |
| Supra-littoral rock | 0 |
| Supra-littoral sediment | 0 |
| Arable and horticulture | 1 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 1 |
| Fen, Marsh & Swamp | 0 |
| Bog | 0 |
| Dwarf shrub heath | 0 |
| Inland rock | 0 |
| Montane habitats | 0 |
| Acid grassland | 0 |
| Calcareous grassland | 0 |
| Rough low-productivity grassland | 0 |
| Built up areas and gardens | 0 |
| Broad leaved, mixed, & yew woodland | 3 |
| Coniferous woodland | 3 |

## Analysis

3.33 This map is a simple picture of where woodlands existed in 2007.

3.34 We have called the service 'wood provision' (to include timber, wood-fuel and other wood products) and excluded the provision of fibre as we considered the different types of fibre as being difficult to link to specific habitats. On this basis only the existing woodland habitats have the highest level of potential covering 9.45% of England.

3.35 The majority of other habitats are considered (by the NEA) as providing little or no wood, timber or co-product producing service. Clearly management choices can and do see new trees planted on other habitats so, in theory, all habitats have some future potential for providing the service.

3.36 Use of other woodland data sources such as the National Forest Inventory would provide a more accurate picture of the existing woodland stock.

## Statistics

**Table 14** Wood provision statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 1,232,660 | 9.45% | 0 | 0.00% | 9,088,950 | 69.69% | 10,321,610 | 79.14% |

All figures in hectares

## Food provision

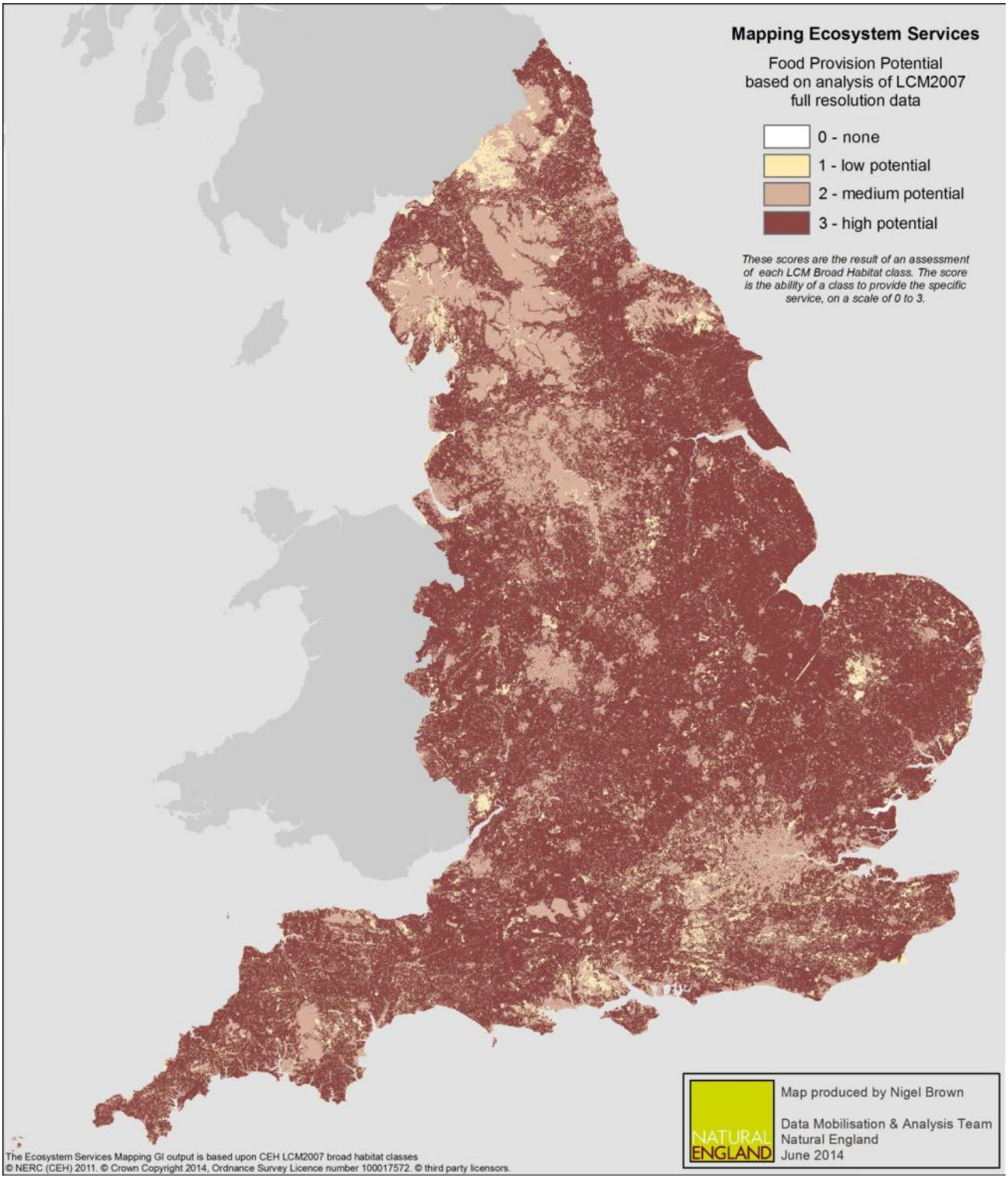


**Figure 9** Food provision potential

## Food provision map – Analysis

**Table 15** Food provision - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 1 |
| Littoral sediment | 1 |
| Supra-littoral rock | 1 |
| Supra-littoral sediment | 1 |
| Arable and horticulture | 3 |
| Improved grassland | 3 |
| Neutral grassland | 3 |
| Freshwater | 1 |
| Fen, Marsh & Swamp | 1 |
| Bog | 2 |
| Dwarf shrub heath | 2 |
| Inland rock | 2 |
| Montane habitats | 2 |
| Acid grassland | 2 |
| Calcareous grassland | 2 |
| Rough low-productivity grassland | 2 |
| Built up areas and gardens | 2 |
| Broad leaved, mixed, & yew woodland | 1 |
| Coniferous woodland | 1 |

## Analysis

3.37 The NEA describes three services – crops, livestock/aquaculture & fish – which we have merged into one service called food provision. The logic behind the merger was to show the areas/habitats from which we get our food. There was also some question about duplication of information between habitats and the three services and the merger was an attempt to iron out these concerns.

