Green infrastructure:

How and where can it help the Northwest mitigate and adapt to climate change?

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Part of the Northwest Climate Change Action Plan & GRaBS Project

communityforestsnorthwest
supporting the mersey, red rose and pennine edge forests

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Executive Summary

This report has been produced through the green infrastructure strand of the Northwest Climate Change Action Plan, and is part of the EU funded 'Green and Blue Space Adaptation for Urban Areas and Eco Towns (GRaBS)' project. It builds upon a report from 2008 on 'Critical climate change functions of green infrastructure for sustainable economic development in the Northwest'.

Green infrastructure is defined as "the region's life support system – the network of natural environmental components and green and blue spaces that lies within and between the Northwest's cities, towns and villages, which provides multiple social, economic and environmental benefits". "Building greater resilience to climate change" is included as one of five essential actions for Northwest England in the recently Green infrastructure Prospectus.

This report sets out how and where green infrastructure can help the Northwest to mitigate and adapt to climate change. It is intended to raise awareness in the Northwest of the climate change services that green infrastructure can provide, and to start to target where these may be considered to be the most important; highlighting that it may be possible to get multiple services from the same piece of land and the need to take opportunities as they arise to do this. Indeed, green infrastructure can be seen as a 'win-win' solution as it can also deliver multiple other benefits whilst combating climate change.

A number of services that green infrastructure provides which help to combat climate change are identified and mapped according to where they are considered to be the most important across the Northwest. Broadly speaking, the mitigation services provided by green infrastructure are considered limited but important, whereas the adaptation services provided by green infrastructure are considered substantial.

Mitigation services	**Adaptation services**
• Carbon storage and sequestration • Fossil fuel substitution • Material substitution • Food production • Reducing need to travel by car	• Managing high temperatures • Managing water supply • Managing riverine flooding • Managing coastal flooding • Managing surface water • Reducing soil erosion • Helping other species to adapt • Managing visitor pressure

A number of approaches to targeting where action is needed are identified:

1. Targeting action where each service is considered important.
This is a good place to start if an organisation is interested in only one (or a few) of these services. Opportunities should still be taken by any green infrastructure intervention to maximise the other services that are important in that area.

Service	Where to safeguard	Where to enhance
Carbon storage and sequestration	Highest density areas, e.g. where carbon density is greater than the regional average of 178 tC/ha	Everywhere
Fossil fuel substitution	Woodlands currently managed for biofuels production	Areas of high potential yields of miscanthus or short rotation coppice
Material substitution	Woodlands currently managed for timber production and local processing plants	Other existing woodlands could be brought into management for this purpose and new processing plants created
Food production	Best and most versatile agricultural land	Urban areas
Reducing the need to travel by car	Existing green walking and cycling routes and local recreation areas in and near (e.g. within 5 km of) urban areas	Improving and linking existing green walking and cycling routes and local recreation areas in and near (e.g. within 5 km of) urban areas
Managing high temperatures	In urban areas, especially where vulnerable people live, where green infrastructure levels are currently low, and where people congregate	In urban areas, especially where vulnerable people live, where green infrastructure levels are currently low, and where people congregate
Managing water supply	Areas where water is currently available	Areas where the water resource is over-licensed or over-abstracted
Managing riverine flooding	Within flood zones and strategic locations in the catchment, especially areas designated as 'policy option 6' within Catchment Flood Management Plans	Within flood zones and strategic locations in the catchment, especially areas designated as 'policy option 6' within Catchment Flood Management Plans
Managing coastal flooding	Existing coastal habitats which provide a natural buffer	Where natural flood defence / realignment is suitable
Managing surface water	Existing green infrastructure in urban areas	In settlements at the greatest risk of surface water flooding
Reducing soil erosion	Where soil erosion risk is high or very high	Where soil erosion risk is high or very high
Helping other species to adapt	Existing habitats	Around existing habitat taking into account species' dispersal ability. In landscape character areas assessed as having a high vulnerability to climate change. Increasing the permeability of the wider landscape and linear corridors
Managing visitor pressure	Low or very low capacity to accommodate visitors	High or very high capacity to accommodate visitors, especially where these are within or close to urban areas, or to good public transport links

2. Targeting action in areas which are important for the greatest number of services.

Perhaps unsurprisingly, urban areas tend to come out strongly as being important for the greatest number of climate change services. Any green infrastructure intervention should then seek to optimise these services. The extent to which the services can be optimised will depend on their compatibility; whilst some services are considered to be generally incompatible with each other, many are considered to be generally compatible. This often depends on the considered and careful design and management.

3. Targeting action where prioritised services are considered important.
Urban areas and floodplains tend to come out as important for the priority services. Priority services were determined by scoring the need for mitigation or adaptation and the potential for green infrastructure as a solution (both in terms of effectiveness and practicality). Again, opportunities should still be taken by any green infrastructure intervention to maximise the other services that are important in that area. The priority services were identified as:

- Managing surface water
- Managing high temperatures
- Carbon storage and sequestration
- Managing riverine flooding
- Food production.

4. Targeting action where change or investment is taking place.
It is crucial to optimise climate change related services wherever structural change, new development and investment is taking place across the Northwest.

There is a wealth of information held in this report, including regional scale mapping. At this scale broad conclusions about areas where the climate change services of green infrastructure are most important can be made as a way of targeting and getting more out of regional interventions. The report also holds examples of sub-regional and local mapping and analysis, which demonstrate the possible use of the information at a finer resolution.

This report will be used to help develop a forthcoming action plan for the Northwest, which will set out green infrastructure actions to be taken to mitigate and adapt to climate change. This should set out green infrastructure actions to be taken for each climate change service, where these should be taken, delivery mechanisms and organisations who could lead on each.

All work produced through the green infrastructure strand of the Northwest Climate Change Action Plan can be accessed via www.ginw.co.uk/climatechange. Please refer to this website for the latest updates and contact us via this website if further clarification is needed.

1. Introduction

The recently published Green Infrastructure Prospectus[1] includes "building greater resilience to climate change" as one of five essential actions for Northwest England. Green infrastructure is defined as "the region's life support system – the network of natural environmental components and green and blue spaces that lies within and between the Northwest's cities, towns and villages, which provides multiple social, economic and environmental benefits"[2].

The Natural Economy Northwest project identified eleven interlinked groups of economic benefits provided by green infrastructure: climate change adaptation and mitigation, flood alleviation and water management, quality of place, health and well-being, land and property values, economic growth and investment, labour productivity, tourism, recreation and leisure, land and biodiversity, and products from the land[3].

In this report, we are concerned with the climate change adaptation and mitigation benefit. However, as climate change is a cross-cutting concept, we inevitably touch on aspects of the other benefits, most notably flood alleviation and water management. Indeed, green infrastructure can be seen as a 'win-win' solution precisely because it can deliver other benefits whilst combating climate change[4].

Two broad approaches are needed to combat climate change – mitigation and adaptation – and green infrastructure provides services which can help with both.

Climate change mitigation can be defined as "actions that reduce our contribution to the causes of climate change"[5]; this involves both reducing our emissions of greenhouse gases such as carbon dioxide (e.g. through increased energy efficiency, using alternative forms energy and transport) and reducing their concentrations in the atmosphere (e.g. by planting trees to remove carbon from the atmosphere).

Climate change adaptation, on the other hand, can be defined as "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities"[6]; this involves having an understanding of how the climate may change, what the impact of this may be, and building capacity and taking action to deal with these impacts (e.g. planting trees to provide shade for people and buildings in a warmer climate).

This report explores how and where green infrastructure can help the Northwest to both mitigate and adapt to climate change.

