DEVELOPING ECOSYSTEM ACCOUNTS FOR PROTECTED AREAS IN ENGLAND AND SCOTLAND: LAKE DISTRICT NATIONAL PARK SUMMARY REPORT

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INTRODUCTION

The Lake District National Park (NP) is made up of a mosaic of interconnected ecosystems including open waters, moorland, woodland, and grassland. These **ecosystem assets** provide a range of important services to people living within and visiting the area, including provision of food and water; regulation of air quality, water quality, and flood risk; and cultural services such as aesthetic value, a sense of heritage, and opportunities for recreation.

The value of these services is significant and the capacity of the environment to continue to provide such services has a direct impact on the Lake District's prosperity and well-being. However, the monetary value of these **ecosystem services** is not always fully accounted for in the management of land and natural assets.

Ecosystem accounts provide a framework for measuring the extent and condition of these assets, and monitoring changes in the provision of services over time. This provides a way to communicate the contribution that the environment plays in supporting economic vitality and social wellbeing, and can also be used to evaluate trade-offs as to how investment can support or risk the capacity of ecosystems to function and provide services.

Developing an ecosystem account for Lake District NP

In 2014, Defra and the Scottish Government funded a project to scope the potential for developing ecosystem accounts for protected and other land areas in the UK. The project builds on work by Defra and the Office for National Statistics and draws on the UN System of Environmental Economic Accounting guidance.

The aim of the accounts is to quantify the extent and condition of ecosystem assets within six pilot areas, as well as to quantify and value the flow of ecosystem services from these assets. In addition to testing the principles of ecosystem accounting methodologies, a key aim of the project is to help inform resource management decisions within the pilot areas.

As part of this project, the Lake District NP was selected as one of the pilot areas. This report sets out some of the key findings for the Lake District NP from the development of the ecosystem accounts. The report is divided into seven sections:

- **Asset account** – provides an overview of the quantity and quality of ecosystems in Lake District NP to monitor changes in the extent and condition of the stock of ecosystem assets.
- **Physical flows** – provides an overview of the physical quantity of services provided within Lake District NP in 2013.
- **Monetary flows** – provides an overview of the monetary value of the services provided in Lake District NP in 2013.
- **Appendix A** – provides full details of the asset account tables for Lake District NP.
- **Appendix B** – provides a series of maps highlighting the physical flows of ecosystem services at a 1 km^2 level.
- **Appendix C** – provides an overview of the methodology used to estimate the physical and monetary flows.
- **Appendix D** – provides a discussion of some of the areas where local data could enhance the accounts.

Experimental nature of the ecosystem account

It is important to note that the Lake District NP ecosystem account has been developed as part of a wider effort to demonstrate the concept of ecosystem accounts in practice. As such, the findings outlined in this report should be read with an appreciation of the experimental nature of this exercise.

The number of ecosystem services covered by the account and the accuracy of its findings could be increased through methodological advances and the availability of improved data. This could include steps to further refine the Lake District NP ecosystem accounts for local use, with a greater emphasis on local circumstances and the use of local data sources.

As examples of the potential to refine the accounts at the local scale, the following opportunities have been discussed with the Lake District NP:

- Inclusion of data on the Lake District's population of Arctic Alpine plant species.
- Exploring the soil erosion and water quality benefits of woodland and scrub creation.
- Quantifying the provision of hydroelectric power from small-hydro schemes in the NP.
- Using tranquillity data as an indicator of wellbeing.

In terms of local circumstances, it is important to note two key caveats associated with the Lake District NP account:

- **Peat depth**: feedback from the Lake District NP indicated that the approach used to estimate the area of degraded peatland which is emitting greenhouse gasses (i.e. using Land Cover Map 2007 data and SSSI condition) may have underestimated the extent and condition of the Lake District's peatland assets. This is due to the presence of shallow peaty soils in upland areas such as the Lake District NP, which are not accounted for in this approach. The use of shallow peatland data incorporated in Natural England's (2010) *England's peatlands* report may support the development of a more appropriate local value in future.

- **Moorland line**: the Moorland Line encloses land within England that is defined as being predominantly semi-natural upland vegetation. The Lake District NP believe that the 'open fell' land in the Park situated above the Moorland Line should be considered part of the mountain, moorland and heaths (MMH) ecosystem type. However, in LCM 2007 this area is classified as acid grassland. As a result, MMH ecosystems appear underrepresented in the Lake District account while semi-natural grassland (SNGL) is overrepresented. The use of a single ecosystem GIS layer for the Moorland Line could be used to re-categorise the acid grassland ecosystems found in upland areas to rectify this issue.

Further details on the methods used and the results can be found in the **Main Report** and the **Technical Appendix**.

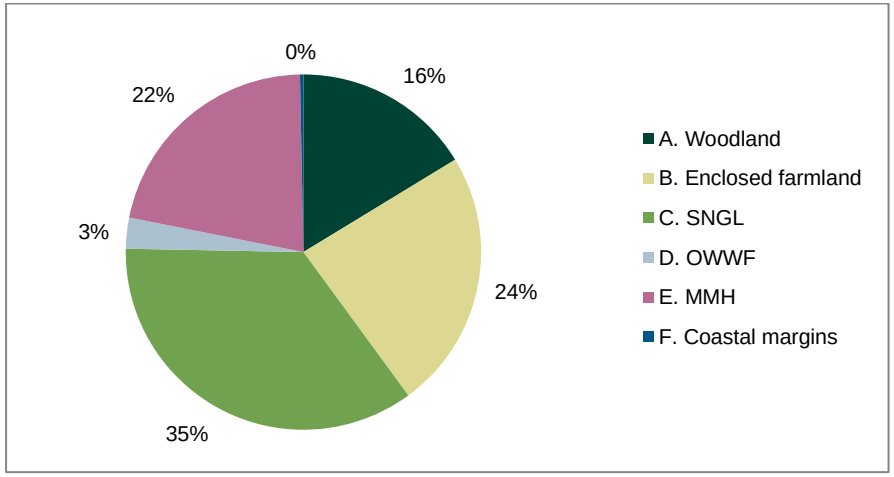
ASSET ACCOUNT

The asset account was developed for six broad ecosystem types:

A. Woodland
B. Enclosed farmland
C. Semi-natural grassland (SNGL)
D. Open waters, wetlands, and floodplains (OWWF)
E. Mountains, moorlands, and heaths (MMH)
F. Coastal margins

Of these six broad ecosystem types, the centre of the Lake District is made up of MMH interspersed with woodland, SNGL, and large areas of OWWF. This area is surrounded by enclosed farmland ecosystems. An overview of ecosystem coverage is set out in Figure 1 and a map is provided in Figure 3 overleaf.

Figure 1. Ecosystem types in Lake District NP



A set of indicators was developed to quantify the extent and condition of each of the six ecosystem types. The indicators are grouped into five categories and can be used to track changes in each ecosystem's capacity to provide services over time. This section provides an example of some of the indicators used to monitor ecosystem condition across the five categories.

1) Biomass/carbon

Good data was available from the Countryside Survey on the concentration of carbon in the topsoil layer for four of the six ecosystem types. The results indicate that MMH ecosystems in the Lake District have higher topsoil carbon concentrations than other ecosystems, suggesting that they are able to provide significant carbon stores, while enclosed farmlands and woodlands have much lower soil carbon density. See Figure 2 below.

Figure 2. Topsoil carbon concentration (tonnes per ha)

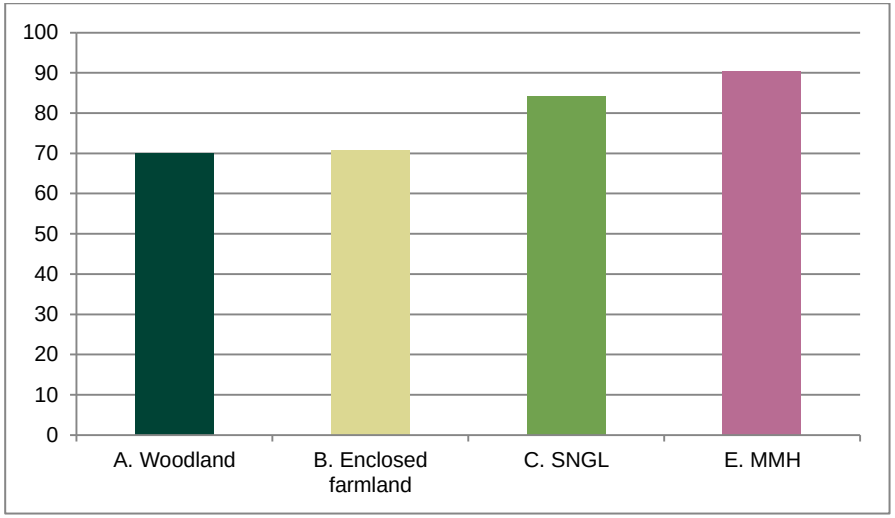
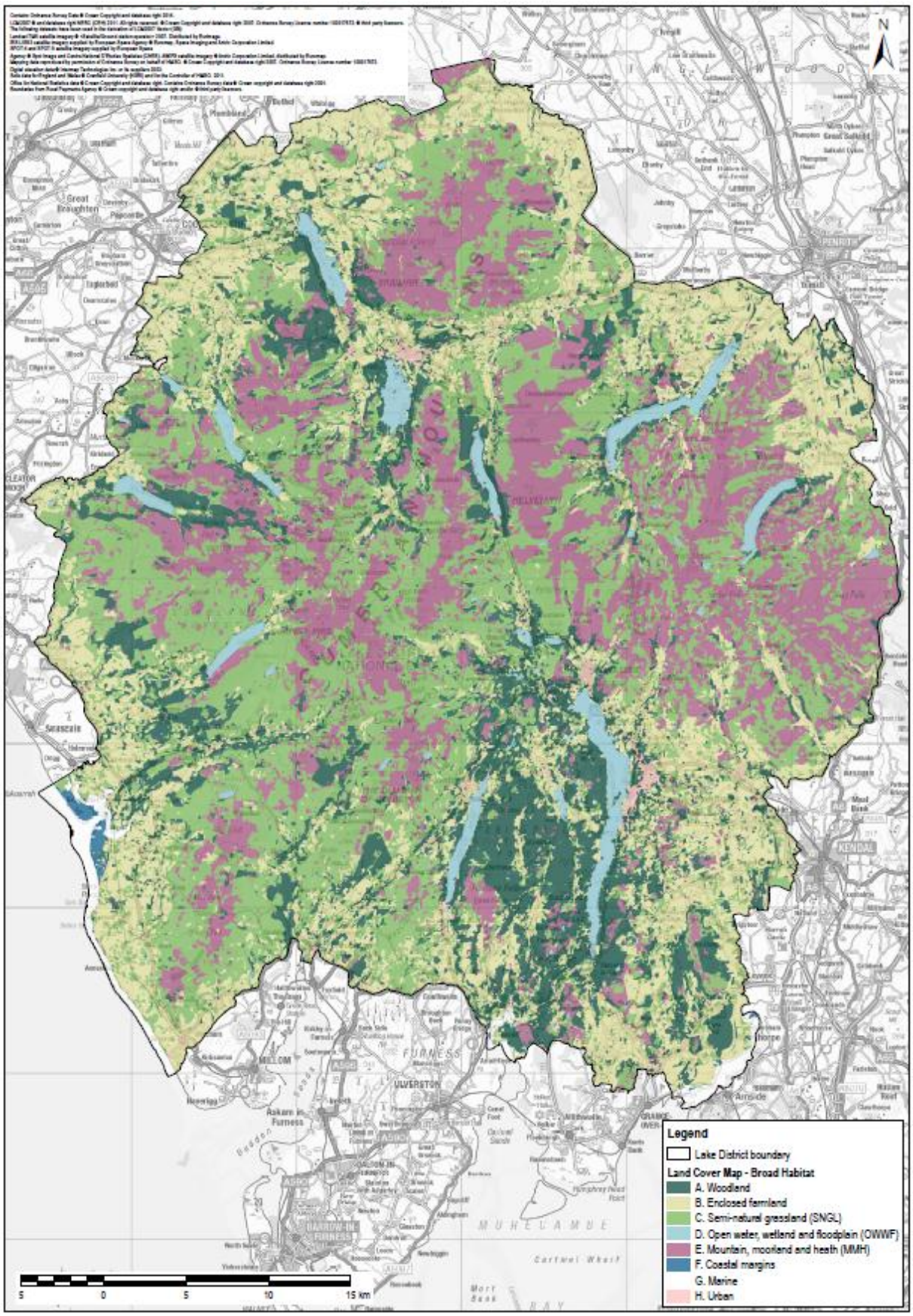