3.38 While the map does show where our food is produced, the merger has resulted in many habitats having high potential for the service and so much of the country is in the top category (69.11%).

3.39 The map does not differentiate between the service potential of enclosed grassland (for example, in North Devon) and the prime arable soils of East Anglia. They are all assessed as being equally important.

## Statistics

**Table 16** Food provision statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 9,014,154 | 69.11% | 2,655,108 | 20.36% | 1,372,866 | 10.53% | 13,042,128 | 100% |

All figures in hectares

## Wild species diversity

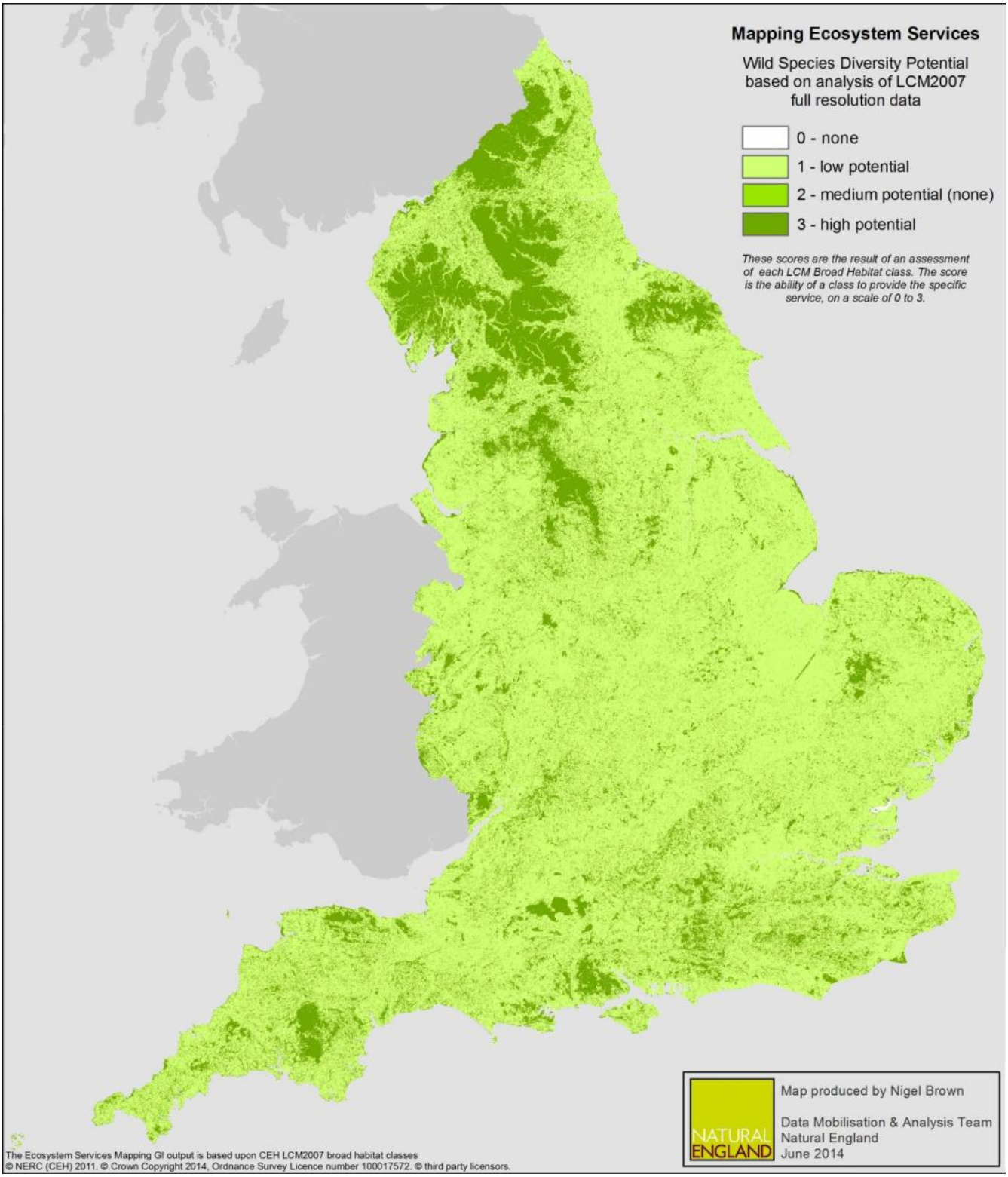


**Figure 10** Wild species diversity potential

## Wild species diversity map – Analysis

**Table 17** Wild species diversity - Habitat scoring table

| Sub habitat type | Score |
|---|---|
| Littoral rock | 3 |
| Littoral sediment | 3 |
| Supra-littoral rock | 3 |
| Supra-littoral sediment | 3 |
| Arable and horticulture | 1 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 1 |
| Fen, Marsh & Swamp | 3 |
| Bog | 3 |
| Dwarf shrub heath | 3 |
| Inland rock | 3 |
| Montane habitats | 3 |
| Acid grassland | 3 |
| Calcareous grassland | 3 |
| Rough low-productivity grassland | 3 |
| Built up areas and gardens | 1 |
| Broad leaved, mixed, & yew woodland | 3 |
| Coniferous woodland | 3 |

## Analysis

3.40 In line with the NEA, we refer here to a wild species diversity service rather than 'Biodiversity' which is a confusing concept for many. The map shows the habitats that have the greatest potential to support the widest diversity of living things, if in good condition. All habitats have some potential with the most important areas covering 21.36% of England.

3.41 At a national level it is possible to pick out large areas of upland and woodland on the map. Smaller, more fragmented habitats, with high wild species diversity (such as an individual hay meadow) are not discernable at this scale.

3.42 The map will be of little assistance for local decision making on issues such as the protection of populations of a particular species (which may not be linked to high potential habitats). Local data is required to take specific actions for specific species.