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[1] Natural Economy Northwest (2010). Green Infrastructure Prospectus. www.ginw.co.uk/resources/Prospectus_V6.pdf

[2] Northwest Green Infrastructure Think Tank (2006). Northwest Green Infrastructure Guide (version 1.1). www.ginw.co.uk

[3] Whilst the list is of economic benefits, it could be interpreted more broadly to include social and environmental benefits; (see Natural Economy Northwest. The economic value of green infrastructure. www.nwda.co.uk/PDF/EconomicValueofGreenInfrastructure.pdf)

[4] Win-win solutions minimise risks or exploit opportunities associated with climate change, but also have other social, environmental or economic benefits. www.ukcip.org.uk/index.php?option=com_content&task=view&id=84

[5] www.ukcip.org.uk/index.php?option=com_content&task=view&id=57&Itemid=180

[6] www.ukcip.org.uk/index.php?option=com_content&task=view&id=54&Itemid=179

It starts by setting out both the climate change mitigation and adaptation contexts for the UK and the Northwest; considering how green infrastructure can help with each agenda (sections 2 and 3). It then explores each identified climate change related service of green infrastructure in turn; setting out for each how green infrastructure can help and where it may be most important (section 4). We then explore ways of targeting where action is needed (section 5); taking into account areas where each service, a number of services, and prioritised services are considered important, as well as areas where change or investment is taking place. Finally we propose how this work can be taken forward (section 6), including how the mapping in this report, which is presented at the regional scale, can be interrogated at different spatial scales.

This report has been produced through the green infrastructure strand of the Northwest Climate Change Action Plan[7], and is part of the EU funded 'Green and Blue Space Adaptation for Urban Areas and Eco Towns (GRaBS)' project[8]. The work produced through the green infrastructure strand of the Northwest Climate Change Action Plan can be accessed via www.ginw.co.uk/climatechange, which includes a searchable evidence base, reports, and updates to mapping (which will include any future updates to maps presented within this report). This report builds upon a report from 2008 on 'Critical climate change functions of green infrastructure for sustainable economic development in the Northwest'. It will be used to help develop a plan for the Northwest, which will set out green infrastructure actions to be taken to mitigate and adapt to climate change.

[7] NWDA *et al* (2010). Rising to the challenge: a climate change action plan for England's Northwest 2010-2012. www.climatechangenorthwest.co.uk/assets/_files/documents/feb_10/cli__1265921054_NW_Climate_Change_Action_Plan_.pdf
[8] www.grabs-eu.org/

2. Climate change mitigation

The Intergovernmental Panel on Climate Change states that the warming of the global climate system is now unequivocal. Whilst coherent changes can be seen in many aspects of the climate system, the temperature change observed in the last 50 years is very likely (>90% chance) due to increases in man-made greenhouse gas concentrations[9].

Climate change mitigation involves reducing greenhouse gas emissions and concentrations. Mitigation is a vital response to a changing climate; the greater the reduction of emissions and concentrations of greenhouse gases, the less severe the negative impacts of climate change will be.

This has been recognised on an international scale by the Kyoto Protocol of 1997. In the EU and UK there is a commitment to avoid 'dangerous' climate change by taking mitigation actions to limit average global temperature increases to no more than 2°C above pre-industrial levels.

2.1 National context

In 2008, with the adoption of the UK Climate Change Act[10], the UK became the first country in the world to adopt a long-term, legally binding framework to cut carbon emissions. The Act sets targets of at least an 80% cut in greenhouse gas emissions by 2050 and 34% by 2020, against a 1990 baseline. In order to stay on track for the 2050 target, the Act also includes a carbon budgeting system which caps emissions over five-year periods, with three budgets set at a time; the first three run from 2008-12, 2013-17 and 2018-22[11].

The UK Low Carbon Transition Plan[12] sets out a strategy to deliver the 2020 target, which equates to an 18% emission cut on 2008 levels (figure 1). It will mean emissions falling faster than before; emissions have fallen about 1% a year since 1990, and will now fall 1.4% a year. A number of key policies are set out to drive emissions reductions (figure 2), the most important being the EU Emissions Trading System, energy efficiency policies, and the increased use of renewable energy for heat and transport.

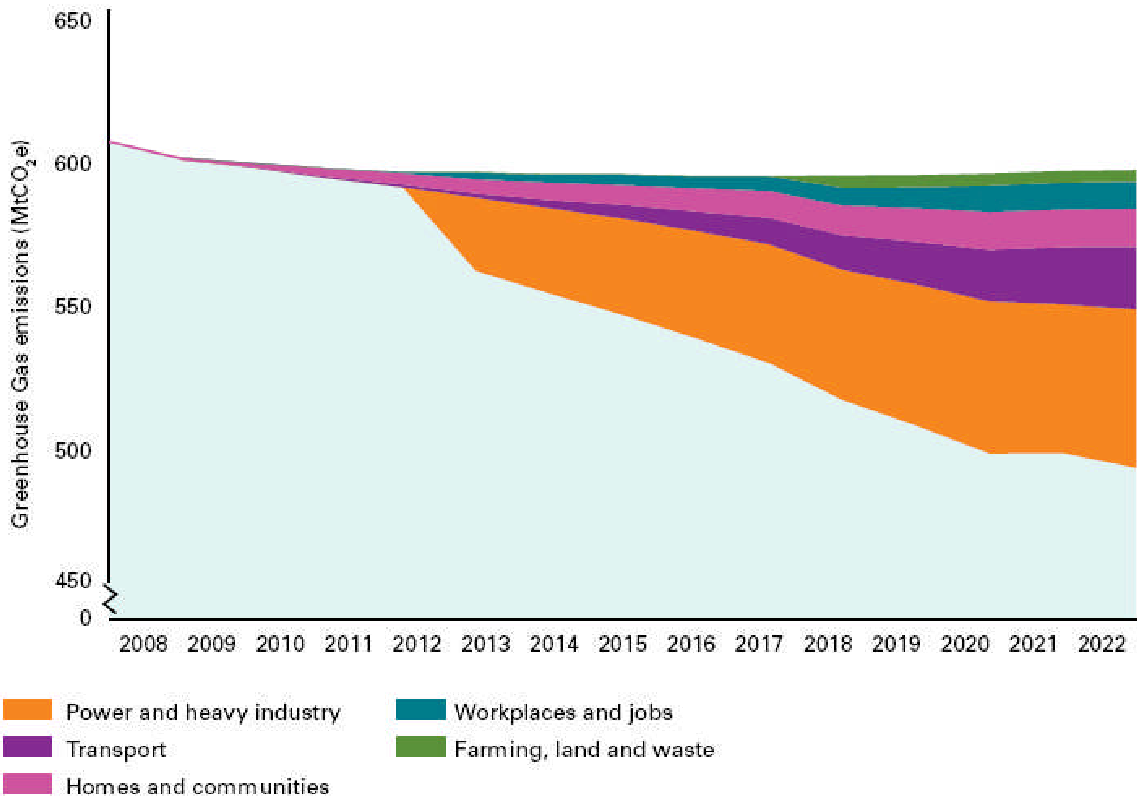
[9] IPCC (2007). Climate Change 2007: The Physical Science Basis, Summary for Policymakers. www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

[10] DEFRA (2008). The Climate Change Act. www.opsi.gov.uk/acts/acts2008/ukpga_20080027_en_1

[11] The Tyndall Centre for Climate Change Research has argued for more ambitious reductions of 70% by 2030 and 90% by 2050, in order to have a 30% chance of not exceeding the 2°C threshold. It stressed that cumulative emissions are more important than long term targets, with 6-9% emission cuts needed year on year. www.tyndall.ac.uk/sites/default/files/bn17.pdf.