Figure 3. Map of broad ecosystem types in Lake District NP. Source: Land Cover Map 2007

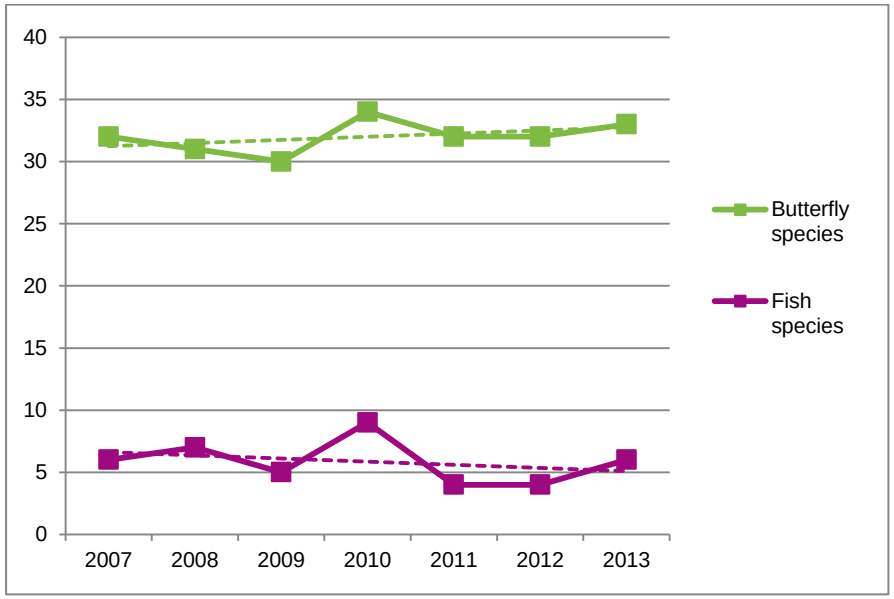


2) Biodiversity

Time series data on the trends in abundance and diversity of butterfly species was available from the Butterfly Conservation Monitoring Scheme. Butterfly data was chosen as an indicator of the condition of SNGL ecosystems although it should be noted that other factors such as climate can also affect butterfly populations.

For OWWF ecosystems, data was available on the number of fish species based on surveys by the Environment Agency. As set out in Figure 4 below, the diversity of butterfly and fish species appears to be relatively stable over time, with slight increases in butterfly species and declines in fish species.

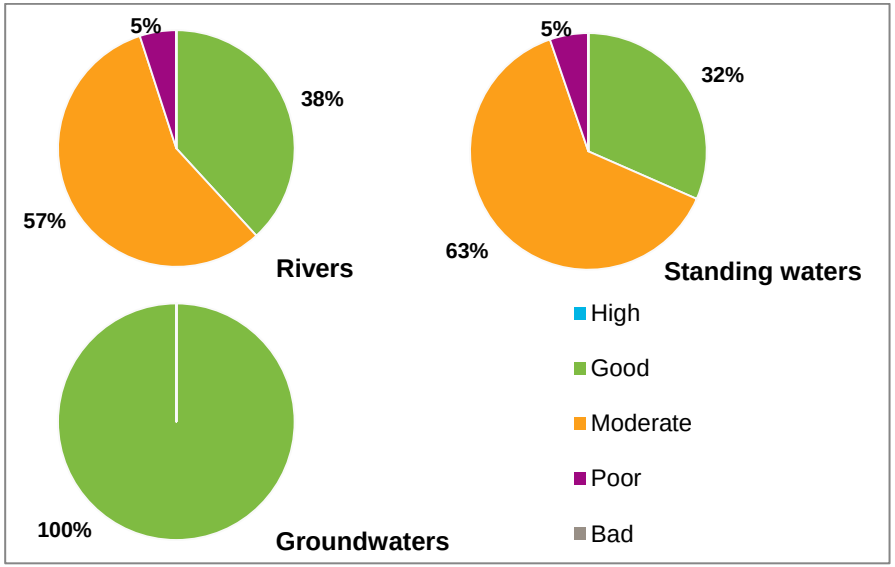
Figure 4. Number of butterfly and fish species recorded in Lake District NP (2007 to 2013)



3) Soil/water quality

As an indicator of the condition of OWWF ecosystems, data was available on the Water Framework Directive ecological classification for rivers, standing waters, and groundwater. As set out in Figure 5, 38% of rivers in the Lake District were in 'High' or 'Good' status in 2013, 32% of standing waters, and 100% of groundwaters.

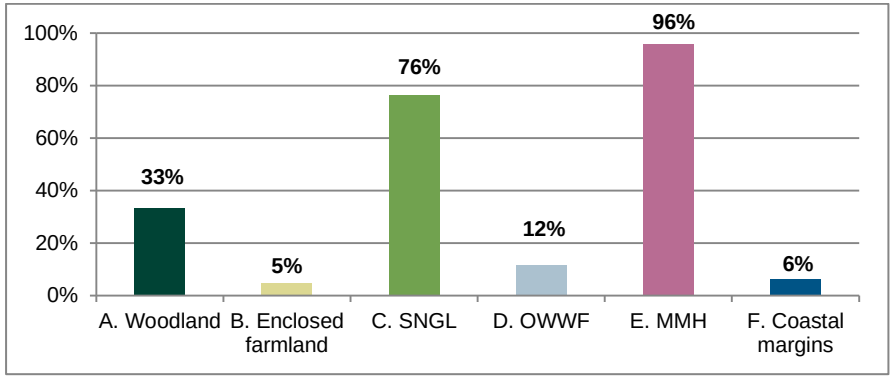
Figure 5. Ecological classification in the Lake District NP 2013



4) Accessibility

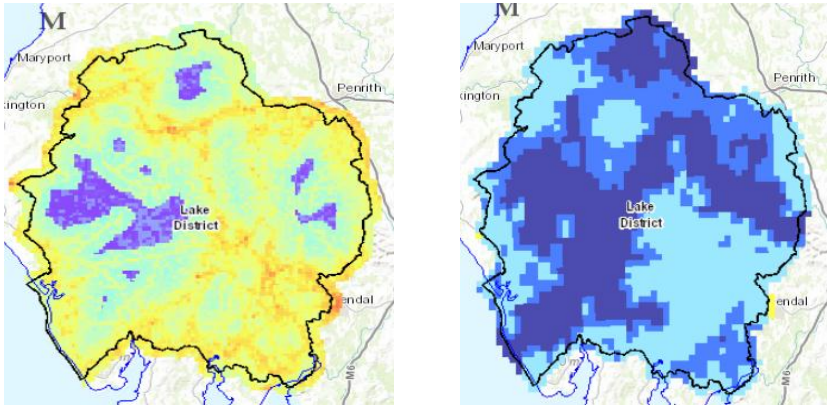
The proportion of land within each ecosystem that is publically accessible in terms of Countryside Right of Way (CRoW) designations was assessed using data held by Natural England. As set out in Figure 6, accessibility is highest for MMH and SNGL ecosystems, and lowest for enclosed farmland and coastal margins.

Figure 6. Area of ecosystem accessible via CRoW (%)



While not strictly a measure of accessibility, the level of tranquility and the extent of dark skies provides an indication of the access to 'wilder' ecosystems in the NP. Good data on tranquility and dark skies was available from a CPRE study undertaken in 2000. The data suggests that MMH are the most tranquil and have the darkest skies. Maps are set out in Figure 7.

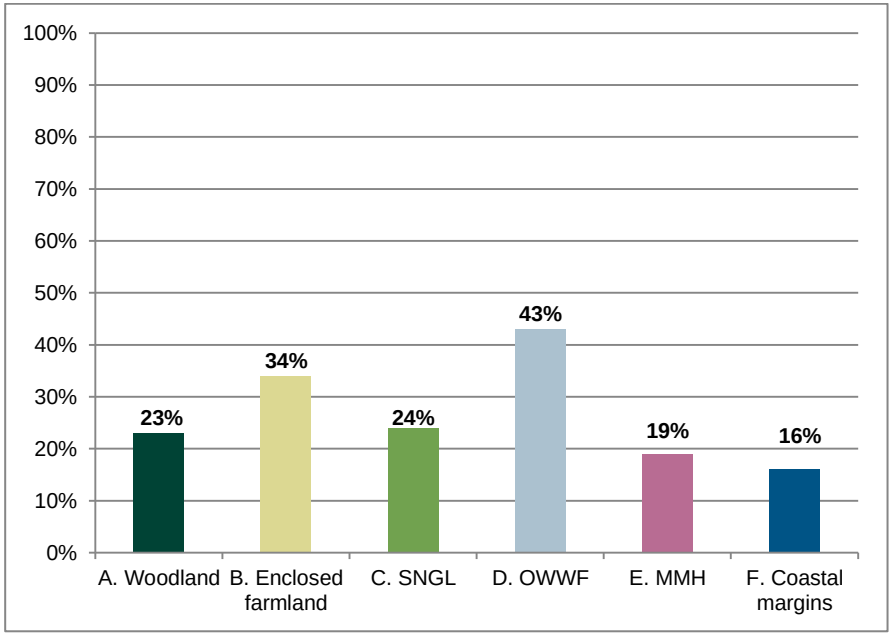
Figure 7. Tranquility and dark skies within Lake District NP
Tranquility (blue high, red low) **Dark skies (blue high, red low)**



5) Conservation status

Information on the area and condition of SSSIs within the NP was available through Natural England GIS datasets and the FMEOPL monitoring framework. Of the six ecosystem types, coverage was highest for OWWF (50%) and lowest for enclosed farmlands (2%). The proportion of designated SSSIs in favourable condition was highest for OWWF ecosystems and lowest for coastal margins. This is set out in Figure 8.

Figure 8. Area of SSSIs in favourable condition (%)



The full set of asset account tables developed for each of the six broad ecosystem types in the Lake District NP is available in Appendix A of this report.

PHYSICAL FLOWS

Ecosystems in the Lake District NP provide a range of important services including timber and livestock, air and climate regulation, drinking water and other water uses, recreation, and aesthetic values. Flood protection, education, and cultural heritage are also important, although it was not possible to quantify the physical flows of these services.

With regards to particular ecosystems:

- **Woodlands** are important for timber and woodfuel production, regulation of air quality and climate, as well as recreation and aesthetic values.
- **Enclosed farmlands** are important for livestock grazing and their aesthetic value.
- **SNGLs** are important for livestock grazing, climate regulation, and aesthetic value.
- **OWWF** are important for the provision of water for drinking and other uses, wild foods, recreation opportunities, aesthetic values, and for supporting charismatic species including osprey and Arctic charr.
- **MMH** are important for climate regulation, recreation, and aesthetic value.