## Statistics

**Table 18** Wild species diversity statistics

| High Potential | % England | Medium Potential | % England | Low Potential | % England | Total | % England |
|---|---|---|---|---|---|---|---|
| 2,785,684 | 21.36% | 0 | 0.00% | 10,256,443 | 78.64% | 13,042,128 | 100% |

All figures in hectares

# Cultural services (#1)

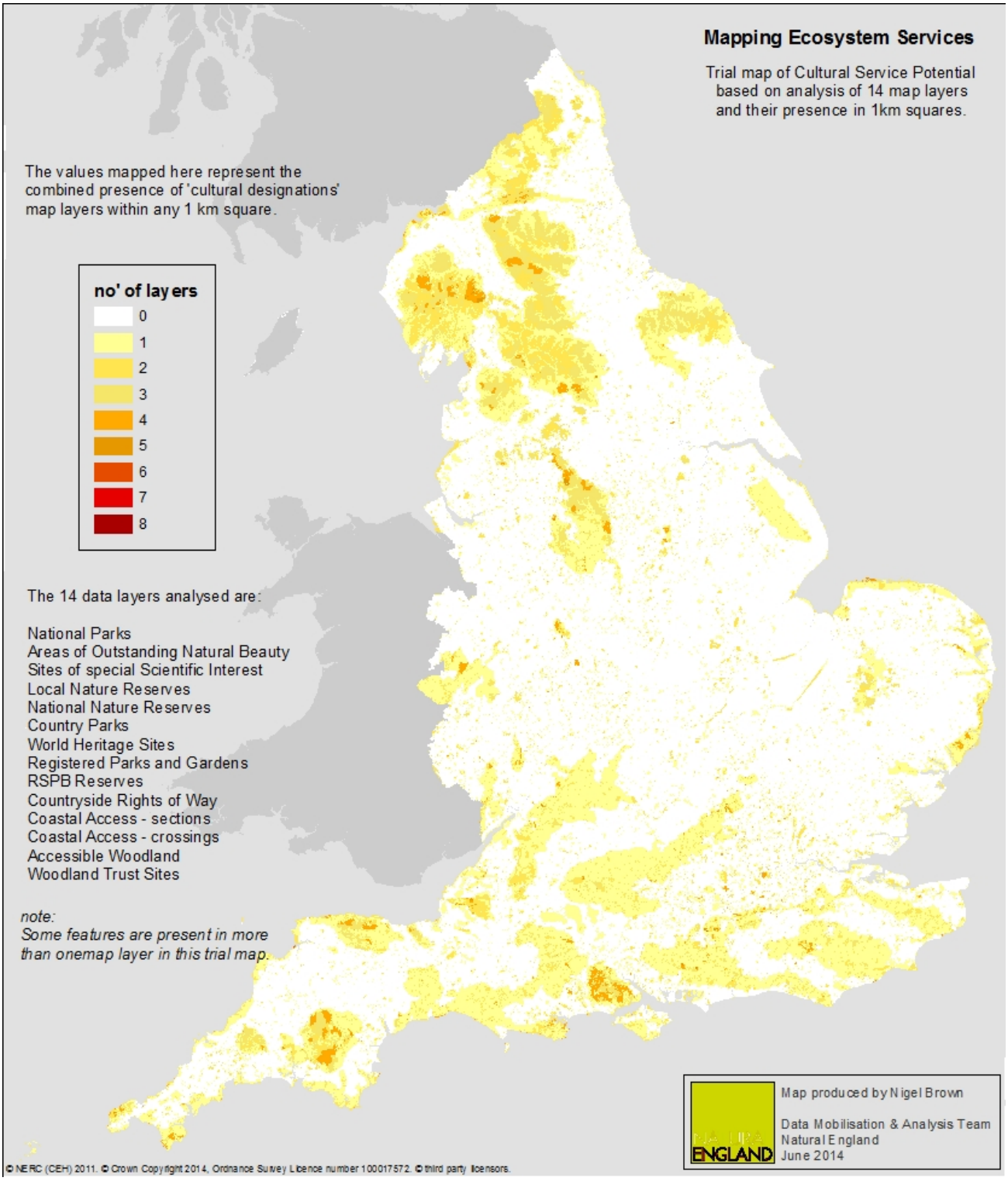


**Figure 11** Cultural services (datasets)

# Cultural services (#2)

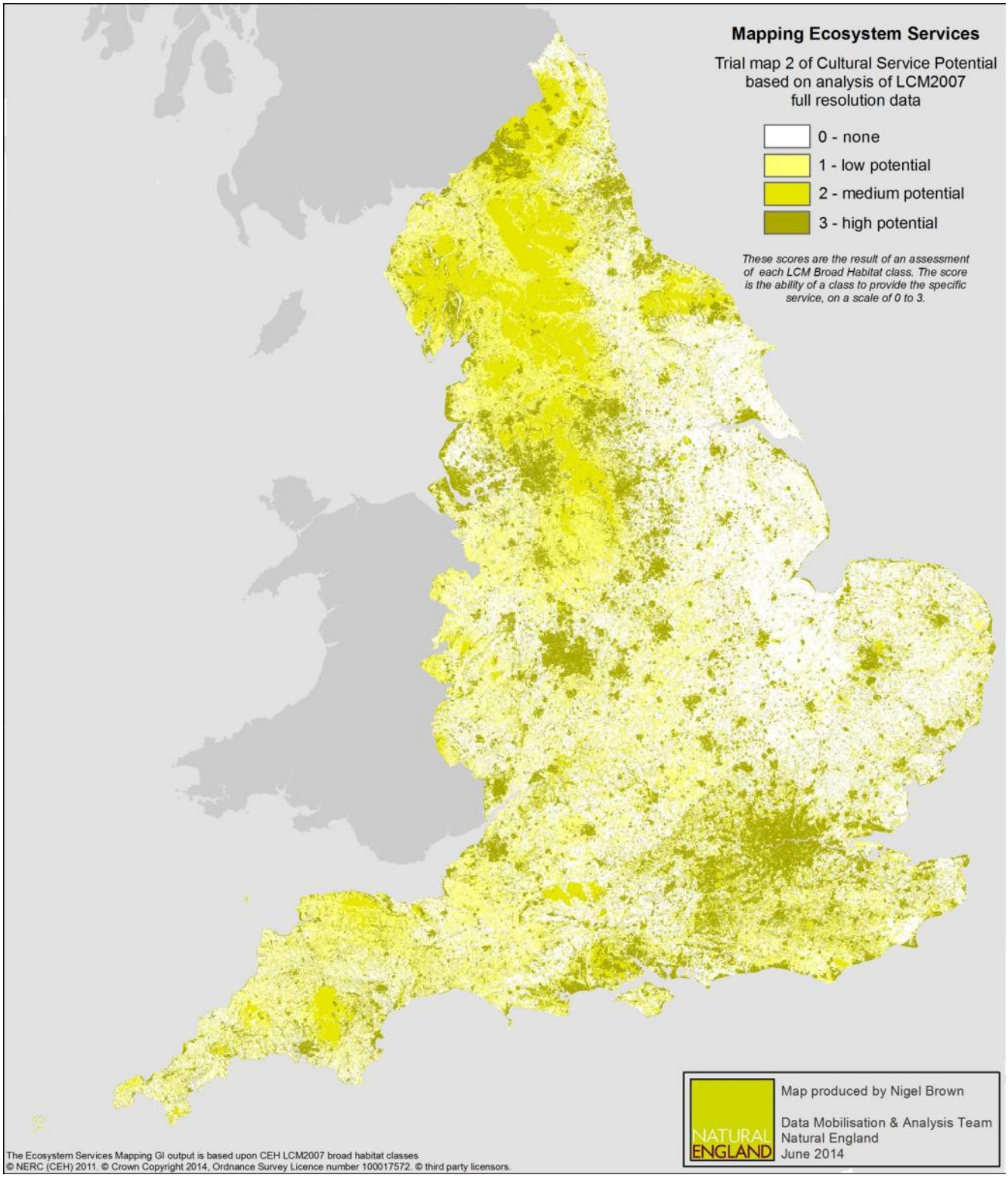


**Figure 12** Cultural services (LCM2007) habitats

## Cultural services – Analysis

**Table 19** Cultural services - Habitat scoring table (Map #2)

| Sub habitat type | Score |
|---|---|
| Littoral rock | 3 |
| Littoral sediment | 3 |
| Supra-littoral rock | 3 |
| Supra-littoral sediment | 3 |
| Arable and horticulture | 0 |
| Improved grassland | 1 |
| Neutral grassland | 1 |
| Freshwater | 3 |
| Fen, Marsh & Swamp | 3 |
| Bog | 2 |
| Dwarf shrub heath | 2 |
| Inland rock | 2 |
| Montane habitats | 2 |
| Acid grassland | 2 |
| Calcareous grassland | 2 |
| Rough low-productivity grassland | 2 |
| Built up areas and gardens | 3 |
| Broad leaved, mixed, & yew woodland | 3 |
| Coniferous woodland | 3 |

## Analysis

3.43 We have provided two maps for Cultural Ecosystem Services (CES).

3.44 To provide a comparison with the other maps and to assist with the testing of CES mapping approaches, we have produced a map (map #2) based on the NEA table. Given the difficulty of representing CES spatially whichever approach is taken, we are not convinced that using habitats as proxies for CES is the best way of presenting the evidence base. Similarly it is hard to envisage how the evidence base presented in the NEA cultural chapter is captured by the habitat map. The two maps are surprisingly similar, something which we were not expecting.

3.45 The approach taken for map #1 is described in the methodology section in **Section 2**. The big difference from the habitat approach is the choice of multiple datasets that have links to actual cultural service provision and the presentation of the data at a 1 km grid. The datasets chosen are those *largely* accessible to the general public, but will include areas which are not (some SSSIs and private land within National Parks, for example).

3.46 Map #1 could best be described as a 'heat' map – one that shows all the 'best' bits of England and which have received formal designation in some way for their wildlife, landscape, historic

environment value or access provision. Within that relatively narrow remit the map is one way of showing the places that society as a whole places most value upon, although with that statement (as with everything to do with CES) there is a certain amount of subjectivity involved.