[12] DECC (2009). UK Low Carbon Transition Plan. www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx

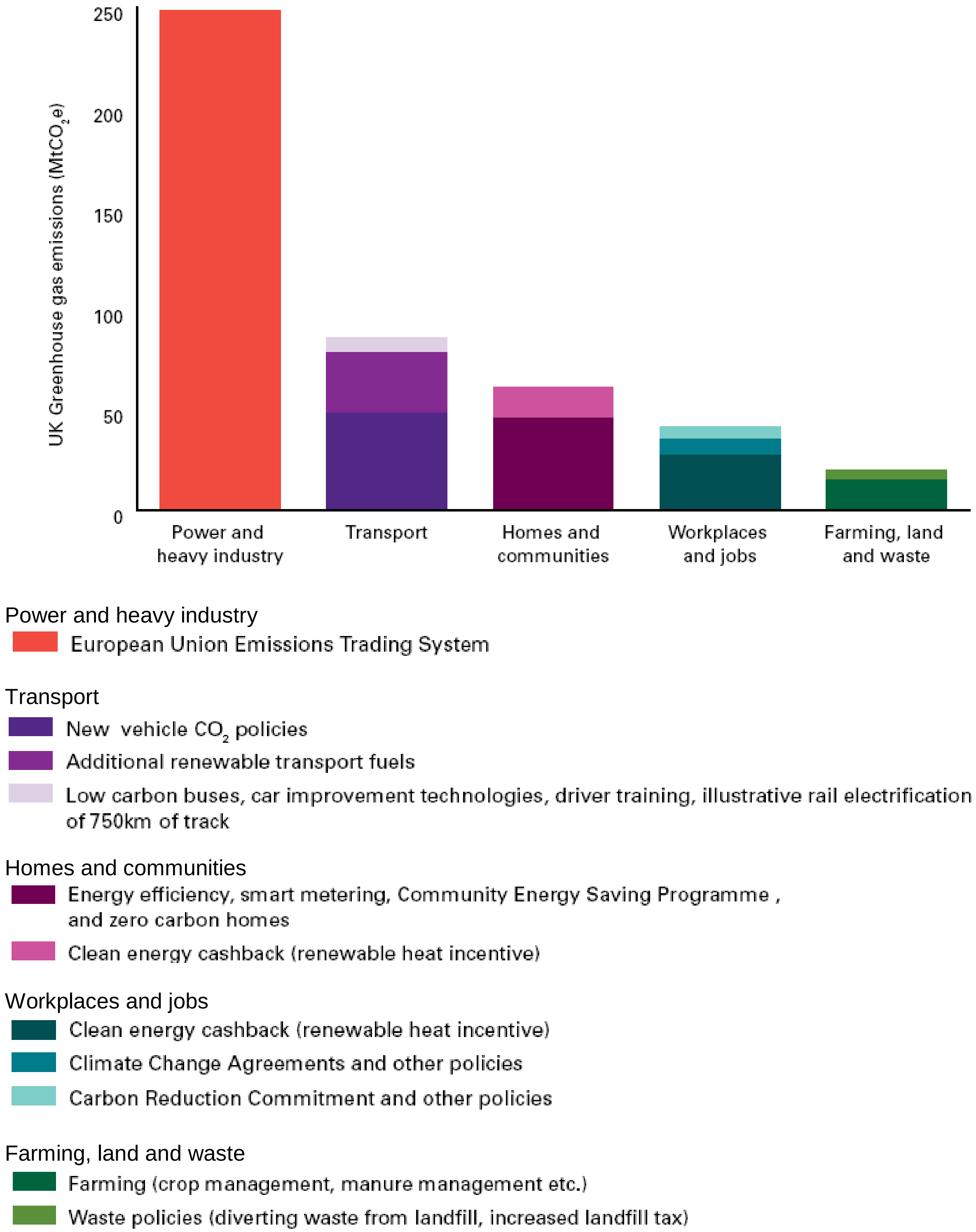
Figure 1. The UK Low Carbon Transition Plan aims to reduce emissions from every sector[12]



Source: Department of Energy and Climate Change

Note: The impact of policies prior to the 2007 Energy White Paper is included in the baseline; without these policies, UK emissions would be higher.

Figure 2. Main policies to reduce greenhouse gas emissions in the UK Low Carbon Transition Plan[12]



Source: Department of Energy and Climate Change

Note: The impact of policies prior to the 2007 Energy White Paper is included in the baseline; without these policies, UK emissions would be higher.

Figures 1 and 2 suggest that the overall emissions reductions that can be achieved by 'farming, land and waste' are, relative to other sectors, fairly minimal. However, the Low Carbon Transition Plan highlights the importance of managing land as a carbon store. It encourages private funding for woodland creation, and states that "changes to the landscape (including building work, soil tilling and forest management) need to be done in a way that protects and where possible grows these stores, particularly as climate change itself is expected to affect natural processes in a way that could cause some of this store to be lost"[12].

2.2 Regional context

The vision set out in the Northwest Climate Change Action Plan[7] is of "a low carbon and well adapting Northwest by 2020"; objectives include reducing greenhouse gas emissions and capitalising on opportunities for growth. Outcomes by 2020 are listed for transport, carbon capture and sequestration, low carbon energy technologies, energy supply, energy efficiency and demand, risks and opportunities, raising awareness and support for practical actions, policy and coordination, and monitoring and research.

The industrial and commercial sector in the Northwest accounts for 47% of the region's carbon dioxide emissions, followed by 27% from domestic sources, and 25% from road transport[13] (figure 3). 'Land use, land use change and forestry' accounts for only 1% of total emissions (figure 3); but importantly whilst it can be a source of emissions, it can also act as a sink (removing carbon dioxide from the atmosphere)[14] (figure 4).

Through the implementation of existing or planned international, national and regional measures, it may be possible to reduce carbon dioxide emissions in the Northwest by 26-37% by 2020 relative to 1990 levels; additional measures could result in reductions of 29-45% (table 1)[15].

[13] DECC data from www.decc.gov.uk/en/content/cms/statistics/climate_change/climate_change.aspx has been used. A greenhouse gas emissions inventory for the Northwest was produced for 4NW in 2007, but has been removed from their website due to evolving methods and data sets and technical inaccuracies; a final version was completed in 2008 but is currently unavailable on the internet.

[14] Emissions are generally from soils due to land use change and liming of soils and removals are through forest growth; (see DEFRA (2006). Local and Regional CO_2 Emissions Estimates for 2004 for the UK. www.airquality.co.uk/reports/cat07/0709061634_laregionalco2rpt20061127.pdf). These estimates are made using dynamic models of changes in stored carbon driven by land use change data. For forestry, the model deals with plant carbon, dead organic matter, soil and harvested wood products and is driven by the area of land newly afforested each year. Changes in soil carbon are driven by estimated time series of land use transitions between semi-natural, cultivated (farm), woodland and urban land uses; (see Mobbs and Dyson (2009). Mapping Carbon Emissions & Removals for the Land Use, Land Use Change & Forestry Sector. www.decc.gov.uk/en/content/cms/statistics/climate_change/gg_emissions/uk_emissions/2007_local/2007_local.aspx).

[15] URS (2009). Assessment of potential carbon savings achievable in the Northwest region by 2020. This work is currently being updated. www.climatechangenorthwest.co.uk/assets/_files/documents/apr_09/cli__1239283253_URS_Report_NW_Carbon_Reduction.pdf

Figure 3. Carbon dioxide emission estimates for 2007 (by end-user) for the Northwest sub-regions[13]