A summary is provided in Table 1 opposite and the full account is set out in Table 2 overleaf.

Table 1. Physical flows of ecosystem services in 2013

Ecosystem service	Measurement unit	Physical flows
Crops	tonnes crops harvested	15,951
Livestock	livestock units on land	83,470
Wild foods	kg meat harvested	6,254
Drinking water	m^3 water abstracted	246,645,732
Timber	tonnes timber harvested	80,997
Other water uses	m^3 water abstracted	352,215,874
Energy	tonnes woodfuel harvested	16,862
Air quality	tonnes PM_{10} absorbed	4,457
Flood protection	-	-
Climate regulation	tonnes carbon absorbed	95,142
Recreation	no. visitors to ecosystems	13,020,000
Education	-	-
Heritage	-	-
Aesthetic	no. photos of landscapes	2,849
Existence		
– ***Osprey***	*no. breeding pairs*	*5*
– ***Arctic charr***	*catch per unit effort*	*0.9*

Table 2. Physical flows account for Lake District NP in 2013

Ecosystem service	Measurement unit	Woodland	Enclosed farmland	SNGL	OWWF	MMH	Coastal margins	Total
Crops	tonnes crops	-	15,951	-	-	-	-	**15,951**
Livestock	livestock units	-	52,763	25,528	0	5,122	57	**83,470**
Wild foods (game birds)	kg meat	-	-	-	-	-	-	**-**
Wild foods (venison)	kg meat	-	-	-	-	-	-	**-**
Wild foods (fish)	kg meat	-	-	-	6,254	-	-	**6,254**
Drinking water	m^3 water	-	-	-	246,645,732	-	-	**246,645,732**
Timber	tonnes timber	80,997	-	-	-	-	-	**80,997**
Other water uses	m^3 water	-	-	-	352,215,874	-	-	**352,215,874**
Energy	tonnes woodfuel	16,862	-	-	-	-	-	**16,862**
Air quality	tonnes PM_{10}	3,607	260	368	-	220	2	**4,457**
Flood protection	-	-	-	-	-	-	-	**-**
Climate regulation	tonnes carbon	77,632	1,557	8,637	0	6,715	600	**95,142**
Recreation	no. visitors	2,604,000	781,200	1,432,200	3,645,600	4,296,600	260,400	**13,020,000**
Education	-	-	-	-	-	-	-	**-**
Heritage	-	-	-	-	-	-	-	**-**
Aesthetic	no. photos	634	518	766	476	454	1	**2,849**
Existence (osprey)	no. breeding pairs	-	-	-	5	-	-	**5**
Existence (Arctic charr)	catch per unit effort	-	-	-	0.9	-	-	**0.9**

Caveats

Provisioning services

An important caveat to make is that while the data on total livestock numbers is relatively accurate, there is a much greater degree of uncertainty over the allocation of livestock to different ecosystems. Upland hill farming in the Lake District, for example, uses a range of ecosystems to varying degrees during the farming year, particularly MMH, SNGL, and enclosed farmland. The pattern of ecosystem use varies between upland areas and within them. Therefore allocation of grazing to different ecosystems is problematic in upland areas. Simple, but reasonable assumptions, have been used to allocate livestock to different ecosystems; these take into account the estimated carrying capacity of semi-natural ecosystems but it is acknowledged that this is a major simplification of a complex area.

Regulating services

It was not deemed possible during the pilot exercise to quantify wider forms of pollution filtration, sequestration and storage, such as the filtration of water through bogs, wetlands, vegetation and the immobilisation of contaminants in soil. There may however be opportunities to develop asset indicators that link to the provision of such services and which may support future quantification. Discussions with the Lake District NP suggested that steps might be taken to develop an indicator for the filtration services from woodland creation. This is set out in greater detail in Appendix D.

Cultural services

Cultural services are of great importance in the Lake District NP as evidenced by the area's forthcoming bid for World Heritage status on the basis of its significance as a cultural landscape. During discussions with the Lake District NP it was felt that further work could lead to the development of additional indicators capable of quantifying the Lake District's cultural services. The results of these discussions are outlined in Appendix E.

MONETARY FLOWS

The total monetary value of the nine ecosystem services which could be quantified in the Lake District NP was estimated to be around £180 million in 2013. This is predominantly made up from air quality, while recreation and drinking water are also significant.

However, it is important to note that due to the challenges of monetising the services provided by ecosystem assets, it was not possible to quantify the monetary flows for all of the services included in the accounting framework. As such, these estimates do not capture all of the value of the Lake District NP.

With regards to the **total value** of specific ecosystems, woodlands (£88 million) were found to have the highest value, while OWWF ecosystems were found to be the most valuable in terms of **average value per ha** (see Figure 9).

Figure 9. Value of service flows per ecosystem in 2013 (£/ha)

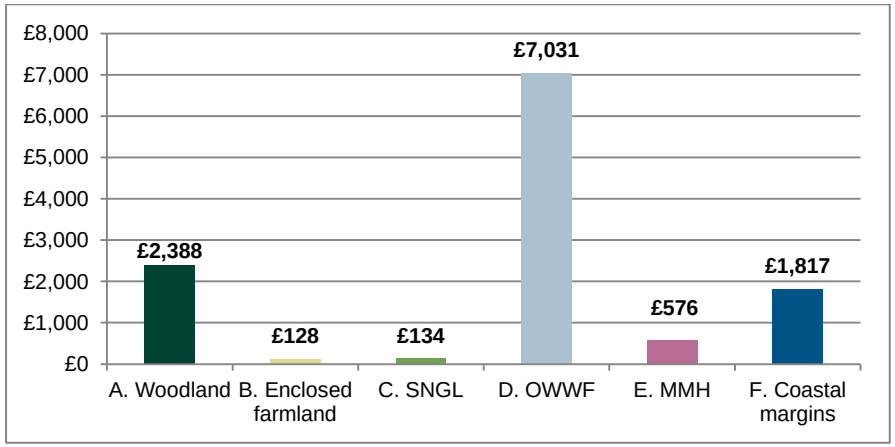


Table 3. Monetary flows of ecosystem services in 2013

Ecosystem service	Valuation basis	Monetary flows
Crops	Resource rent from crops	£27,244
Livestock	Resource rent from livestock	£1,130,989
Wild foods	Market value of meat	£5,739
Drinking water	Resource rent from water	£37,663,631
Timber	Stumpage price of timber	£951,856
Other water uses	-	-
Energy	Resource rent from woodfuel	£112,436
Air quality	Avoided damage costs	£75,094,729
Flood protection	-	-
Climate regulation	Avoided abatement costs	£20,520,799
Recreation	Willingness-to-pay	£43,758,083
Education	-	-
Heritage	-	-
Aesthetic	-	-
Existence	-	-
Total		**£179,265,507**

Table 4. Monetary flows account for Lake District NP in 2013 (all figures are presented in 2013 prices)

Ecosystem service	Woodland	Enclosed farmland	SNGL	OWWF	MMH	Coastal margins	Total
Crops	-	£27,244	-	-	-	-	**£27,244**
Livestock	-	£817,631	£279,588	£0	£33,143	£627	**£1,130,989**
Wild foods (game birds)	-	-	-	-	-	-	**-**
Wild foods (venison)	-	-	-	-	-	-	**-**
Wild foods (fish)	-	-	-	£5,739	-	-	**£5,739**
Drinking water	-	-	-	£37,663,631	-	-	**£37,663,631**
Timber	£951,856	-	-	-	-	-	**£951,856**
Other water uses	-	-	-	-	-	-	**-**
Energy	£112,436	-	-	-	-	-	**£112,436**
Air quality	£60,775,566	£4,384,063	£6,197,463	-	£3,700,565	£37,072	**£75,094,729**
Flood protection	-	-	-	-	-	-	**-**
Climate regulation	£16,744,232	£335,837	£1,862,938	£0	£1,448,319	£129,474	**£20,520,799**
Recreation	£9,192,708	£1,271,614	£2,331,292	£7,009,771	£22,861,231	£1,091,468	**£43,758,083**
Education	-	-	-	-	-	-	**-**
Heritage	-	-	-	-	-	-	**-**
Aesthetic	-	-	-	-	-	-	**-**
Existence (osprey)	-	-	-	-	-	-	**-**
Existence (Arctic charr)	-	-	-	-	-	-	**-**
Total value	**£87,776,797**	**£6,836,389**	**£10,671,280**	**£44,679,141**	**£28,043,258**	**£1,258,641**	**£179,265,507**
Total area (ha)	**36,757**	**53,357**	**79,773**	**6,354**	**48,672**	**693**	**225,606**
Value per ha	**£2,388**	**£128**	**£134**	**£7,031**	**£576**	**£1,817**	**£795**

APPENDIX A. ASSET ACCOUNT TABLES

For each of the six broad ecosystem types within the Lake District NP, an asset account was populated using the methodology described in the **Main Report** and accompanying **Technical Appendix**. Complete versions of the populated asset account tables are provided in the following section.

Table 5. Woodland asset account results for Lake District NP in 2013

Ecosystem extent				
Total area				
Woodland	Broadleaved woodland	Coniferous woodland	Ancient woodland	Managed woodland
(ha)[1]	(ha)[1]	(ha)[1]	(ha)[2]	(ha)[2]
36,757	23,496	13,260	10,804	20,373

Ecosystem condition											
Biomass/carbon				**Biodiversity**	**Soil/water quality**	**Accessibility**				**Conservation status**	
Standing timber volume	Mean annual increment	Topsoil carbon stock	Vegetation carbon stock	Woodland bird index	-	Length national trails	Accessible ecosystem	Light pollution	Tranquillity	SSSI cover	SSSI favourable
(m^3)[4,5]	(m^3)[6,7]	(tonnes carbon in 15 cm)[8]	(tonnes carbon)[9]	-[10]	-	(km)[2]	(%)[2]	(0 to 255)[11]	(-141 to 149)[12]	(%)[2]	(%)[2]
7,676,026	287,961	2,066,389	2,572,920	-	-	0	33%	45	21	14%	23%

[1] CEH (2007) Land Cover Map
[2] Natural England (2015) GIS digital boundary datasets
[3] Natural England (2013) FMEOPL
[4] Forestry Commission (2011) Standing timber volume for coniferous trees in Britain
[5] Forestry Commission (2013) NFI preliminary estimates of quantities of broadleaved species in British woodlands, with special focus on ash
[6] Forestry Commission (2012) GB 25-year forecast of standing coniferous volume and increment
[7] Forestry Commission (2014) 50-year forecast of hardwood timber availability
[8] CEH (2007) Countryside Survey 2007: Model estimates of topsoil carbon
[9] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources
[10] *Data is available from the BTO on bird populations associated with different ecosystems over time although the actual estimates were not available for this project.*
[11] CPRE (2000) Dark skies mapping
[12] CPRE (2000) Tranquillity mapping

Table 6. Enclosed farmland asset account results for Lake District NP in 2013

Ecosystem extent			
Total area			
Enclosed farmland	Arable and horticulture	Improved grassland	Length hedgerows
(ha)[1]	(ha)[1]	(ha)[1]	(km)[2]
53,357	7,248	46,109	2,533

Ecosystem condition (part 1)					
Biomass/carbon		**Biodiversity**	**Soil/water quality**	**Accessibility**	
Topsoil carbon stock	Vegetation carbon stock	Farmland bird index	Grade 1 & 2 land	Length national trails	Accessible ecosystem
(tonnes carbon in 15 cm)[3]	(tonnes carbon)[4]	-[5]	(%)[2]	(km)[2]	(%)[2]
4,537,003	53,357	-	0%	0	5%