3.47 There are some very clear limitations with map #1. The use of a 1 km grid makes the map of limited use at small spatial scales. A smaller grid would have reduced the map's value in showing 'heat' and still have had limited local use.

3.48 The relative value of one site over another is not captured. Sites with the same designation will provide completely different *total* levels of benefits dependent on the actual number of visitors.

3.49 Another limitation of the heat map approach for CES is that it implies a lesser value to squares containing the fewest datasets. Many more people may visit a country park close to a large urban centre than to a more remote area blessed with a much larger offer. The country park is providing a greater volume of CES, but this will not be reflected in the map.

3.50 An associated limitation is that it does not show the importance of green space close to where people live. Evidence from Natural England's Monitoring Engagement with the Natural Environment (MENE) programme suggests that around 75% of all visits made (to the natural environment) are within 5 miles of where people live. Many of these spaces have no designation whatsoever and so do not appear on the map. Looking at it another way, the map does not show where the *demand* for CES resides.

3.51 We know that mapping cultural services is inherently difficult due to the subjective nature of how and when people receive services in different areas and at different scales. People receive can receive services from anywhere, including spaces that are close to home as well as those more distant. Both maps display significant white space, areas which in theory have no value and which is clearly an unrepresentative position. Understanding how we can characterise, measure and map CES is an ongoing challenge.

# 4 Results

4.1 This section describes how far we believe we have met the aims of the project described in Section 1.

4.2 Through this project we have been able to demonstrate that it is possible to create ecosystem service maps at the England level based on existing habitat information. The ease of interpreting the maps is variable. The use of habitats as proxies for services has restricted the ability to represent some services accurately and some maps will have more immediate use than others. Some, because of the restrictions and complexities, may be of very limited use.

4.3 Within the limitations described in the mapping section, we have produced maps that will tell a story of ecosystem service provision in England, but those limitations need to be fully communicated by those using the maps. Ensuring this is done, the maps have value as communication, visualisation and discussion tools.