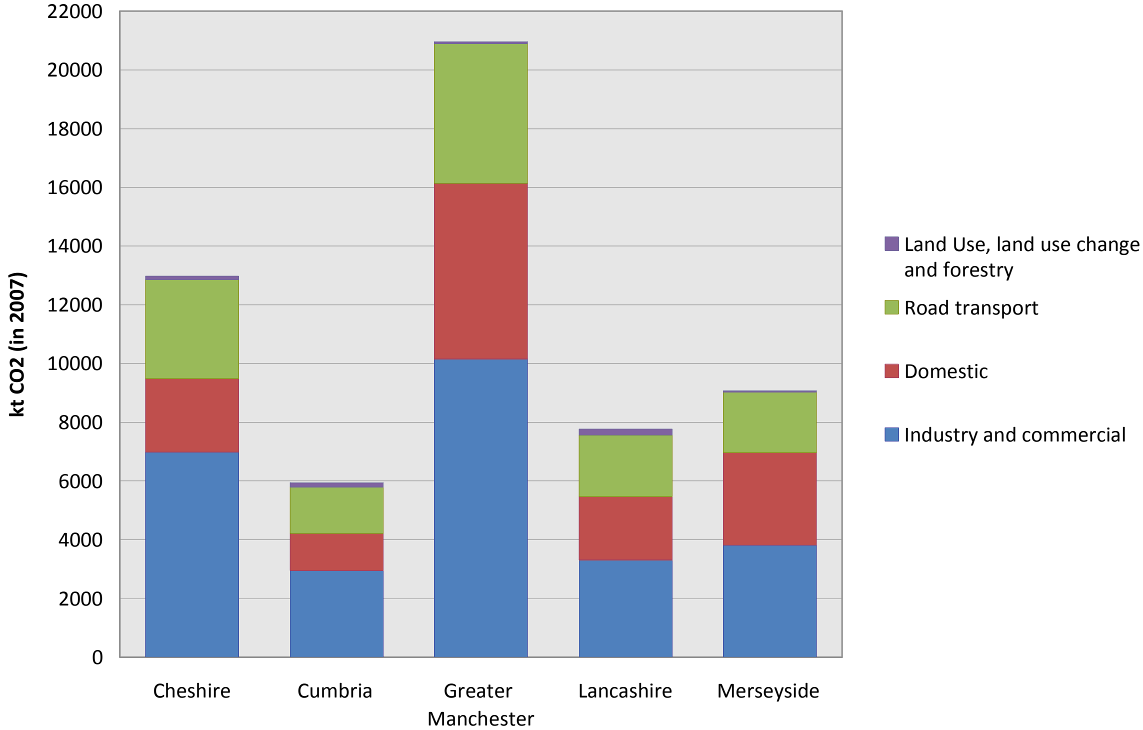


Figure 4. Carbon dioxide emission estimates from 'land use, land use change and forestry' for 2007 for the sub-regions of Northwest England[13]

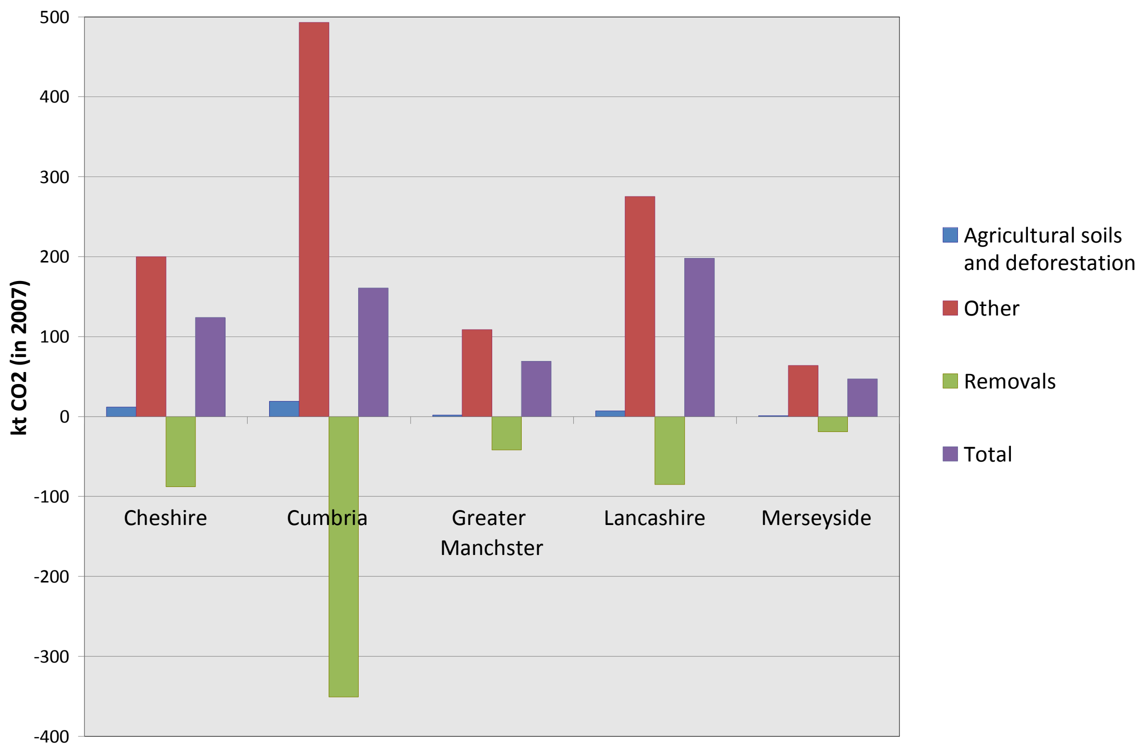


Table 1. Potential measures for carbon saving in the Northwest of England through the implementation of international, national and regional measures[16]

International and national policies (existing or planned)[17] Potential carbon savings in the Northwest by 2020 = 9.7-15.7 Mt CO_2/year Estimated reduction in CO_2 emissions between 1990 and 2020 = 24-34%
EU Emission Trading Scheme EU voluntary agreements on new car fuel efficiency Supplier obligation (successor to Carbon Emissions Reductions Target) More energy efficient products Renewable transport fuel obligation Code for Sustainable Homes / zero carbon homes Energy performance of building directive Carbon reduction commitment Changes to renewable obligation Carbon neutral government Business smart metering Better billing (domestic sector)
Regional measures (existing or planned) Potential carbon savings in the Northwest by 2020 = 1-1.8 Mt CO_2/year Estimated reduction in CO_2 emissions between 1990 and 2020 = 2-3%
Local area agreements NI 186 Regional CHP target Local transport plans (Greater Manchester, Cheshire, Warrington, Lancashire, Blackburn, Blackpool, Merseyside & Cumbria) Tree planting schemes (Community Forests Northwest, Lancashire municipal waste strategy) Northwest Operational Programme ENWORKS resource efficiency programme Local councils' and county councils' carbon management plans United Utilities carbon reduction plan Moors restoration project in Lancashire
Additional measures Potential carbon savings in the Northwest by 2020 = 1.9-5.2 Mt CO_2/year Estimated reduction in CO_2 emissions between 1990 and 2020 = 3-8%
Basic improvements to houses' fabric to improve energy efficiency Heating improvements 'Smarter choices' (soft measures to reduce road traffic and travel needs) 'Eco-driving' training programmes and awareness campaigns Microgeneration in new and existing homes Further tree planting – e.g. of Lancashire All remaining LA councils and County councils to implement carbon management plans Low carbon bus fleets Congestion charging schemes and public transport improvements in the main cities of the region Green roofs to improve energy efficiency Possible extension of carbon capture projects in moorlands – e.g. of Lancashire
Total from existing or planned measures Potential carbon savings in the Northwest by 2020 = 10.7-17.5 Mt CO_2/year Estimated reduction in CO_2 emissions between 1990 and 2020 = 26-37% **Total from existing or planned measures plus additional measures** Potential carbon savings in the Northwest by 2020 = 12.6-22.7 Mt CO_2/year Estimated reduction in CO_2 emissions between 1990 and 2020 = 29-45%

[16] It is notable that greenhouse gas emission reductions from agriculture are not included in the regional carbon reduction measures set out in table 1, yet farming is included in the UK Low Carbon Transition Plan measures.
[17] As described in the Energy White Paper (2007). www.berr.gov.uk/files/file39387.pdf

2.3 Mitigation services provided by green infrastructure

The national and regional contexts set out in sections 2.1 and 2.2 suggest that the contribution of green infrastructure to climate change mitigation may be fairly minimal, relative to overall emissions and greater cuts which can be made elsewhere. That said, they do indicate that green infrastructure can provide some services which will aid mitigation.

This is most notable within the 'farming, land and waste' sector, where 'land use, land use change and forestry' can result in carbon storage and sequestration. We have identified the following services provided by green infrastructure which aid climate change mitigation; they will be discussed in more detail in section 4.1:

- Carbon storage and sequestration
- Fossil fuel substitution
- Material substitution
- Food production
- Reducing the need to travel by car.