Ecosystem condition (part 2)						
Accessibility		**Conservation status**				
Light pollution	Tranquillity	SSSI cover	SSSI favourable	ELS agreements	HLS agreements	OELS agreements
(0 to 255)[6]	(-141 to 149)[7]	(%)[2]	(%)[2]	(%)[8]	(%)[8]	(%)[8]
42	11	2%	34%	46%	33%	1%

[1] CEH (2007) Land Cover Map
[2] Natural England (2015) GIS digital boundary datasets
[3] CEH (2007) Countryside Survey 2007: Model estimates of topsoil carbon
[4] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources
[5] *Data is available from the BTO on bird populations associated with different ecosystems over time although the actual estimates were not available for this project.*
[6] CPRE (2000) Dark skies mapping
[7] CPRE (2000) Tranquillity mapping
[8] Natural England (2013) FMEOPL

Table 7. SNGL asset account results for Lake District NP in 2013

Ecosystem extent				
Total area				
SNGL	Rough grassland	Neutral grassland	Calcareous grassland	Acid grassland
(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]
79,773	15,185	1,202	0	63,387

Ecosystem condition										
Biomass/carbon		**Biodiversity**		**Soil/water quality**	**Accessibility**				**Conservation status**	
Topsoil carbon stock	Vegetation carbon stock	Butterfly abundance	Butterfly richness	-	Length national trails	Accessible ecosystem	Light pollution	Tranquillity	SSSI cover	SSSI favourable
(tonnes carbon in 15 cm)[2]	(tonnes carbon)[3]	(no. butterflies)[4]	(no. species)[4]	-	(km)[5]	(%)[5]	(0 to 255)[6]	(-141 to 149)[7]	(%)[5]	(%)[5]
7,024,422	79,774	8,046	33	-	0	76%	47	38	18%	24%

[1] CEH (2007) Land Cover Map
[2] CEH (2007) Countryside Survey 2007: Model estimates of topsoil carbon
[3] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources
[4] Butterfly Conservation (2013) UK butterfly monitoring scheme
[5] Natural England (2015) GIS digital boundary datasets
[6] CPRE (2000) Dark skies mapping
[7] CPRE (2000) Tranquillity mapping

Table 8. OWWF asset account results for Lake District NP in 2013

Ecosystem extent							
Total area							
OWWF	Fen, marsh, and swamp	(Lowland) bog	Freshwater	Length rivers	Standing waterbodies	Groundwater bodies	Average precipitation
(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]	(km)[2]	(no.)[2]	(no.)[2]	(mm/year/km^2)[2]
6,354	0	-	6,354	1,184	38	5	1,857

Ecosystem condition (part 1)								
Biomass/carbon		**Biodiversity**			**Soil/water quality**			
Topsoil carbon stock	Vegetation carbon stock	Fish abundance	Fish richness	Wetland bird index	Rivers in high / good status	Standing water in high / good status	Groundwater in high / good status	Lowland peatland favourable
(tonnes carbon in 15 cm)[3]	(tonnes carbon)[4]	(no. fish)[5]	(no. species)[5]	-[6]	(%)[2]	(%)[2]	(%)[2]	(%)[7]
0	0	15,324	6	-	38%	32%	100%	-

Ecosystem condition (part 2)								
Accessibility				**Conservation status**				
Length national trails	Accessible ecosystem	Light pollution	Tranquillity	SSSI cover	SSSI favourable	Eutrophic NVZs	Groundwater NVZs	Surface water NVZs
(km)[7]	(%)[7]	(0 to 255)[8]	(-141 to 149)[9]	(%)[7]	(%)[7]	(ha)[7]	(ha)[7]	(ha)[7]
0	12%	44	22	50%	43%	0	0	125

[1] CEH (2007) Land Cover Map
[2] Natural England (2013) FMEOPL
[3] CEH (2007) Countryside Survey 2007: Model estimates of topsoil carbon
[4] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources
[5] Data requested from the Environment Agency.
[6] *Data is available from the BTO on bird populations associated with different ecosystems over time although the actual estimates were not available for this project.*
[7] Natural England (2015) GIS digital boundary datasets
[8] CPRE (2000) Dark skies mapping
[9] CPRE (2000) Tranquillity mapping

Table 9. MMH asset account results for Lake District NP in 2013

Ecosystem extent					
Total area					
MMH	Heather	Heather grassland	Montane habitats	Inland rock	(Upland) bog
(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]
48,672	7,897	19,253	11,973	3,322	6,227

Biomass/carbon		**Biodiversity**	**Soil/water quality**	**Accessibility**				**Conservation status**	
Topsoil carbon stock	Vegetation carbon stock	Upland bird index	Upland peat favourable	Length national trails	Accessible ecosystem	Light pollution	Tranquillity	SSSI cover	SSSI favourable
(tonnes carbon in 15 cm)[2]	(tonnes carbon)[3]	-[4]	(%)[5]	(km)[5]	(%)[5]	(0 to 255)[6]	(-141 to 149)[7]	(%)[5]	(%)[5]
2,063,149	90,700	-	74%	0	96%	41	49	33%	19%

[*] Condition data excluded due to negligible area of ecosystems
[1] CEH (2007) Land Cover Map
[2] CEH (2007) Countryside Survey 2007: Model estimates of topsoil carbon
[3] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources
[4] *Data is available from the BTO on bird populations associated with different ecosystems over time although the actual estimates were not available for this project.*
[5] Natural England (2015) GIS digital boundary datasets
[6] CPRE (2000) Dark skies mapping
[7] CPRE (2000) Tranquillity mapping

Table 10. Coastal margins asset account results for Lake District NP in 2013

Ecosystem extent					
Total area					
Coastal margins	Supra-littoral rock	Supra-littoral sediment	Saltmarsh	Coastal waterbodies	Transitional waterbodies
(ha)[1]	(ha)[1]	(ha)[1]	(ha)[1]	(no.)[2]	(no.)[2]
693	0	463	229	1	4

Biomass/carbon		**Biodiversity**	**Soil/water quality**			
Topsoil carbon stock	Vegetation carbon stock	Seabird index	Bathing water compliance	Blue flag beaches	Coastal waterbodies in high/good status	Transitional waterbodies in high/good status
(tonnes carbon in 15 cm)[3]	(tonnes carbon)[4]	-[5]	(% beaches)[6]	(no.)[7]	(%)[2]	(%)[2]
0	229	-	100	0	0%	50%

Ecosystem condition (part 2)					
Accessibility				**Conservation status**	
Length national trails	Accessible ecosystem	Light pollution	Tranquillity	SSSI cover	SSSI favourable
(km)[8]	(%)[8]	(0 to 255)[9]	(-141 to 149)[10]	(%)[8]	(%)[8]
0	6%	42	28	43%	16%

[1] CEH (2007) Land Cover Map
[2] Natural England (2013) FMEOPL
[3] CEH (2007) Countryside Survey 2007: Model estimates of topsoil carbon
[4] Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources
[5] Data is available from the BTO on bird populations associated with different ecosystems over time although the actual estimates were not available for this project.
[6] Environment Agency (2013) Bathing water quality
[7] Blue Flag Beaches (2015) Beaches and marinas with blue flags
[8] Natural England (2015) GIS digital boundary datasets
[9] CPRE (2000) Dark skies mapping
[10] CPRE (2000) Tranquillity mapping

APPENDIX B. ECOSYSTEM SERVICE MAPS

GIS maps were developed for each of the ecosystem services where data was available on physical flows. The quantities of each service are divided up spatially into 1 km^2 grid squares. All maps are based on data from 2013 (except for aesthetic values).

Colour bars were developed to highlight hotspots of ecosystem service provision. In each of the maps, red indicates low or absence of provision while blue indicates significant provision. For each of the services (except for water values), the same scale is used across the four English pilot areas in order to allow comparison of the provision of services in different areas.

The maps have been developed based on estimates of the services provided by ecosystems within Lake District NP boundaries. As such, squares which overlap the boundaries only represent the value of ecosystem services provided within the boundaries, not the whole value of the 1 km square.

Due to the data limitations, it was not possible to develop maps for the following services: wild foods, flood protection, education, heritage, and existence values.

Figure 10. Crop production in Lake District NP (tonnes of crops in 2013)

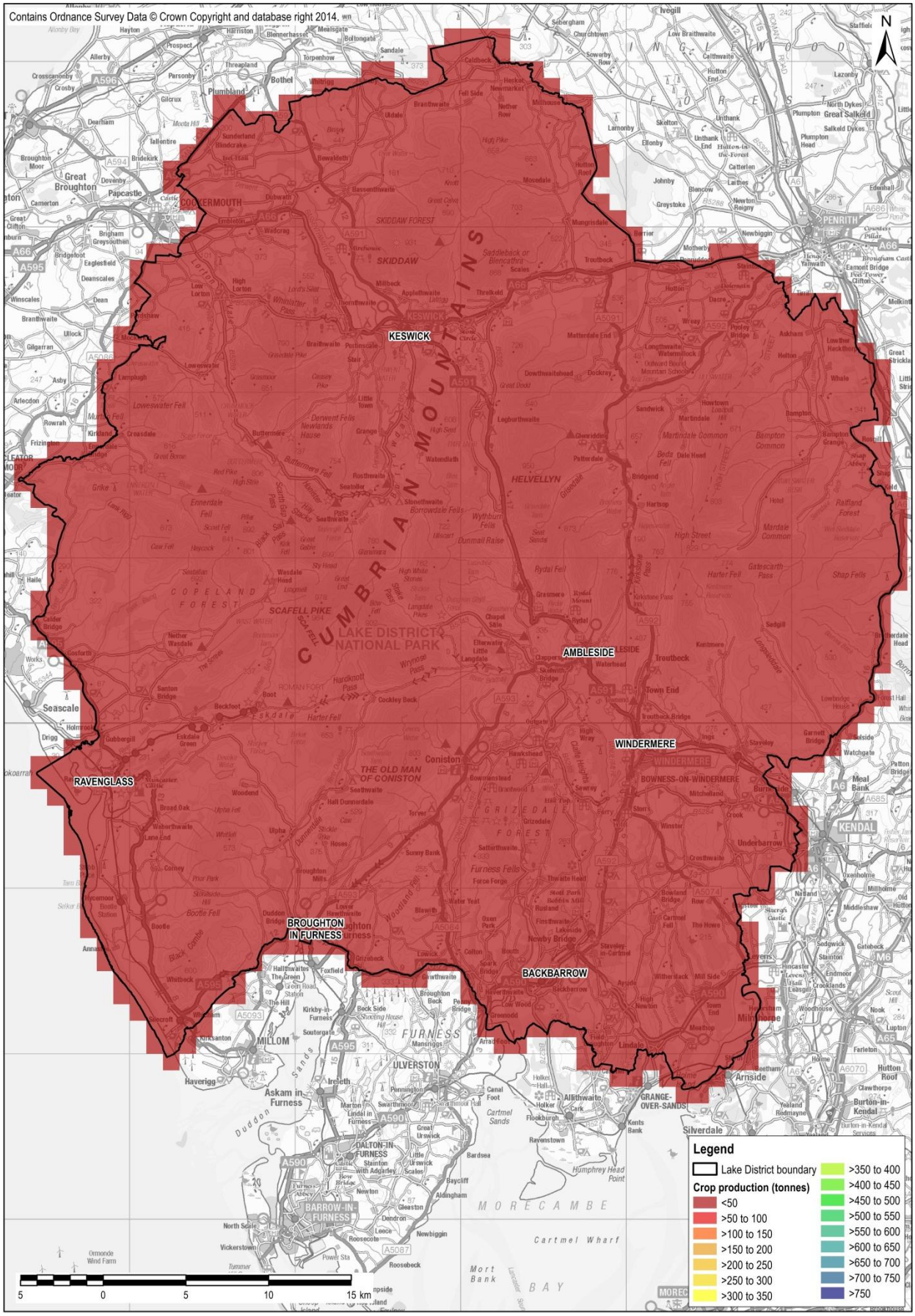


Figure 11. Livestock density in Lake District NP (Livestock Units in 2013)