4.4 We have also shown that it is possible for bodies such as Natural England to produce maps that can be made widely and freely available to others.

4.5 Similarly, we have developed an approach which does not require users to utilise their own resources (staff and financial) to undertake the mapping process.

4.6 Different organisations will have widely differing needs in supporting an ecosystem approach and will have different uses for the maps. Within Natural England we will continue to develop our mapping approach and investigate methodologies that meet the key aims of this current project.

4.7 The maps cannot be used with accuracy at very local levels. The LCM2007 dataset is huge and extremely complex to create. The technical report that accompanied publication of the data suggests that the data has an overall accuracy of 83% (*CEH, July 2011*). The accuracy within habitat classes is variable.

4.8 When we move away from using the maps to give a broad impression of where services are located, towards using them for practical action at local levels, these inaccuracies become apparent.

## Case Study – South Downs Nature Improvement Area (NIA)

1) In March 2013 we prepared copies of the maps for the South Downs NIA partnership who kindly agreed to test them. An example map showing the area concerned is shown at Figure 13.

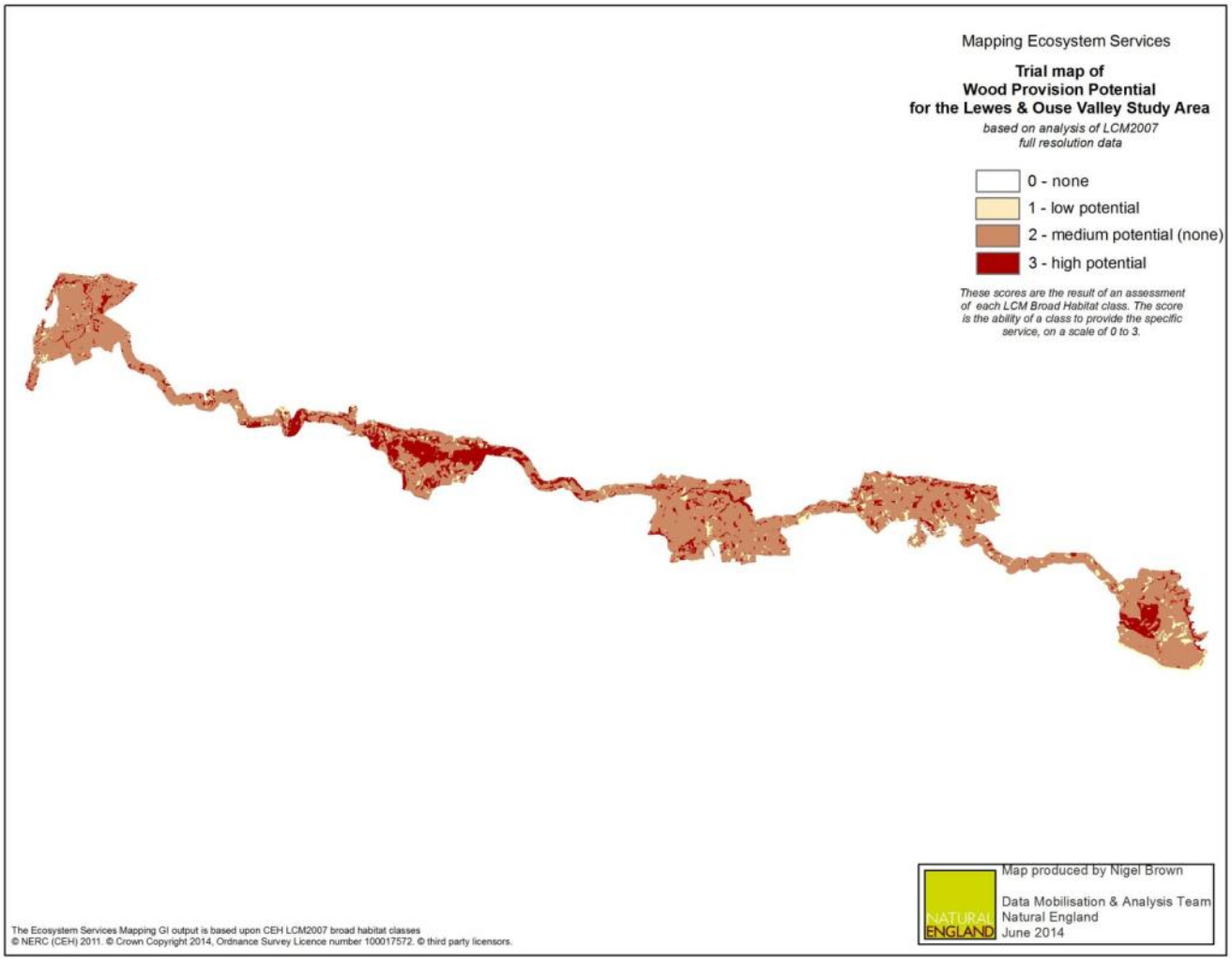


**Figure 13** Wood provision ecosystem service map, South Downs NIA

2) The partnership found the maps useful in demonstrating the broad distribution of ecosystem services in the area and saw potential in their use as communication and visualisation tools.
3) They did have some concerns regarding what the maps were actually showing and also in how they could be used for practical, on the ground decision making. This report was not available to the partnership during testing of the maps and individuals from the NIA partnership gave us feedback, including this from Colin Tingle “We still have some concerns about what the maps actually mean, given that the Ecosystem Service potential is only available by trawling through the whole of the NEA and that members of the public, business people, public servants, etc. who we might show the maps to will not do that and will therefore want a more precise explanation of what they really show”!
4) This feedback proved very valuable and this report has been prepared with these comments received in mind. The methodology and mapping sections should provide the understanding requested by the partnership.
5) As part of the trial, we provided the NIA with maps for a much smaller scale project area – the Lewes & Ouse Valley eco-nomics (L&OVe) project. The project boundary is just 10km by 10km. The wood provision map and an OS map of the project area is shown below.