In addition, by helping to manage high temperatures (see section 4.2.1) green infrastructure could also reduce energy demand for cooling in buildings, further helping to reduce greenhouse gas emissions.

3. Climate change adaptation

We have seen that The Intergovernmental Panel on Climate Change states that the warming of the global climate system is now unequivocal, with coherent changes seen in many aspects of the climate system[9]. Whilst climate change mitigation is essential to reduce the severity of future changes, some of the changes we will experience over the next 30-40 years are now inevitable as they have already been determined by historic greenhouse gas emissions[18]. Alongside mitigation, we therefore also must adapt to climate change.

Climate change adaptation can be defined as “adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities”[6]. Measures are needed both to enhance our capacity to adapt and to take action to respond to impacts.

This has been recognised at a European level in the recent EU White Paper on ‘Adapting to Climate Change’[19]. In the UK, in addition to mitigation, the Climate Change Act[10] contains provisions for adaptation which include: that the Government must report at least every 5 years on climate change risks; publish a programme setting out how these will be addressed; powers to require public bodies and statutory undertakers to carry out risk assessments and make plans to address them; an Adaptation Sub-Committee of the Committee on Climate Change, to provide advice and scrutiny of Government’s adaptation work. The programme for adapting to climate change is cross-government, but is coordinated by Defra[20]. It aims to coordinate and drive forward work on adapting to climate change. The first phase includes objectives to: provide the evidence; raise awareness and help others to take action; ensure and measure progress; and embed adaptation into Government policies and processes.

In the Northwest, the vision set out in the Climate Change Action Plan[7] is of “a low carbon and well adapting Northwest by 2020”. Objectives include adapting to unavoidable climate change and capitalising on opportunities for growth. There is specific activity on a well adapting region, including developing a Regional Adaptation Framework.

3.1 Climate change projections

The recently published UK Climate Projections (UKCP09)[21] contains information on observed and future climate change, based on the latest scientific understanding.

Future climate change is presented for high, medium, and low emissions scenarios (representing different levels of greenhouse gas emissions) for 30-year overlapping time periods (with the 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099) commonly presented). A range of ‘probability levels’ are also shown (where change is ‘very likely to be greater than’ the 10% level, ‘very likely to be less than’ the 90% level, and ‘as likely as not’ to be at the central estimate or 50% level). The data is available in a number of formats,

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[18] Hulme *et al* (2002). Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. UK Climate Impacts Programme. www.ukcip.org.uk
[19] EU (2009). Adapting to Climate Change: Towards a European Framework for Action. EU White Paper. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0147:FIN:EN:PDF
[20] HM Government (2008). Adapting to Climate Change in England: A Framework for Action. www.defra.gov.uk/environment/climate/programme/index.htm
[21] http://ukclimateprojections.defra.gov.uk/

including maps of a 25 km^2 resolution. A range of climate variables are modelled, including: temperature (winter and summer means, maximums and minimums, warmest summer day), precipitation (winter, summer and annual means, wettest winter and summer days), humidity (winter and summer mean relative humidity), cloud amount (winter and summer), and sea level rise. A weather generator is also available which provides more detailed information on how daily weather may alter (as opposed to averaged changes in climate), including extremes.

The general storyline for the UK told by UKCP09 is that temperatures increase, and more so in summer than in winter. Precipitation patterns alter, with an overall decrease in summer precipitation and an increase in winter precipitation. Sea levels rise, and this is more pronounced in the south of the country than the north[22] (table 2). There are also some notable changes in extreme weather including: increases in heat wave frequency (figure 5), major increases in maximum temperature, reduction in frost days, increases in dry spell frequency (figure 6), and increases in annual wettest day amounts[23].

Table 2. Central estimates of relative sea level changes with respect to 1990 levels (cm)[21, 24]

	London			Cardiff			Edinburgh			Belfast		
	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low
2000	3.5	3.0	2.5	3.5	2.9	2.5	2.2	1.6	1.2	2.3	1.7	1.3
2010	7.3	6.2	5.3	7.3	6.2	5.3	4.7	3.5	2.6	4.9	3.8	2.8
2020	11.5	9.7	8.2	11.5	9.7	8.2	7.5	5.7	4.3	7.8	6.0	4.6
2030	16.0	13.5	11.4	15.9	13.4	11.4	10.7	8.2	6.1	11.1	8.6	6.6
2040	20.8	17.5	14.8	20.8	17.5	14.8	14.2	10.9	8.2	14.7	11.4	8.7
2050	25.9	21.8	18.4	25.9	21.8	18.4	18.0	13.9	10.5	18.6	14.5	11.1
2060	31.4	26.3	22.2	31.4	26.3	22.2	22.1	17.1	13.0	22.9	17.8	13.7
2070	37.2	31.2	26.3	37.1	31.1	26.3	26.6	20.6	15.7	27.4	21.4	16.5
2080	43.3	36.3	30.5	43.3	36.2	30.5	31.4	24.4	18.6	32.3	25.3	19.6
2090	49.7	41.6	35.0	49.7	41.6	35.0	36.5	28.4	21.8	37.6	29.4	22.8
2095	53.1	44.4	37.3	53.1	44.4	37.3	39.2	30.5	23.4	40.3	31.6	24.5

[22] Lowe *et al* (2009). UK Climate Projections Science Report: marine and coastal projections. Met Office Hadley Centre. http://ukclimateprojections.defra.gov.uk/images/stories/marine_pdfs/UKP09_Marine_report.pdf

[23] Jones *et al* (2009). UK Climate Projections Science Report: projections of future daily climate for the UK from the weather generator. University of Newcastle. http://ukclimateprojections.defra.gov.uk/images/stories/UKCP09_WGenerator.pdf

[24] Relative sea level rise combines absolute sea level changes and vertical land movements.

Figure 5. Number of hot days (above 25°C) annually, estimated by the weather generator[22]