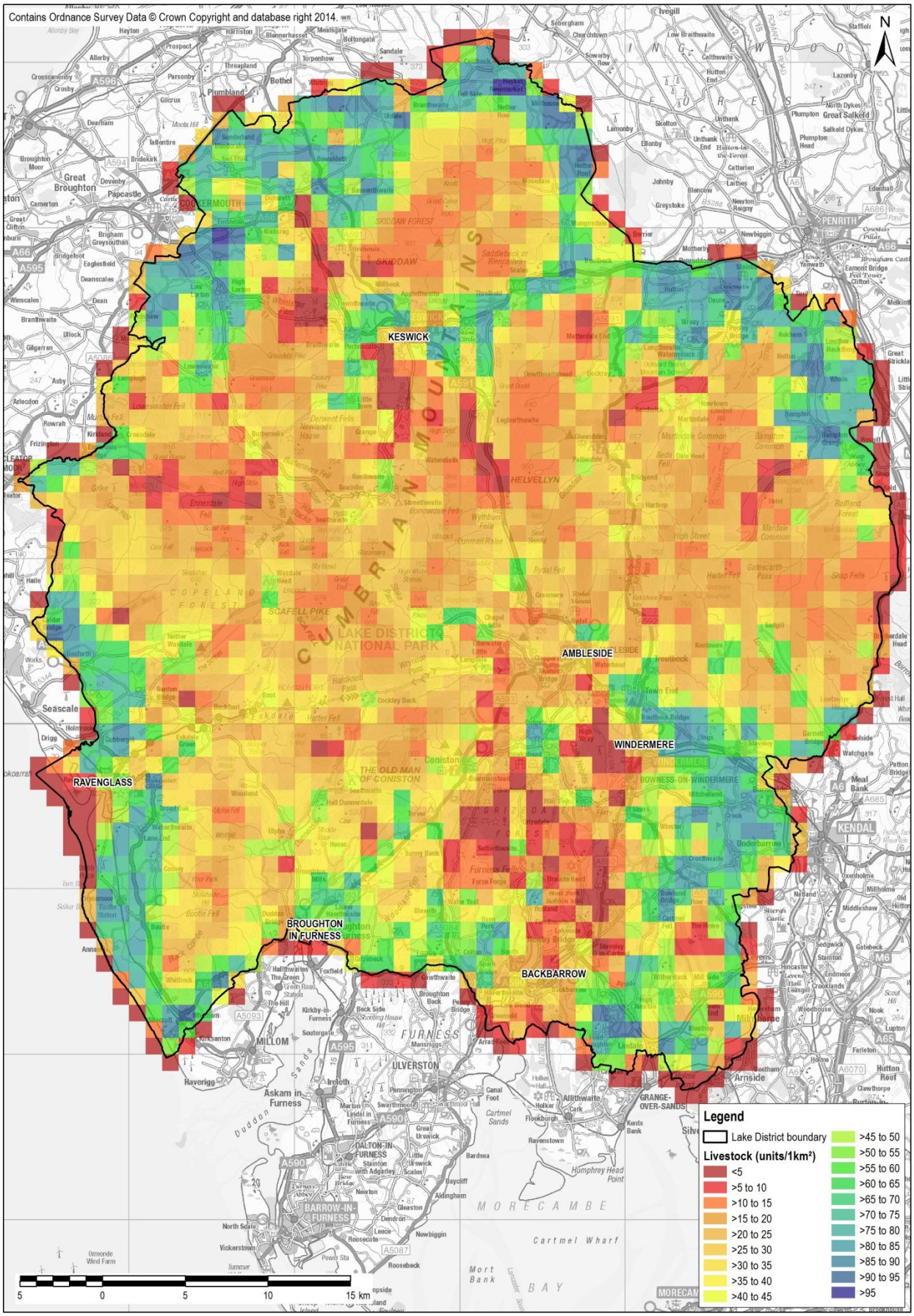


Figure 12. Potential water abstractions in Lake District NP (m^3 of water in 2013)

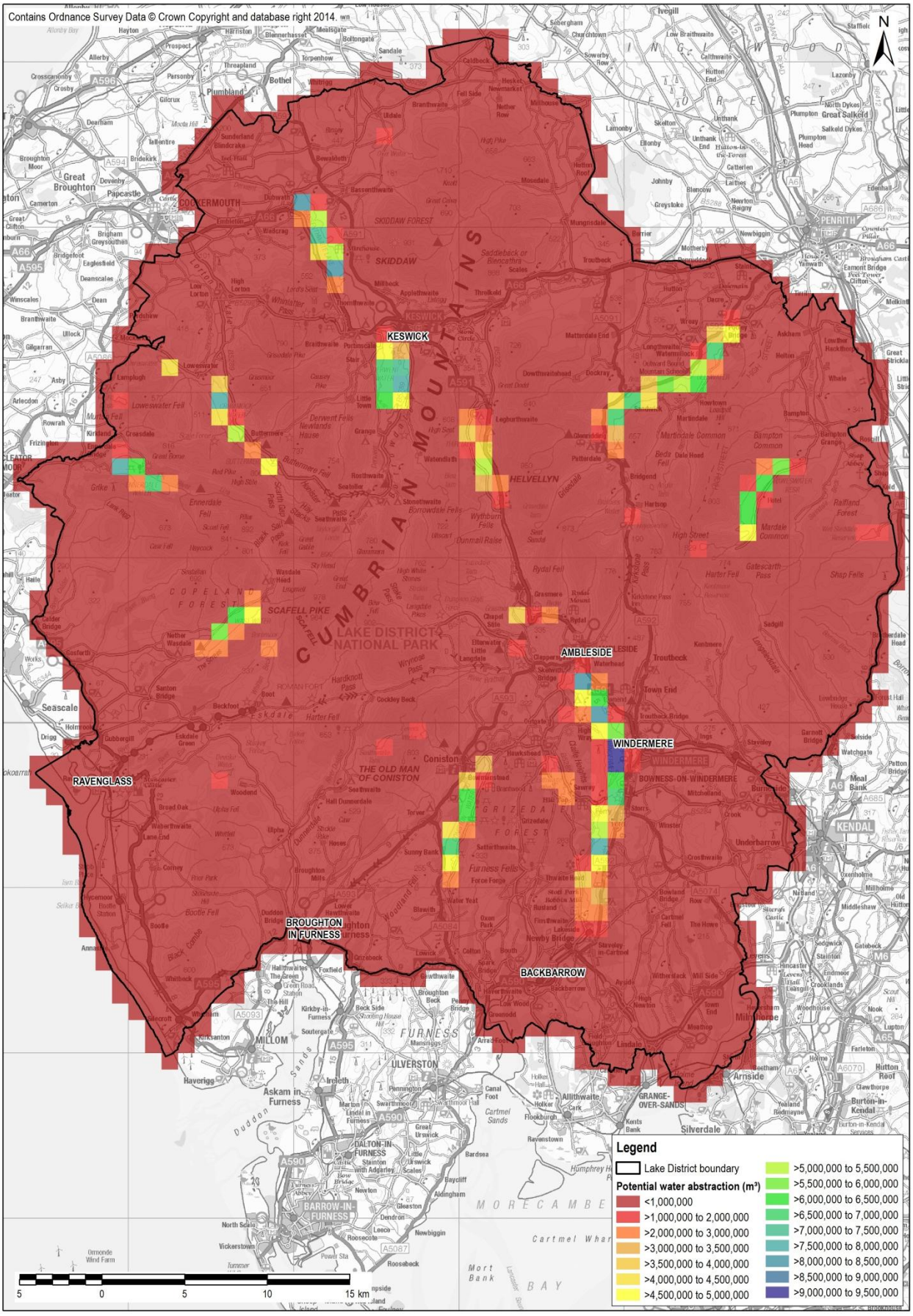


Figure 13. Timber production in Lake District NP (tonnes of timber in 2013)

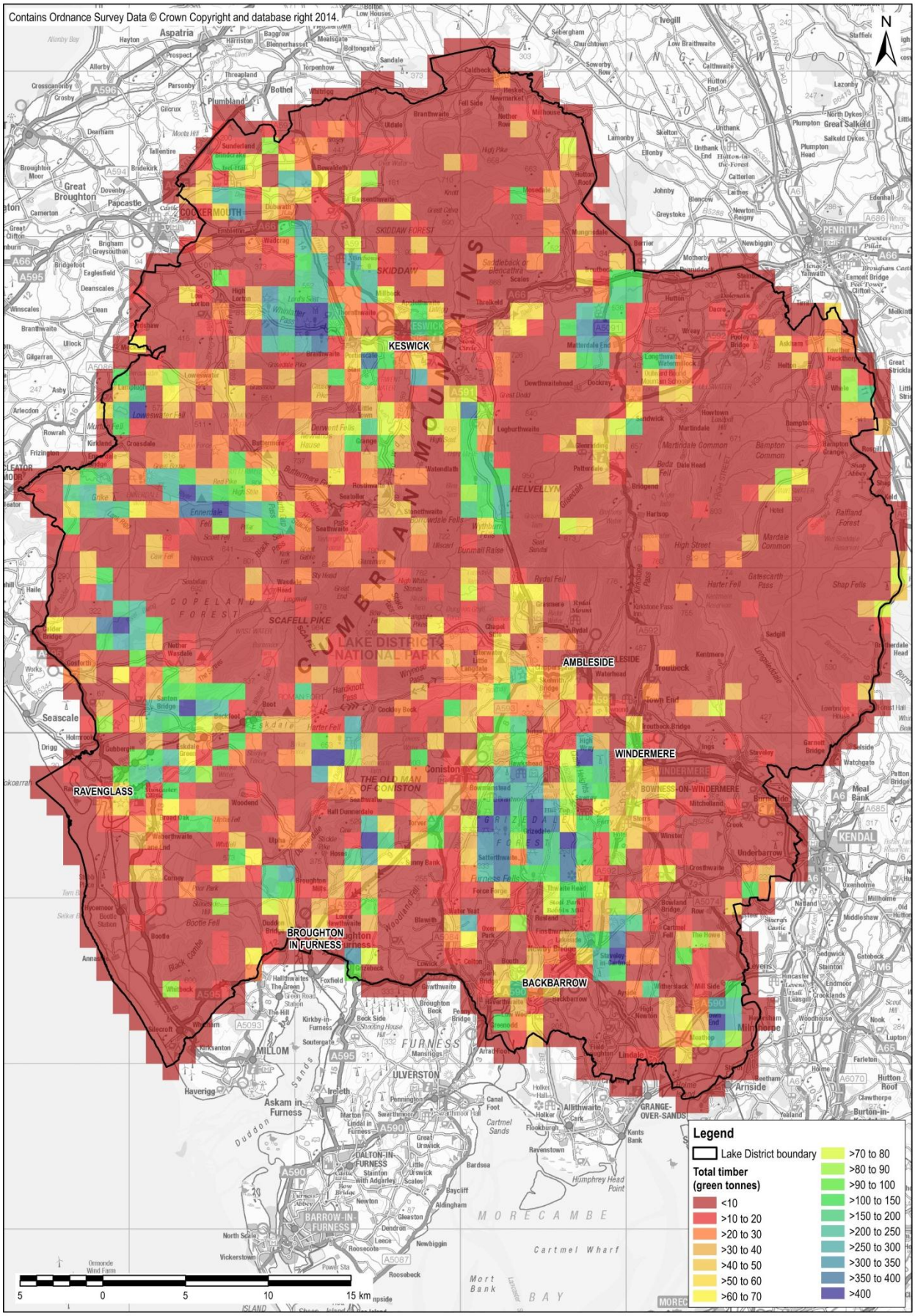


Figure 14. Woodfuel production in Lake District NP (tonnes of woodfuel in 2013)