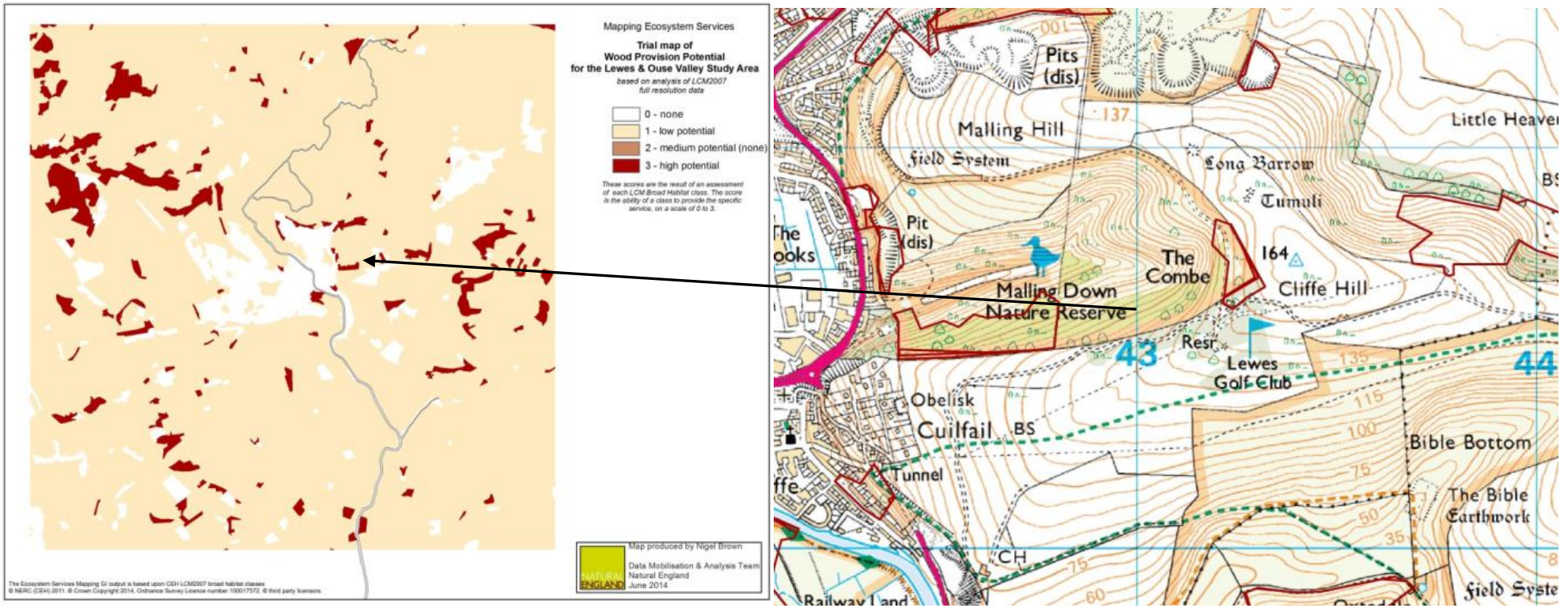


**Figure 14** Wood provision map and OS[6] map of the L&OVe project area

6) With scrutiny and detailed local knowledge, it was promptly clear to the partnership that the maps were not reliable at this local level without additional and more accurate data. The arrow across the maps indicates an area of actual woodland which is not represented on the wood provision map. At this scale, the small inaccuracies in the source data become more apparent and are of greater significance. Clearly, with access to our own data and standard GIS systems, the partnership would have been able to amend the service map, but this would defeat the purpose of what we wished to achieve.

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[6] © Crown copyright and database rights 2012. Ordnance Survey 100022021.

4.9 Another of our aims was for our data to be useable for further more complex analysis. In this we have not been totally successful. We would have liked the data to be immediately useable but it is clear, especially at local levels, that a certain amount of cleaning would be required before more complex analyses could be attempted. This would require scarce resources to be utilised by practitioners which flies against the aspiration for our maps and data.

4.10 Our final aim was to provide maps that are easy to understand and which can be used as effective communication and visualisation tools. Within the limitations described throughout this report – and with the overall complexity of ecosystem service science, we believe that this aim has been achieved at the national and sub-regional scale.

4.11 In summary, we believe that the aims of the project have only partially been met. We *have* provided ecosystem service maps at the England scale, but there are some limitations in using them. The quality of the maps, based on the links to existing habitats, is variable and we have demonstrated that they are not immediately effective at local scales.

4.12 Perhaps most significantly we have demonstrated that the production of the simplest of ecosystem service maps is still incredibly complex. We had hoped to demonstrate that it *is* possible to prepare simple, useable maps that would not require any input from practitioners. Using our approach, practitioners would need to undertake a certain amount of quality assurance before any further analysis could be done.

4.13 We conclude that more work must be done before simple ecosystem service maps can be provided to practitioners that meet the aspirations contained in our project. The lessons learned from this project have highlighted some key areas for further investigation:

- More than one dataset (or map) may be needed to accurately depict services more clearly. As an example, it would be beneficial for the Water quality service to have data on both impacts (from the Water Framework Directive) and the location of the habitats which can contribute to regulating the service.
- The condition of the habitat is critical. For example, depending on condition, peatland can be either sources or sinks for carbon.
- The location of beneficiaries needs to be investigated further for some services – especially cultural and water supply.
- Additional data to provide an indication of flow is needed for some services. For the pollination service, for example, the location of crops requiring insect pollinators.

# 5 Recommendations

5.1 This section outlines recommendations for further work on simple ecosystem service map provision based on the lessons learned from our project. Some of the recommendations are general, some specific to individual services. They are based on addressing the limitations to mapping we have highlighted during the project.

5.2 It is extremely useful to have a UK wide land cover dataset in the shape of LCM2007 and it would be highly desirable to have just one dataset from which to develop ecosystem service maps. The consistency that this would bring to any mapping project is very attractive. At larger scales this approach can work, but at local scales there will be a need to incorporate additional datasets.

5.3 Natural England has recently completed a single habitat layer for priority habitats and it is recommended that investigating how this could be used in conjunction with more general land use data would be an appropriate course of action.