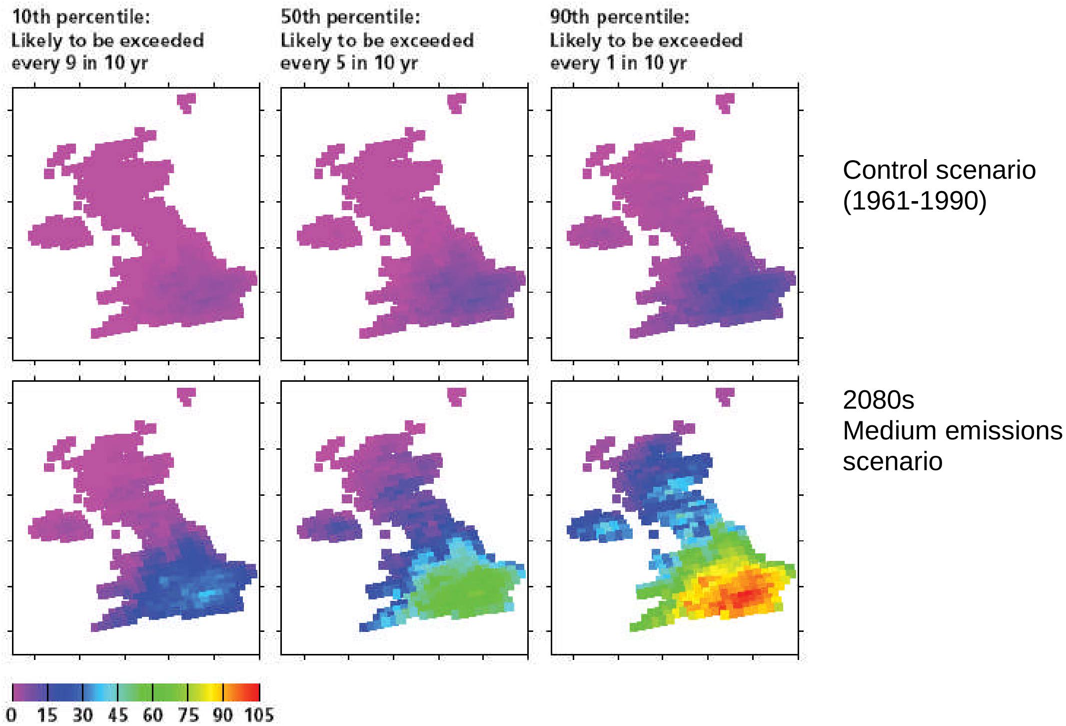
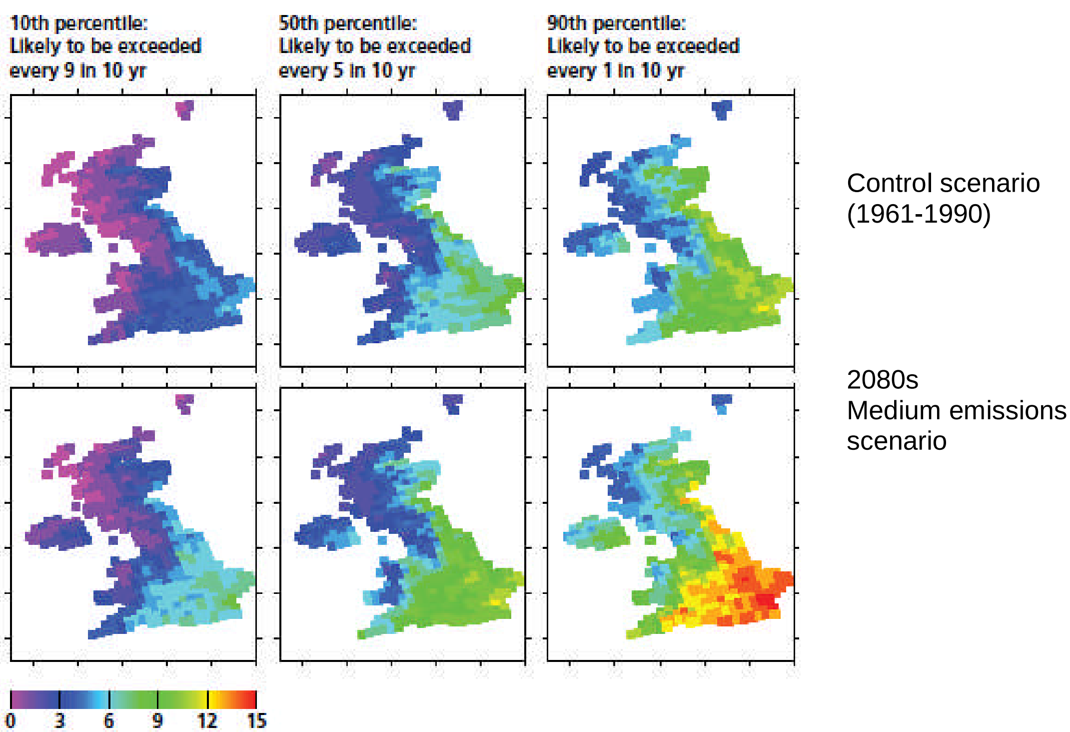


Figure 6. Number of dry spells (longer than 10 days) annually, estimated by the weather generator[22]



The storyline for the Northwest told by UKCP09 is similar to that for the UK; warmer wetter winters, hotter drier summers, and more extreme events. In the Northwest, by the 2080s under a high emissions scenario (table 3): in winter, mean temperatures could increase by 1.9-4.8ºC and precipitation could increase by 9-50%; in summer, mean temperatures could increase by 2.5-7.3ºC, with daily maximum temperatures increasing by 2.3-10.1ºC, and precipitation decreasing by 2-51%.

Table 3. UKCP09 climate change projections, relative to 1961-1990, for the Northwest for the 2020s, 2050s and 2080s, under Low, Medium, and High emissions scenarios[25]

	2020s			2050s			2080s		
	Very unlikely to be less than	Central estimate	Very unlikely to be more than	Very unlikely to be less than	Central estimate	Very unlikely to be more than	Very unlikely to be less than	Central estimate	Very unlikely to be more than
Winter mean temp	+0.4ºC	+1.4ºC	+2.0ºC	+0.8ºC	+1.8ºC	+2.8ºC	+1.3ºC	+2.3ºC	+3.5ºC
	+0.5ºC	+1.2ºC	+2.0ºC	+1.0ºC	+1.9ºC	+3.0ºC	+1.4ºC	+2.6ºC	+4.0ºC
	+0.3ºC	+1.2ºC	+2.0ºC	+1.2ºC	+2.1ºC	+3.3ºC	+1.9ºC	+3.1ºC	+4.8ºC
Summer mean temp	+0.8ºC	+1.6ºC	+2.5ºC	+1.1ºC	+2.4ºC	+3.8ºC	+1.3ºC	+2.8ºC	+4.6ºC
	+0.6ºC	+1.5ºC	+2.5ºC	+1.2ºC	+2.6ºC	+4.1ºC	+2.0ºC	+3.7ºC	+5.9ºC
	+0.6ºC	+1.5ºC	+2.5ºC	+1.5ºC	+3.0ºC	+4.7ºC	+2.5ºC	+4.7ºC	+7.3ºC
Summer mean daily max temp	+0.6ºC	+2.0ºC	+3.5ºC	+1.0ºC	+3.1ºC	+5.3ºC	+1.0ºC	+3.6ºC	+6.6ºC
	+0.4ºC	+1.9ºC	+3.5ºC	+1.0ºC	+3.3ºC	+5.8ºC	+1.6ºC	+4.8ºC	+8.3ºC
	+0.5ºC	+1.9ºC	+3.3ºC	+1.3ºC	+3.8ºC	+6.5ºC	+2.3ºC	+6.0ºC	+10.1ºC
Summer mean daily min temp	+0.6ºC	+1.5ºC	+2.6ºC	+0.9ºC	+2.3ºC	+3.9ºC	+1.1ºC	+2.8ºC	+4.9ºC
	+0.5ºC	+1.5ºC	+2.6ºC	+1.0ºC	+2.5ºC	+4.4ºC	+1.6ºC	+3.7ºC	+6.4ºC
	+0.5ºC	+1.4ºC	+2.5ºC	+1.3ºC	+2.9ºC	+4.9ºC	+2.2ºC	+4.6ºC	+7.8ºC
Annual mean precipitation	-5%	+1%	+7%	-8%	-1%	+6%	-6%	-1%	+8%
	-5%	0%	+6%	-6%	0%	+6%	-8%	0%	+8%
	-6%	0%	+6%	-7%	0%	+8%	-10%	0%	+12%
Winter mean precipitation	-4%	+4%	+14%	-1%	+8%	+20%	+5%	+15%	+30%
	-1%	+6%	+14%	+3%	+13%	+26%	+3%	+16%	+34%
	-4%	+4%	+13%	+3%	+13%	+27%	+9%	+26%	+50%
Summer mean precipitation	-20%	-6%	+8%	-34%	-14%	+8%	-35%	-17%	+3%
	-23%	-8%	+9%	-36%	-18%	+1%	-43%	-22%	0%
	-19%	-5%	+10%	-37%	-18%	+2%	-51%	-28%	-2%

[25] Change is 'very likely to be greater than' the 10% probability level, 'as likely as not' to be at the central estimate or 50% level, and 'very likely to be less than' the 90% level.
http://ukclimateprojections.defra.gov.uk/content/view/2150/680/

3.2 Climate change impacts

The projected climate changes set out in section 3.1 will have a range of impacts across the UK which will be felt by society, our economy and our environment (table 4). These will be experienced differently in different locations, and the magnitude of the impacts will depend on how well adapted we are to cope with them. It should be noted that impacts can be both negative and positive; climate change not only presents risks, but also benefits and potential opportunities. The findings from a number of impacts studies undertaken within the Northwest[26] are summarised in table 5.