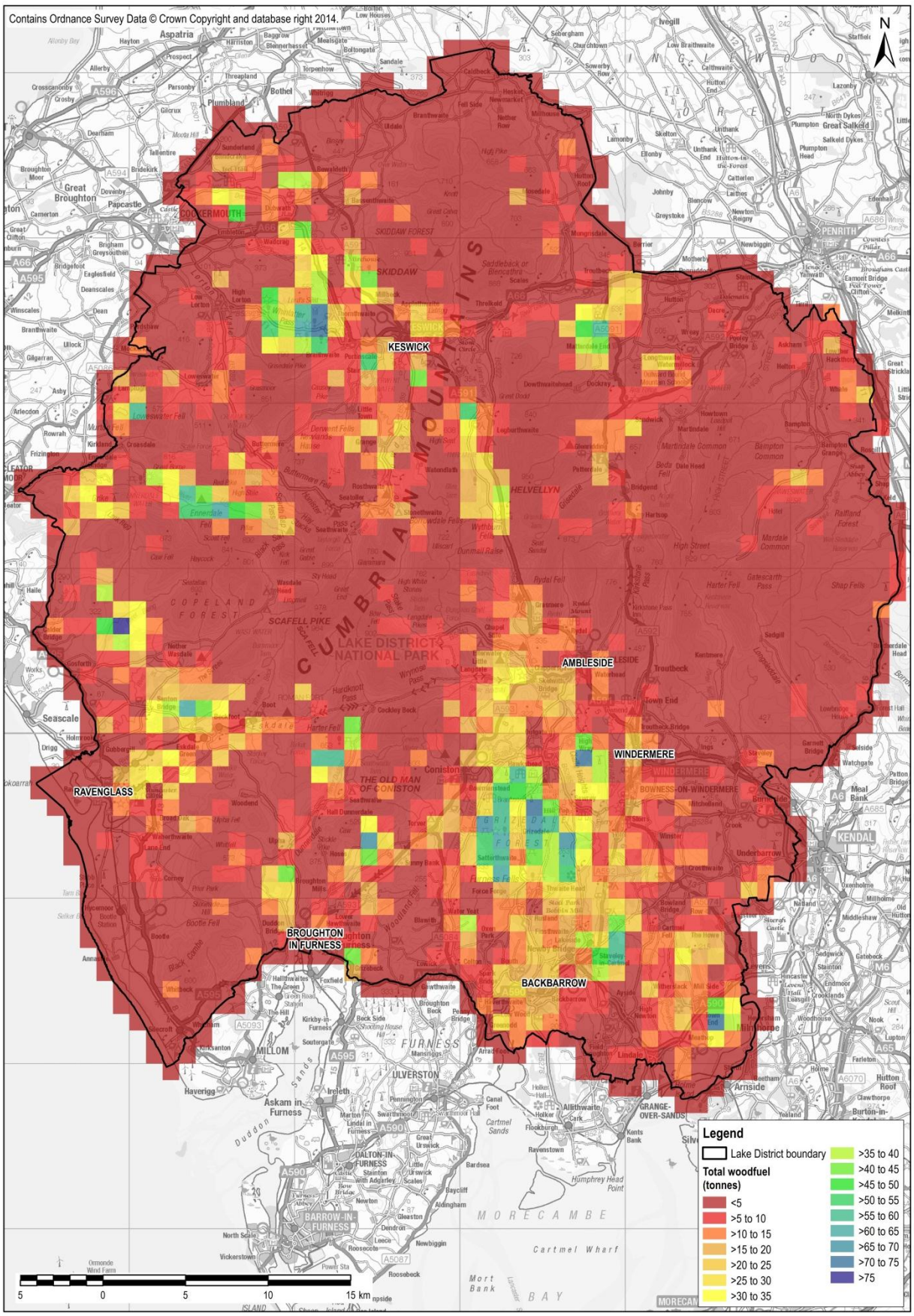


Figure 15. Regulation of air quality in Lake District NP (kg of PM_{10} absorbed in 2013)

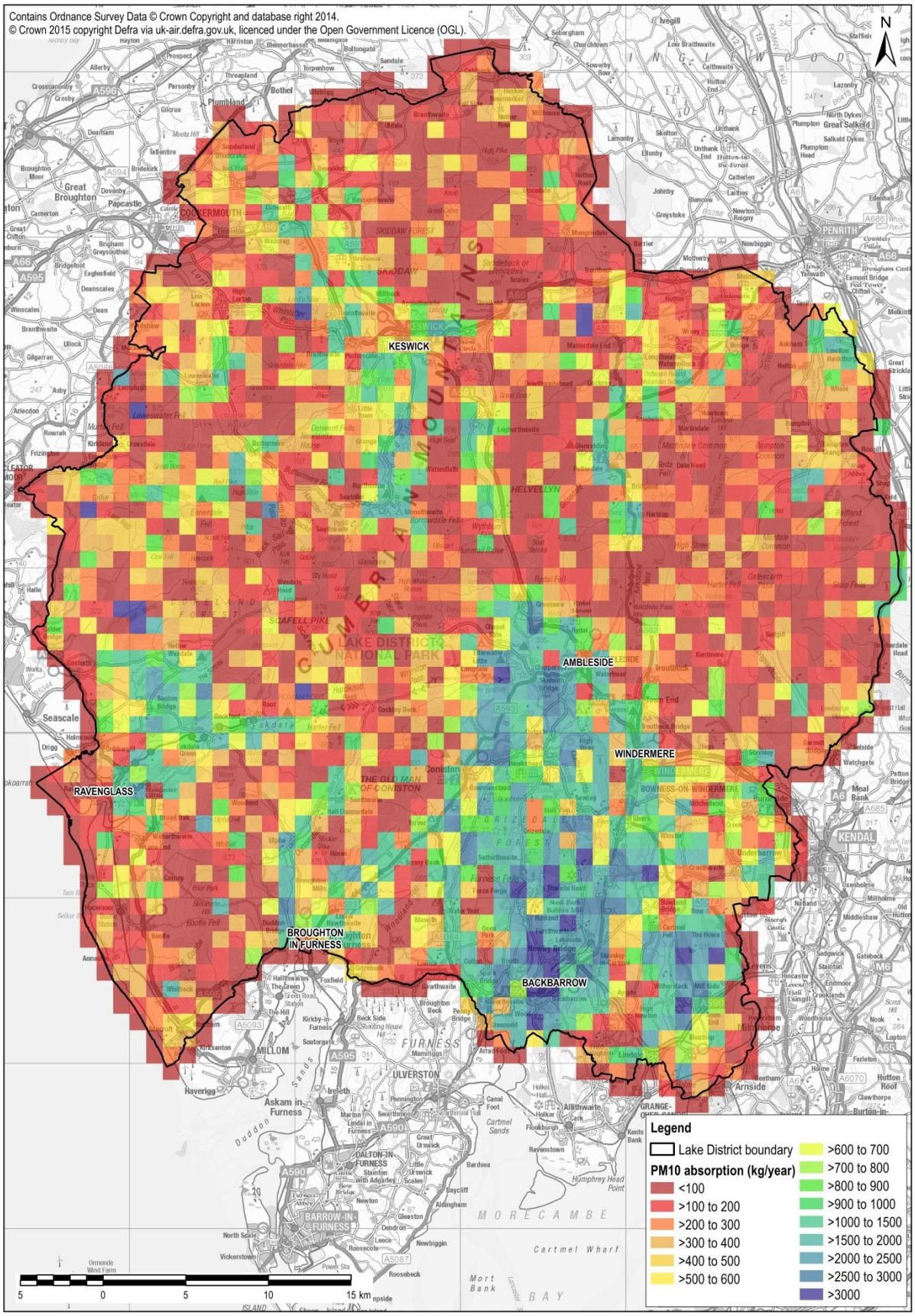


Figure 16. Regulation of climate in Lake District NP (tonnes of carbon sequestered in 2013)

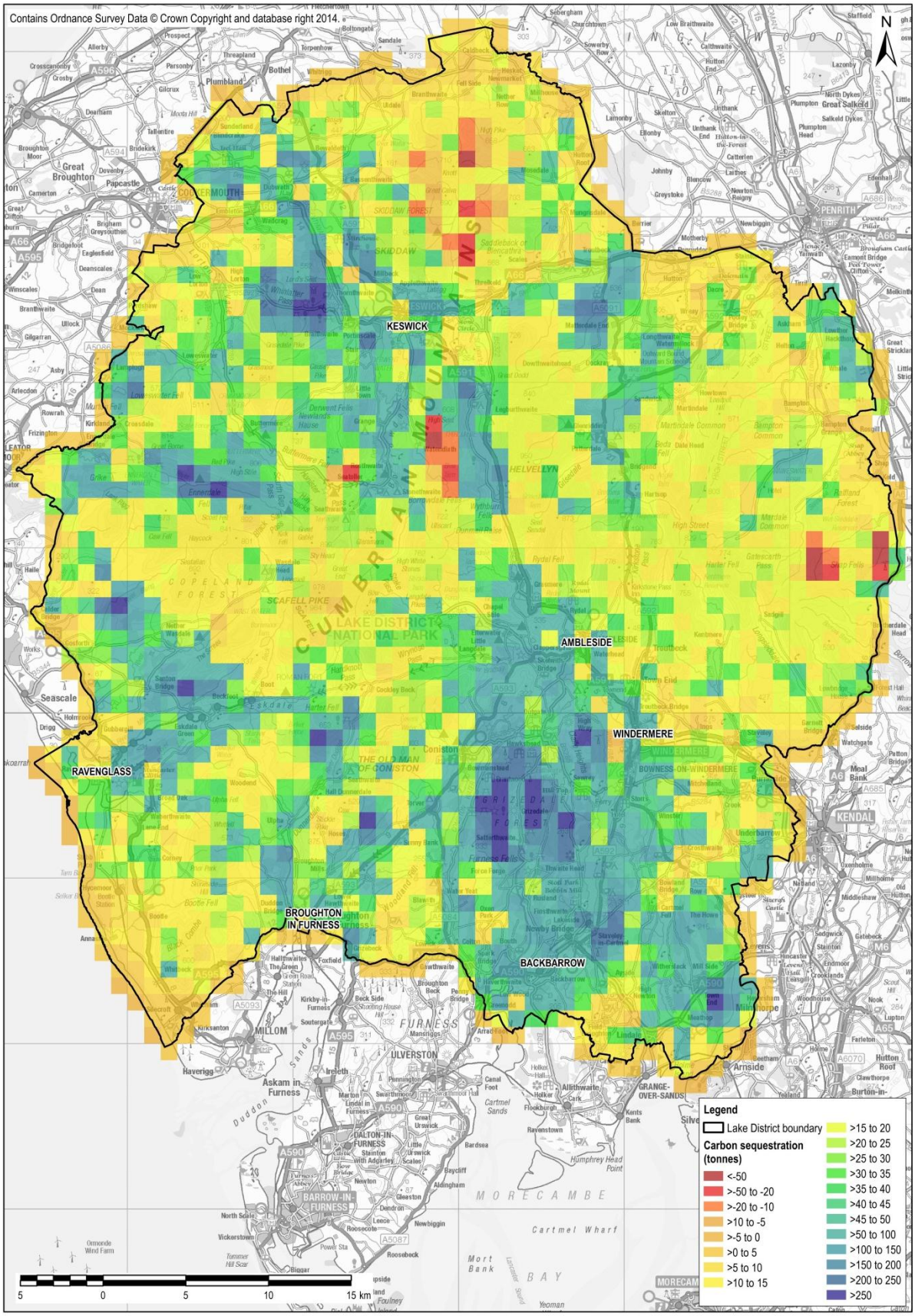


Figure 17. Recreational visits to Lake District NP (number of visits in 2013)