5.4 We have highlighted how a lack of qualitative assessment of habitats limits the effectiveness of the maps and it is recommended that inclusion of available condition data is used in further mapping attempts. Information on the condition of habitats is variable across the country and local knowledge and local data will be required. Data available from long term monitoring sites might also assist at local levels. At the national level, the condition of SSSI (Sites of Scientific Special Interest) units is widely available.

5.5 There is no land use or land cover dataset, nor one on habitat condition, that covers the whole of England or is 100% accurate. Irrespective of the steps that can be taken to provide more effective maps, we conclude that local practitioners will need to accept the need to allocate additional resources to ensure accurate local base data.

5.6 For the **climate regulation** map we recommend that a different approach is needed. One map will not provide all the information required to understand this service correctly. It is recommended that separate maps for carbon storage, sequestration and cooling effects should replace the single map and that data on soils should be included in mapping efforts. This would allow important areas 'missed' by the single layer approach to be incorporated.

5.7 The **pollination for crops** map needs further work. We recommend that further work on this map looks at either additional datasets that help identify habitats important for pollinators missed by a national approach or the scoring is changed to reflect the potential contribution of existing habitats. Scoring changes are also required to ensure habitats close enough to benefit insect pollinated crops have a higher priority than those more distant. This will require data on where cropping requiring insect pollination is taking place, which may be problematic for non governmental bodies (for licensing and data protection reasons).

5.8 It is difficult to see how the **Air Quality** map can be developed further on a habitats basis. Where data is available, identification of areas with the poorest air quality would be beneficial.

5.9 The complexity of mapping the regulating services is encapsulated by the **soil function** map. We recommend that to fully understand and map this service accurately will require a complete move away from a habitat based approach. The approach we have taken only shows where good quality soils may exist, but such a broad based, non qualitative approach, is barely helpful.

Soils data – and data on the quality of those soils is required to enable an accurate picture to be made. Soils data may also help to understand the other final services to which soil quality contributes. We recommend further investigation into this and the need, perhaps, for soils data to be used in combination with habitat data.

5.10 The **water quality** map does show habitats that contribute most to water quality but it is recommended that actual data on water quality, where available (possibly through Water Framework Directive monitoring) is used in conjunction with the habitats data to make a clearer link between habitat and need. Identification of areas at highest risk of or suffering from the effects of diffuse pollution would also be useful.

5.11 There are two main recommendations for developing the **water supply** map. First, data on groundwater supply should be included so that all sources of water are shown together. Secondly, while it takes the mapping exercise away from the simple approach we are advocating, knowledge of where water is being supplied to is required. This is so we can identify the sources of water most important to the public and where protective interventions may be required. This will be complex and may benefit from being trialled at local levels in the first instance.

5.12 The **wood provision** map works at the national level but would become more accurate through use of data from the national forest inventory which is the recommended next step.

5.13 The **food provision** map is currently too visually 'busy' to be of use. Our recommendation is to once more separate out the livestock and arable elements and exclude fish altogether[7]. This would best be done through the use of available agricultural data which may again prove difficult for non governmental bodies and with the presentation of any outputs.

5.14 For **wild species diversity**, the map provided here can be used at larger scales although inclusion of data on the quality of habitats will be important.

5.15 Cultural services are the most complex of all services to map accurately due to the subjective nature of how people experience nature's benefits. There are a number of ongoing projects that are seeking to understand, measure and map cultural services that will help to us to further develop our thinking and refine our approach. For example the NEA Follow On (NEAFO) project on CES has developed cultural service indicators which could, potentially, be mapped. There is also significant potential to explore alternative mapping approaches through the use of new technologies and social media.

[7] Although identifying where fish farms are located may be of interest. Differentiation between farms that supply food markets, the recreational sector or both will be difficult.

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# Appendix 1 12 principles from the Convention of Biological Diversity

### Principle 1: The objectives of management of land, water and living resources are a matter of societal choices

Different sectors of society view ecosystems in terms of their own economic, cultural and society needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

### Principle 2: Management should be decentralized to the lowest appropriate level

Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

### Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems

Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

### Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

- Reduce those market distortions that adversely affect biological diversity;
- Align incentives to promote biodiversity conservation and sustainable use; and
- Internalize costs and benefits in the given ecosystem to the extent feasible.

The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems. Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (for example, pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

### Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach

Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

### Principle 6: Ecosystem must be managed within the limits of their functioning

In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable of artificially maintained conditions and, accordingly, management should be appropriately cautious.

### Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales

The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

### Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term

Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

### Principle 9: Management must recognize the change is inevitable

Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential "surprises" in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

### Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity

Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems.

### Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices

Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, taking into account, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

### Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines

Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

# Appendix 2 Deviations from the NEA habitat to service importance assessments

| Habitat | Sub-habitat | Crops | Livestock | Fish | *Ag Production* | Trees | *Timber* | Water Supply | *Water Supply* |
|---|---|---|---|---|---|---|---|---|---|
| **Coastal** | Littoral Rock | 1 | 1 | 2 | *1* | 1 | *0* | 1 | *1* |
| **Coastal** | Littoral Sediment | 1 | 1 | 2 | *1* | 1 | *0* | 1 | *1* |
| **Coastal** | Supra-Littoral Rock | 1 | 1 | 2 | *1* | 1 | *0* | 1 | *1* |
| **Coastal** | Supra-Littoral Sediment | 1 | 1 | 2 | *1* | 1 | *0* | 1 | *1* |
| **Farmland** | Arable & Horticulture | 3 | 3 | 0 | *3* | 2 | *1* | 2 | *0* |
| **Farmland** | Improved Grassland | 3 | 3 | 0 | *3* | 2 | *1* | 2 | *0* |
| **Farmland** | Neutral Grassland | 3 | 3 | 0 | *3* | 2 | *1* | 2 | *0* |
| **Freshwater** | Freshwater | 1 | 1 | 2 | *1* | 2 | *1* | 3 | *3* |
| ***Grasslands*** | ***Fen, Marsh, Swamp*** | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *0* |
| **Uplands** | Bog | 0 | 1 | 0 | *2* | 2 | *0* | 3 | *3* |
| **Uplands** | Dwarf Shrub Heath | 0 | 1 | 0 | *2* | 2 | *0* | 3 | *3* |
| **Uplands** | Inland Rock | 0 | 1 | 0 | *2* | 2 | *0* | 3 | *3* |
| **Uplands** | Montane Habitats | 0 | 1 | 0 | *2* | 2 | *0* | 3 | *3* |
| **Grasslands** | Acid Grassland | 1 | 1 | 0 | *2* | 1 | *0* | 0 | *0* |
| **Grasslands** | Calcareous Grassland | 1 | 1 | 0 | *2* | 1 | *0* | 0 | *0* |
| **Grasslands** | Rough Grassland | 1 | 1 | 0 | *2* | 1 | *0* | 0 | *0* |
| **Urban** | Built up Areas & Gardens | 1 | 1 | 1 | *2* | 2 | *0* | 2 | *0* |
| **Woodland** | Deciduous | 0 | 1 | 0 | *1* | 3 | *3* | 1 | *2* |
| **Woodland** | Coniferous | 0 | 1 | 0 | *1* | 3 | *3* | 1 | *2* |