Table 4. Commonly perceived climate change impacts for the UK[27]

Risks	Benefits
• An increase in the risk of flooding and erosion • Pressure on drainage systems • Possible winter storm damage • Habitat loss • Summer water shortages and low stream flows • Increased subsidence risk in subsidence prone areas • Increased demand for summer cooling • Increasing thermal discomfort in buildings • Health issues	• Less winter transport disruption • Reduced demand for winter heating • Less cold-related illness and mortality **Opportunities** • Agricultural diversification • Increased tourism • A shift to more outdoor-orientated lifestyles

[26] Findings are drawn from:
(1) Sustainability Northwest (1998). Climate change impacts in the Northwest: everyone has an impact.
(2) Sustainability Northwest (2005). Climate change in the Northwest and its impacts: a summary document. www.climatechangenorthwest.co.uk/assets/_files/documents/jan_09/cli__1231759907_Climate_change_in_the_Northwes.pdf
(3) Arup (2009). Climate change impacts and responses for key business sectors and public services in the Northwest.
www.climatechangenorthwest.co.uk/assets/_files/documents/jul_09/cli__1246471269_0011Final_Report_April_2009_LH.pdf
(4) Gill *et al* (2004). 'Adaptation Strategies for Climate Change in Urban Environments (ASCCUE)' Literature Review: impacts of climate change on urban environments. University of Manchester.
www.sed.manchester.ac.uk/research/cure/downloads/asccue_litreview.pdf

[27] Adapted from West and Gawith (eds.) (2005). Measuring progress: preparing for climate change through the UK Climate Impacts Programme. UKCIP. www.ukcip.org.uk/images/stories/Pub_pdfs/MeasuringProgress.pdf

Table 5. Impacts of climate change in the Northwest (N.B. green infrastructure responses to impacts in green are discussed in section 4.2)

Risks	Benefits
• Increased heat stress and mortality in urban areas for vulnerable populations, and people in poorly designed, insulated and ventilated buildings • Increased uptake of air conditioning, which uses energy and creates waste heat • Negative health impacts from an increase in ozone pollution episodes in summer (due to hotter, sunnier days with lower wind speeds) • Increased incidence of food poisoning and potential increase in transmissible diseases • Increased water deficit, which will cause stress to vegetation, potentially reducing evapo-transpiration and further increasing temperatures • Greater fire risk in upland areas due to drought and high temperatures • Ecological impacts from shifting patterns of agriculture • Expansion northwards and upwards in the ranges of species (may be limited by habitat fragmentation and urban development, and species' dispersal ability) • Loss of mudflats and salt marshes due to sea level rise and coastal squeeze between sea defences, disrupting internationally significant bird-feeding grounds • Additional stress for remnant semi-natural habitats and loss of niche habitats in uplands • Wetter conditions may result in increased accumulation of carbon in peatlands, however the ability of peat to act as a carbon store may be compromised as a warmer climate may result in increased decomposition • Increased pollution runoff in rural lowlands from saturated winter soils • Water quality decreases as a result of low water levels in summer (increasing pollutant concentrations) and a warmer climate increasing algal blooms • Increased saline intrusion into coastal aquifers as a result of sea level rise • Reduced water availability during prolonged droughts; manufacturing may be particularly affected • Increased flood risk from streams, rivers and sewers • Increased coastal flooding risk from increased wave heights (as a result on increased wind speeds) combined with sea level rise • Greater soil erosion as the intensity of rainfall increases • Pressures on vulnerable landscapes from increased visitors and soil erosion • Inundation of coastal aquifers as sea level rise and hydrology changes • Structural damage to buildings and other infrastructure from storms • Impacts on the historic environment (ancient burial sites, buildings, gardens and parks) from altered rainfall, sunshine and humidity • Changes in timing of seasonal events, such as flowering, bud burst and migration has seen the general trend of earlier spring and summer events. The major impacts of this shift are life cycles of species that have evolved together no longer occurring together.	• Wetter conditions may result in increased accumulation of carbon in peatlands, however the ability of peat to act as a carbon store may be compromised as a warmer climate may result in increased decomposition • Lower heating bills and reduced winter mortality rates • Fewer winter air pollution incidents (typically associated with high concentrations of NO_2, CO and VOCs), due to warmer and windier conditions • Migration of species into the region **Opportunities** • New and expanding markets for some sectors, for example, for recreation and tourism • Increase in outdoor-oriented lifestyles as a result of hotter, drier summers; bringing positive commercial, social and health impacts • Increased coastal recreation will provide opportunities for coastal zone regeneration • Agricultural options will broaden out as new crops and varieties become viable

3.3 Adaptation services provided by green infrastructure

The national and regional contexts set out in sections 3.1 and 3.2 suggest that the contribution of green infrastructure to climate change adaptation may be fairly substantial. In particular, many of the impacts of climate change in the Northwest may have a green infrastructure response (highlighted in green in table 5). We have identified the following services provided by green infrastructure which can aid climate change adaptation; they will be discussed in more detail in section 4.2:

- Managing high temperatures
- Managing water supply
- Managing riverine flooding
- Managing coastal flooding
- Managing surface water
- Managing soil erosion
- Helping other species to adapt
- Managing visitor pressure.

In addition, there are climate change adaptation aspects to food production; in this report we have included it within the climate change mitigation services provided by green infrastructure (see section 4.1.4).

We have split how green infrastructure helps manage flooding into three distinctive services: riverine flooding, coastal flooding and surface water. In practice the three are interlinked (and also linked very closely with managing water supply), however, we have split them because the way in which green infrastructure can help with each is different, so different adaptation solutions will be required. Flooding is a complex issue, and the Environment Agency identifies five different types: river, coastal, surface water, sewer, and ground water[28]. Our 'surface water' service includes the last three of these types.

[28] www.environment-agency.gov.uk/homeandleisure/floods/31652.aspx

4. Climate change services of green infrastructure

Sections 2 and 3 have set out the case for climate change mitigation and adaptation in the Northwest; highlighting a number of services provided by green infrastructure (table 6). The mitigation services are limited but important, whereas the adaptation services are substantial. It should be noted that some of these services can help with both mitigation and adaptation. For example, managing high temperatures could also reduce energy demand for cooling in buildings, further helping to reduce greenhouse gas emissions; and there are adaptation aspects to food production.

Table 6. Climate change mitigation and adaptation services provided by green infrastructure

Mitigation	Adaptation
• Carbon storage and sequestration • Fossil fuel substitution • Material substitution • Food production • Reducing need to travel by car	• Managing high temperatures • Managing water supply • Managing riverine flooding • Managing coastal flooding • Managing surface water • Reducing soil erosion • Helping other species to adapt • Managing visitor pressure

This section takes each of these services in turn. It includes a description of each, drawing on information held within the searchable evidence base[29] (appendix A holds a snapshot of the supporting evidence). An attempt is then made to identify where each services should be *safeguarded* or *enhanced* in relation to maps which show where each service may be most important in the Northwest[30]. The mapping does not show where green infrastructure is, but where it may be important.

[29] www.ginw.co.uk/climatechange/search_start.php
[30] Refer to www.ginw.co.uk/climatechange for updated versions of the maps. Updates will be made as our understanding of the roles improves and as better data sets become available.

4.1 Mitigation services provided by green infrastructure

4.1.1 Carbon storage and sequestration

Whilst primarily a mitigation service, carbon storage and sequestration has some adaptation aspects in relation to the following climate change impact (from table 5):

- Wetter conditions may result in increased accumulation of carbon in peatlands, however the ability of peat to act as a carbon store may be compromised as a warmer climate may result in increased decomposition.