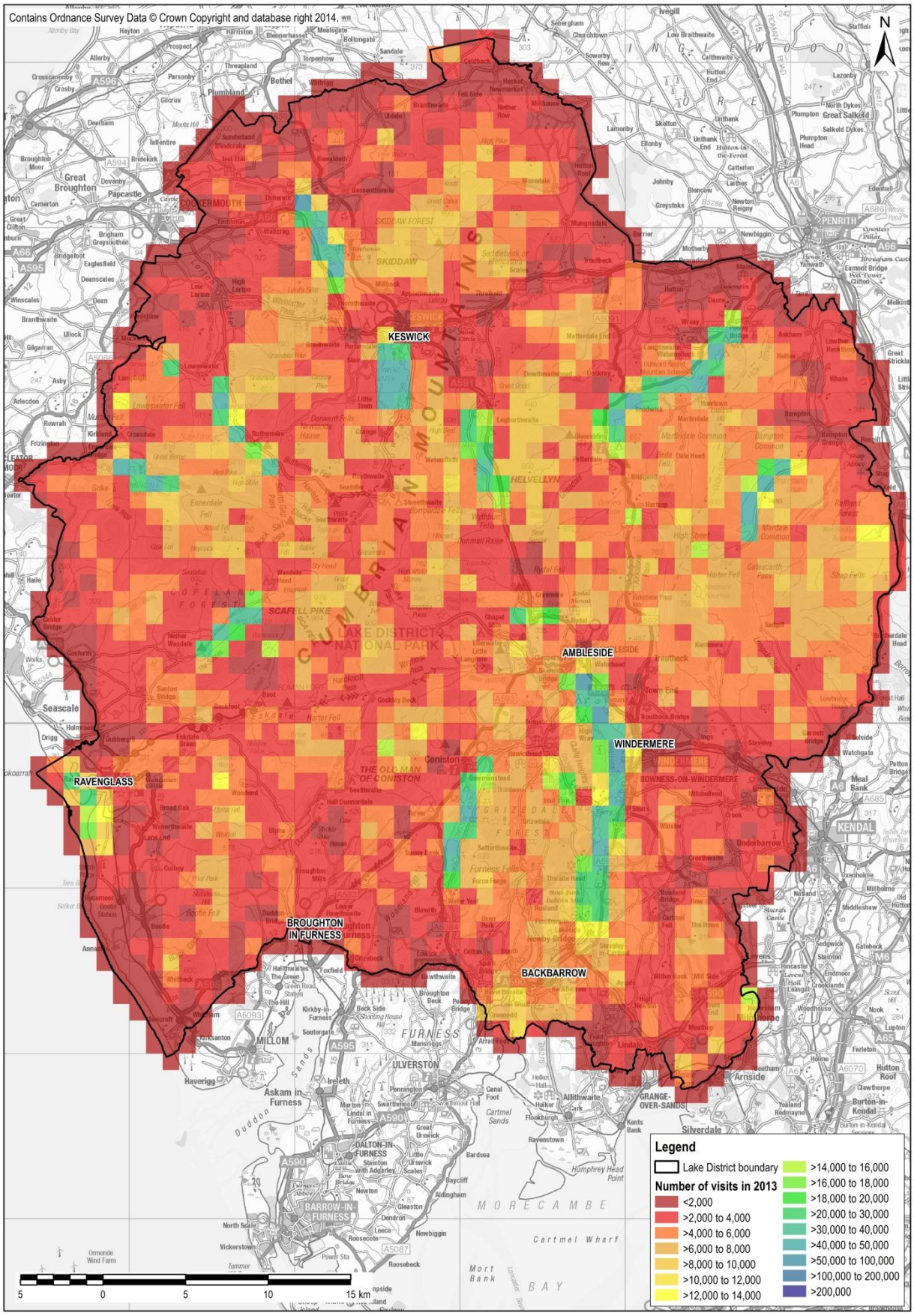
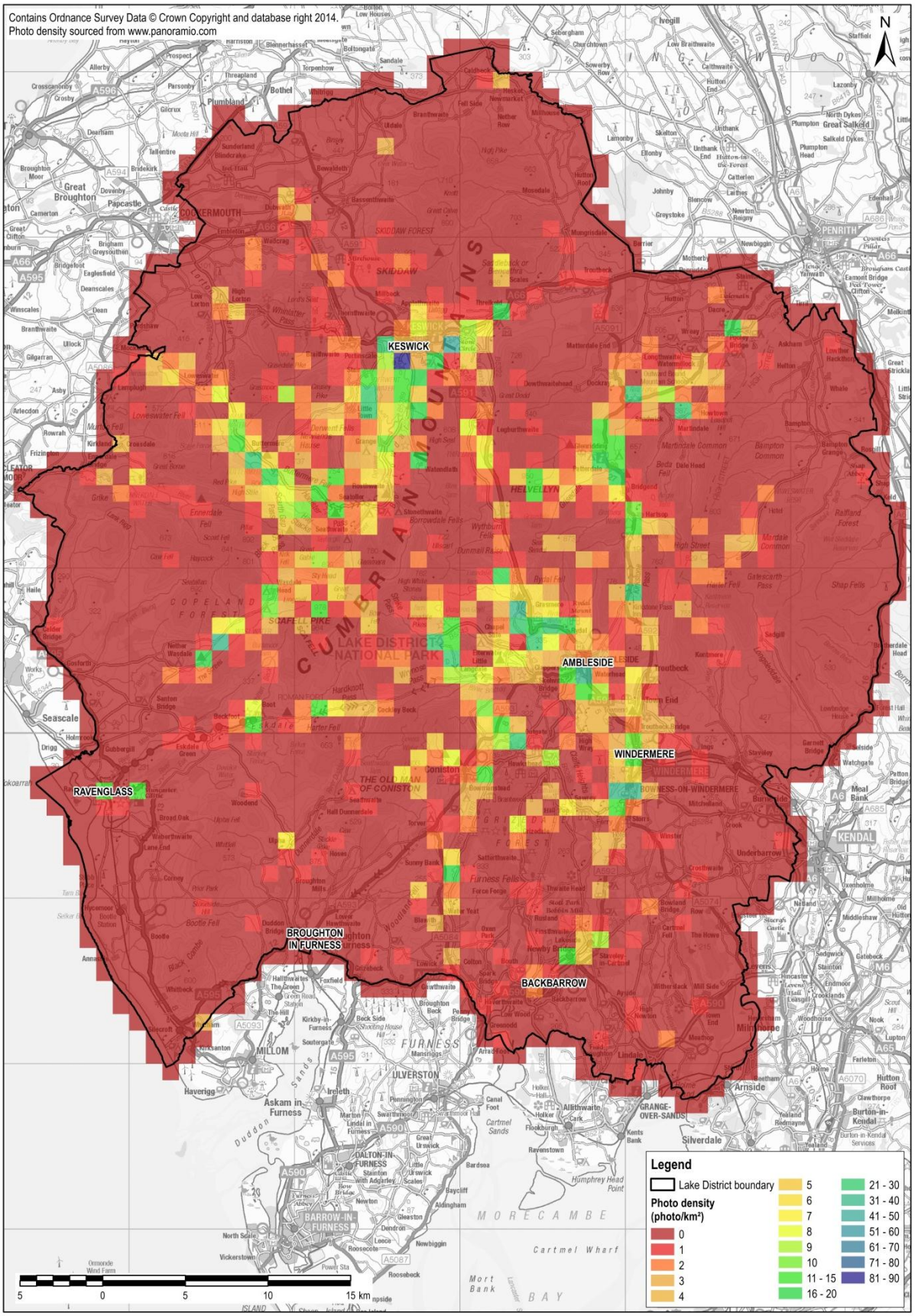


Figure 18. Aesthetically valued landscapes in Lake District NP (number of photographs from 2005 to 2015)



APPENDIX C. METHODOLOGY

The following table sets out the methodology used to develop the estimates of physical and monetary flows for each of the fifteen ecosystem services. Further details on the methods used can be found in the accompanying **Main Report** and **Technical Appendix**.

Ecosystem service	Physical flows	Monetary flows
Crops	The volume of crops harvested each year was estimated by multiplying the area of thirteen crop types within the pilot areas by the yield per crop. A breakdown of crop areas was obtained from the Defra June Survey and Scottish Government RESAS Statistics (Agriculture). National and, where available, regional crop yields were obtained from Defra datasets, supplemented by industry publications where necessary.	Market prices were obtained from Defra datasets although these values include the returns to human inputs such as machinery, fertilisers, and labour which therefore leads to an over estimation of the ecosystem service value (the bundle of inputs such as pollination, pest control, nutrient cycling etc.). As such, the market values were converted to resource rents i.e. the value of crop production after all human-related inputs have been subtracted.
Livestock	Livestock numbers were estimated using data from the Defra June Survey and RESAS Statistics. These were then converted to Livestock Units and allocated to different ecosystems based on the carrying capacity of each ecosystem, which was calculated by multiplying the area of each ecosystem with a stocking rate for each ecosystem type.	Yields for different livestock were obtained from Defra datasets. These were differentiated for lowland and upland livestock enterprises. Livestock production was estimated by multiplying livestock numbers (by type) by the appropriate yields. As for crops, market prices were obtained from Defra datasets and were converted to resource rents.
Wild foods	Data on the number of deer and game birds killed within the pilot areas was provided by the Game and Conservation Wildlife Trust although no data was available for the Lake District NP. Data on the number and weight of salmon and sea trout caught from rivers flowing through the pilot areas was extracted from EA and Scottish Government data.	Market prices were used to estimate the value of the meat harvested from wild foods. It was assumed that the resource rent was similar to the market price due to the limited human inputs required to support provision of wild foods.
Drinking water & Other water uses	Annual volumes of water abstracted from surface and ground water resources within the pilot areas was provided by the EA and SEPA. Agricultural water use was excluded from the analysis in order to avoid double counting of water as an input to agricultural production. It was assumed that all water abstracted for the public water supply is classed as drinking water, while all other water uses are classed as other water uses.	The resource rent approach was used to quantify the monetary flows of water abstractions for drinking water. The resource rent was calculated using Annual Business Survey (ABS) data on the revenues and costs for 'water collection, treatment and supply' businesses. Due to a lack of data, it was only possible to develop a resource rent estimate for water abstracted for the public water supply.
Timber & Energy	The average productivity of timber on public and private woodlands was estimated by dividing the total UK production of softwood and hardwood by the area of coniferous and broadleaved woodland in private and public ownership. These average productivity values were combined with data from the Land Cover Map to estimate the total annual hardwood and softwood production within the pilot area boundaries. Forestry Commission data was then used to estimate the share of this wood production that was allocated for timber versus that allocated for woodfuel.	For softwood timber, annual data on the standing price per cubic metre of overbark (or 'stumpage' price) was used, assuming that the stumpage price is broadly equivalent to the unit resource rent for a tonne of timber. For hardwood timber, a constant market price of £35 per cubic metre of overbark was used due to data limitations. The value of woodfuel was estimated using an approximate resource rent based on the market price of woodfuel minus the harvesting, extraction, processing, and transportation costs.
Air quality	Defra data on annual background concentrations of PM_{10} for 1 km grid squares across the UK was combined with ecosystem coverage for each 1 km grid square from the Land Cover Map dataset. The quantity of PM_{10} absorbed each year was then estimated using the formula: ABSORPTION = FLUX x SURFACE x PERIOD FLUX = deposition velocity for ecosystem x pollutant concentration SURFACE = area of ecosystem x surface area index of ecosystem PERIOD = period of analysis x % dry days x % in-leaf days	Defra air quality guidance was used to calculate the avoided damage cost for absorption of PM_{10}. In particular, the central estimate of IGCB air quality damage costs per tonne for emissions of PM_{10} in rural areas was used to estimate monetary benefit of the avoided damage due to storage of PM_{10} in vegetation within the pilot area boundaries.