| Habitat | Sub-habitat | Cultural 1 | Cultural 2 | *Cultural* | Climate | *Climate* | Pollination | *Pollination* |
|---|---|---|---|---|---|---|---|---|
| **Coastal** | Littoral Rock | 3 | 3 | *3* | 2 | *2* | 1 | *1* |
| **Coastal** | Littoral Sediment | 3 | 3 | *3* | 2 | *2* | 1 | *1* |
| **Coastal** | Supra-Littoral Rock | 3 | 3 | *3* | 2 | *2* | 1 | *1* |
| **Coastal** | Supra-Littoral Sediment | 3 | 3 | *3* | 2 | *2* | 1 | *1* |
| **Farmland** | Arable & Horticulture | 2 | 2 | *0* | 3 | *1* | 3 | *2* |
| **Farmland** | Improved Grassland | 2 | 2 | *1* | 3 | *1* | 3 | *2* |
| **Farmland** | Neutral Grassland | 2 | 2 | *1* | 3 | *1* | 3 | *2* |
| **Freshwater** | Freshwater | 3 | 3 | *3* | 1 | *1* | 0 | *1* |
| ***Grasslands*** | ***Fen, Marsh, Swamp*** | *2* | *3* | *3* | *2* | *2* | *3* | *3* |
| **Uplands** | Bog | 2 | 3 | *2* | 3 | *3* | 1 | *1* |
| **Uplands** | Dwarf Shrub Heath | 2 | 3 | *2* | 3 | *3* | 1 | *1* |
| **Uplands** | Inland Rock | 2 | 3 | *2* | 3 | *3* | 1 | *1* |
| **Uplands** | Montane Habitats | 2 | 3 | *2* | 3 | *3* | 1 | *1* |
| **Grasslands** | Acid Grassland | 2 | 3 | *2* | 2 | *2* | 3 | *3* |
| **Grasslands** | Calcareous Grassland | 2 | 3 | *2* | 2 | *2* | 3 | *3* |
| **Grasslands** | Rough Grassland | 2 | 3 | *2* | 2 | *2* | 3 | *3* |
| **Urban** | Built up Areas & Gardens | 3 | 2 | *3* | 3 | *2* | 2 | *1* |
| **Woodland** | Deciduous | 3 | 2 | *3* | 3 | *3* | 1 | *1* |
| **Woodland** | Coniferous | 3 | 2 | *3* | 3 | *3* | 1 | *1* |

| Habitat | Sub-habitat | Water Quality | *Water Quality* | Soil Quality | *Soil Quality* | Air Quality | *Air Quality* | Wild Species | *Wild Species* |
|---|---|---|---|---|---|---|---|---|---|
| **Coastal** | Littoral Rock | 3 | *3* | 1 | *1* | 1 | *1* | 3 | *3* |
| **Coastal** | Littoral Sediment | 3 | *3* | 1 | *1* | 1 | *1* | 3 | *3* |
| **Coastal** | Supra-Littoral Rock | 3 | *3* | 1 | *1* | 1 | *1* | 3 | *3* |
| **Coastal** | Supra-Littoral Sediment | 3 | *3* | 1 | *1* | 1 | *1* | 3 | *3* |
| **Farmland** | Arable & Horticulture | 3 | *1* | 3 | *1* | 2 | *1* | 1 | *1* |
| **Farmland** | Improved Grassland | 3 | *1* | 3 | *1* | 2 | *1* | 1 | *1* |
| **Farmland** | Neutral Grassland | 3 | *1* | 3 | *1* | 2 | *1* | 1 | *1* |
| **Freshwater** | Freshwater | 3 | *3* | 2 | *2* | 1 | *2* | 3 | *1* |
| ***Grasslands*** | ***Fen, Marsh, Swamp*** | *3* | *2* | *3* | *3* | *2* | *2* | *3* | *3* |
| **Uplands** | Bog | 3 | *2* | 3 | *3* | 1 | *2* | 3 | *3* |
| **Uplands** | Dwarf Shrub Heath | 3 | *2* | 3 | *3* | 1 | *2* | 3 | *3* |
| **Uplands** | Inland Rock | 3 | *2* | 3 | *3* | 1 | *2* | 3 | *3* |
| **Uplands** | Montane Habitats | 3 | *2* | 3 | *3* | 1 | *2* | 3 | *3* |
| **Grasslands** | Acid Grassland | 3 | *2* | 3 | *3* | 2 | *2* | 3 | *3* |
| **Grasslands** | Calcareous Grassland | 3 | *2* | 3 | *3* | 2 | *2* | 3 | *3* |
| **Grasslands** | Rough Grassland | 3 | *2* | 3 | *3* | 2 | *2* | 3 | *3* |
| **Urban** | Built up Areas & Gardens | 2 | *1* | 2 | *2* | 3 | *3* | 1 | *1* |
| **Woodland** | Deciduous | 2 | *3* | 3 | *3* | 3 | *3* | 3 | *3* |
| **Woodland** | Coniferous | 2 | *3* | 3 | *3* | 3 | *3* | 3 | *3* |


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