Ecosystem service	Physical flows	Monetary flows
Flood protection	The UK NEA identifies woodland, OWWF, MMH, and coastal margin ecosystems as playing an important role in storing and slowing the flow of surface water runoff. However, there is a lack of scientific understanding in terms of quantifying the role such ecosystems play in reducing flood risk.	Due to the lack of a physical indicator for this service it was not possible to develop estimates of the monetary value although this could potentially be done in future through estimates of the avoided damage costs of a reduction in flood risk.
Climate regulation	Average carbon sequestration rates for each ecosystem were combined with data from the Land Cover Map to estimate the annual tonnes of carbon sequestered. In order to account for emissions from degraded peatlands, SSSI data was extracted from Natural England and SNH datasets and was combined with the Land Cover Map data to identify the area of peatland in favourable and unfavourable condition. Peatland mapping data undertaken within the Lake District NP could potentially be incorporated to provide more accurate local estimates.	The monetary value of this service was estimated using the non-traded DECC carbon values for the period 2008-2015 which are calculated based on the abatement cost per tonne of carbon. As such, this approach focuses on the financial benefits of carbon sequestration, rather than the avoided impacts on ecosystem functioning.
Recreation	The number of recreational visits was estimated using local data on visitor numbers, typically based on the STEAM model. From the total visitor numbers, the number visiting the natural environment was calculated based on visitor feedback surveys. The proportion of visitors to each ecosystem type was then estimated using MENE survey data which asks respondents the types of ecosystem they have visited.	The value of visits to each of the ecosystems was estimated by multiplying the number of visits allocated to each ecosystem with a monetary value per visit. This value was based on a meta-analysis of around 300 previous estimates of values for recreational visits to broad ecosystems in the UK.
Education	It was difficult to develop a comprehensive picture of the number of educational visits to the pilot areas, as there are many different organisations that organise field trips for educational purposes and a lack of data collected on the different types of educational visits.	Due to the lack of a physical indicator for this service it was not possible to develop estimates of the monetary value, although this could potentially be done in future through using estimates of the cost of travel for school visits.
Heritage	A number of approaches were looked at for quantifying the physical flows of this service although it was not possible to identify a clear, measurable indicator which could be included in the accounts. The cultural mapping projects undertaken in the Lake District could potentially provide a useful approach for quantifying flows of this service.	Due to the lack of a physical indicator for this service it was not possible to develop estimates of the monetary value, although this could potentially be done (at least in part) through hedonic analysis of the impact of proximity to different ecosystems on house prices in terms of amenity value.
Aesthetic	The website www.panoramio.com hosts photographs of aesthetically beautiful natural landscapes. A program was developed to extract data on the photos uploaded to the site, such as the date a photo was uploaded, the latitude and longitude of where the photo was taken, and the unique user ID of the account that uploaded the photo. This data was extracted to identify the number of photographs taken of each ecosystem type.	Due to the lack of available approaches for monetising flows of this service, it was not possible to develop estimates of the monetary value. This could potentially be explored in future through the use of willingness-to-pay surveys.
Existence	Interviews were held with representatives from each of the pilot areas in order to identify which species are considered to be 'charismatic' or to have important existence value to that area. Local data sources were then collected to monitor changes in the populations of these species over time.	Due to the lack of available approaches for monetising flows of this service, it was not possible to develop estimates of the monetary value. This could potentially be explored in future through the use of willingness-to-pay surveys.

APPENDIX D. LOCAL DATA

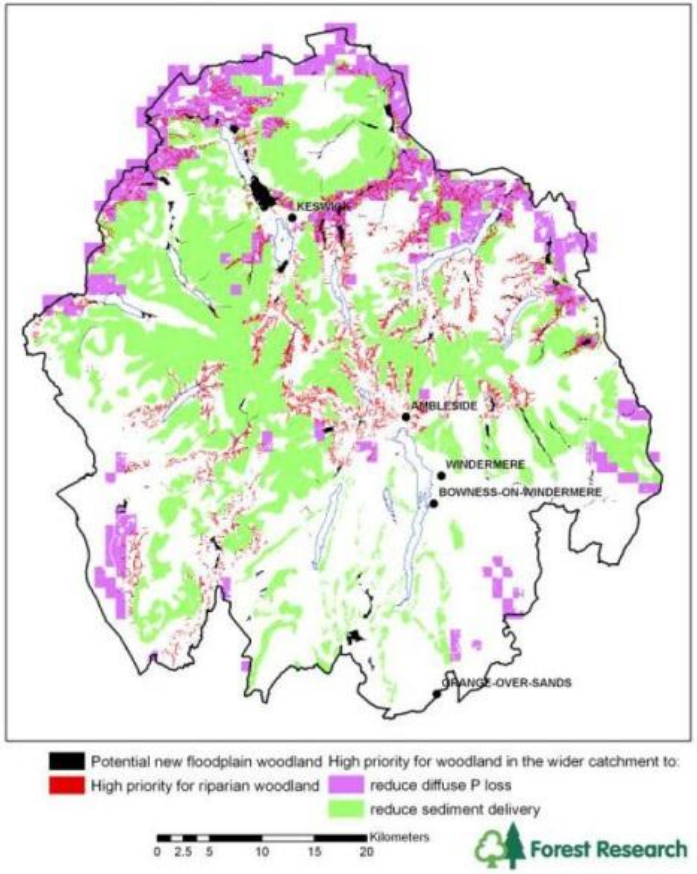
Regulating diffuse sediment and phosphate pollution

The Lake District NP features a number of standing water ecosystems which are regarded as being of international importance due to their ecological, aesthetic, recreational, and cultural value, with many designated as SSSIs or National Nature Reserves. These freshwater ecosystems are considered vulnerable to disturbance and highly sensitive to pollution, and as such, they are threatened by high levels of soil erosion in some areas (e.g. due to overgrazing, land cultivation, drainage, and human trampling) with resulting siltation and eutrophication (due to phosphate in eroded soils).

Woodland ecosystems have the potential to reduce soil erosion at source and limit the delivery of diffuse pollutants to watercourses. In light of this, a Forest Research study sought to establish opportunity areas where woodland creation could help to manage sediment problems within the NP through the identification of the main sediment sources and pathways of delivery to watercourses. This involved the characterisation of observed bank erosion, modelled sediment and phosphorus sources, and the recording of the presence of major constraints.

In total, over 85,000 ha (33%) of the National Park were found to comprise highly vulnerable soils free from planting constraints, and this land was ranked as being a high priority for planting. In addition, 28,021 ha of land was estimated to have diffuse phosphate losses exceeding 100 kg/km^2/yr whilst being free of constraints. This area is considered a high priority for new woodland to help reduce phosphate losses into the Park's watercourses. The below figure shows high priority areas in the Lake District NP for woodland creation in the wider catchment, riparian zone and floodplain to reduce diffuse sediment and phosphorus pollution.

Figure 19. Opportunity areas for woodland creation in the Lake District NP



This case study illustrates how local level mapping exercises can be used to identify opportunities for changes in land use management and/or use that can help to immobilise contaminants. Monitoring changes in woodland extent in these opportunity areas could provide an asset account indicator. In addition, monitoring of water quality could also provide an indication of the physical flow of the service (providing steps were taken to isolate the impact of woodland creation from other influences), so offering a route to the eventual valuation of this service.

Valuing the Lake District's cultural landscape

The landscape of the Lake District NP is the result of the long term influences and interactions of farming, industry, picturesque landscape design, and the conservation movement. The landscape of the area stimulated poets and artists of the Romantic Movement in the late 18th century and conservationists in the 19th century. A bid for World Heritage status (Protected Areas Category V) is due to be submitted in 2016 on the basis of the Lake District's significance as a cultural landscape.

Two broad categories of indicator can be associated with cultural landscapes such as the Lake District. These relate to the:

- **Historic environment –** which provides evidence for past human interaction with the landscape / environment.
- **Cultural heritage** – which reflects continuing traditional aspects of human interaction with the landscape / environment.

Indicators on the extent and condition of the historic environment are held by the Lake District NP. These include data on archaeological sites, scheduled monuments, listed buildings and registered historic parks and gardens. However, with such indicators it is difficult for the ecosystem contribution to be isolated as in many instances the interrelationship between historic features and their natural setting (both original and as relict features) will contribute to their value. Therefore, in future, historic value could potentially be ascertained through visitor surveys in the Park focused on establishing the perceived contribution of natural environment to the appreciation of particular historic assets.

The presence of uncultivated land was suggested as a further indicator that could be associated with the historic environment, given that such land is more likely to have preserved archaeological remains. This has the advantage of providing a cleaner link between ecosystem contribution and historic value than those indicators that also relate to the built environment (e.g. listed buildings). However, this indicator can be seen only a proxy of value given that just a few areas of uncultivated land will conceal and so protect a historic asset. As such, it is likely to be very difficult to identify beneficiaries and value the service provided by undisturbed land. This indicator would therefore need to be placed in the asset account to demonstrate the potential a particular ecosystem has to provide historic value. It should also be noted that archaeological features in unmanaged land can suffer damage through vegetation growth.

The cultural heritage of the Lake District NP could potentially be measured through indicators of traditional farming practices and land management. Indicators could include: the extent of common land with continuing traditional management of grazing; the condition of boundaries (e.g. stone walls, kests and hedges), the

overall condition and health of local breeds of sheep, and the extent of traditional woodland management (e.g. coppicing, pollarding and woodland pasture). The use of such indicators is supported by research in the Lake District which found that peoples' appreciation of landscape views increased when (traditional) cultural detail such as stone walls and Herdwick sheep were added (and conversely reduced when people and power lines were added). Monitoring could be carried through fixed point photography of selected views, measured against a baseline established by research and consultation.

Work to record the benefits of the Lake District's cultural landscape has been undertaken by the National Park Authority. A GIS data layer has been created that reflects the past appreciation of the landscape which makes use of indicators such as: the locations associated with Constable's painting tour, references in Wordsworth's poems, Thomas West's viewing stations, and wider literary references. This data tends to reflect an 18th and 19th century appreciation of the landscape, and so cannot be said to represent the current flow of cultural services. To rectify this, records could be kept of continuing cultural work in the Lake District NP (e.g. notable landscape paintings or landscape-orientated literature) so as to gain a modern perspective.

Alternatively, the sites associated with great artists and writers of the past (as represented in the current GIS layer), could be subject to visitor surveys to measure the extent to which they are visited for their past value to writers and artists. In both cases, a challenge will be to link the value with a particular ecosystem, given the often complex interplay between ecosystem-types within those Lake District landscapes that are artistically appreciated.

Whilst it will be necessary for other areas to take account of their own specific contexts, a lesson from these discussions is that, with sufficient data, indicators reflecting the condition and extent of the assets that contribute to cultural landscapes can be developed. Establishing the value of the cultural ecosystem services for any landscape is however much more challenging. The interaction of natural and built environment makes separating the contribution of particular ecosystems difficult, particularly when a mosaic of ecosystems and management practices produces a distinctive landscape character.