Carbon is stored in both soils and vegetation. Changes to land use and/or management practices can lead to changes in the amount of carbon stored. In the UK soils contain more carbon than vegetation[31]. However, different soils have different carbon contents (e.g. peat stores more carbon than sand). The Peat Partnership Project[32] aims to minimise further peat degradation and restore degraded areas, through a range of policies and practical restoration projects. A recent report finds that, overall, peatland restoration delivers greenhouse gas benefits by protecting stored carbon and drastically reducing the amount of carbon dioxide emitted, even after accounting for the increased emissions of methane following re-wetting[33].

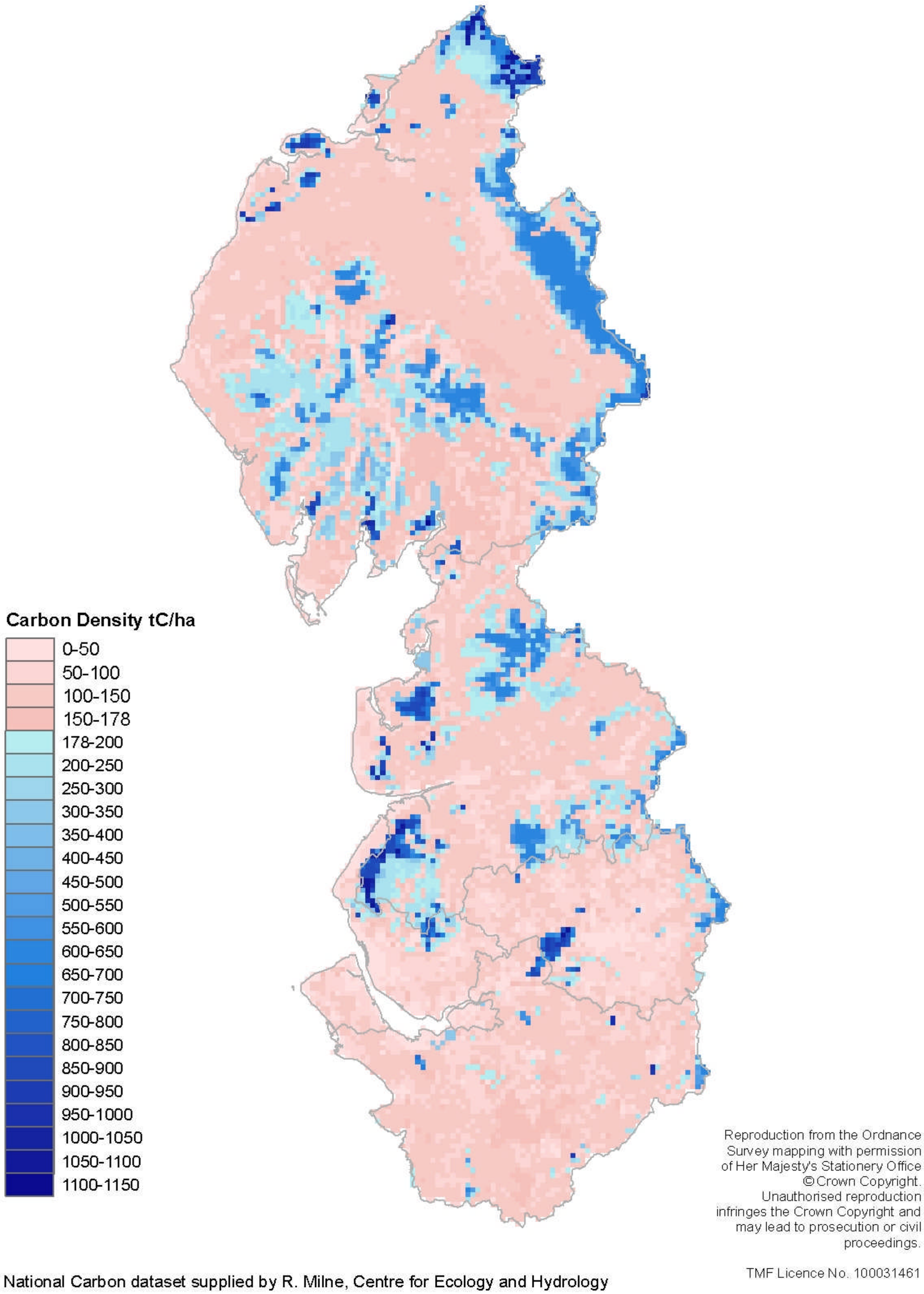
Different types of vegetation also store different amounts of carbon. Forests generally have significantly higher above-ground carbon reservoirs than other vegetation types[34]. The UK Low Carbon Transition Plan[12] encourages private funding for woodland creation to increase the carbon store. However, we would require twice the land area of the UK for the UK to become carbon neutral through woodland planting[34]. Despite this, the role of woodland in carbon storage is significant, not least because woodland creation provides a highly cost-effective and achievable abatement of greenhouse gases when compared with potential abatement options across other sectors[35].

In the Northwest, soils and vegetation store 2.5 MtC, with a mean density of 178 tC/ha (figure 7). In the highest density areas (highlighted in blue in figure 7) it is important to *safeguard* the carbon storage and sequestration service provided by green infrastructure; elsewhere action should be taken to *enhance* the resource. English peatlands are estimated to contain around 584 MtC, or around 5 years of England's total annual CO_2 emissions[33].

- In their current state English peatlands emit ~3 Mt CO_2e a year, similar to emissions from a third of a million households. Restoration of key degraded peatlands could reduce emissions by up to 2.4 Mt CO_2e each year, with 1.1 Mt of this delivered by rewetting cultivated deep peatlands[33].
- At the lowest shadow carbon value, restoration of cultivated or agriculturally improved deep peat generates net economic benefits of up to £19,000/ha after 40 years. Costs associated with blocking moorland grips are repaid by the value of emissions reductions over this period. Most peatland restoration options are a cost effective means to reduce greenhouse gas emissions[33].
- The annual value of carbon sequestration benefits for the Northwest per annum are: for woodlands £116m, for wetlands £0.7m, for peatlands £1.3m[36].

[31] Milne and Brown (1997). Carbon in vegetation and soils of Great Britain. Journal of Environmental Management: 49, 413-433.
[32] www.defra.gov.uk/environment/quality/land/soil/peat/partnership-project.htm
[33] Natural England (2010). England's Peatlands: Carbon storage and greenhouse gases. http://naturalengland.etraderstores.com/NaturalEnglandShop/NE257
[34] Broadmeadow and Matthews (2003). Forests, carbon and climate change: the UK contribution. Forestry Commission Information Note 48. www.forestry.gov.uk/pdf/fcin048.pdf/$FILE/fcin048.pdf
[35] Read *et al* (eds.) (2009). Combating climate change: a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. The Synthesis Report. The Stationery Office. www.tsoshop.co.uk/gempdf/Climate_Change_Synthesis_Report.pdf
[36] Jacobs (2008). Valuing England's Terrestrial Ecosystem Services. http://randd.defra.gov.uk/Document.aspx?Document=NR0108_7324_FRA.pdf

Figure 7. Carbon density in the Northwest (blue areas are greater than the mean of 178 tC/ha)



4.1.2 Fossil fuel substitution

Direct substitution of fossil fuels could substantially reduce the amount of greenhouse gases emitted to the atmosphere. Biomass woodfuel includes forest and woodland products, energy crops including short rotation coppice and miscanthus, short rotation forestry, forest residues, co-products from primary processing, arboricultural arisings and reprocessed waste wood and biomass materials that comply with the Waste Incineration Directive. In addition, other green infrastructure types could potentially supply bioenergy.

According to a recent assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change: "within the next five years sustainably-produced wood fuel has the potential to save the equivalent of approximately 7 $MtCO_2$ emissions per year by replacing fossil fuels in the UK. This contribution could be increased further as bioenergy, including energy derived from woody biomass, makes an increasing contribution to UK targets for renewable heat, power and liquid fuels. The use of biomass for heating provides one of the most cost-effective and environmentally acceptable ways of decreasing UK greenhouse gas emissions"[35].

In the Northwest, the Climate Change Action Plan includes an outcome on energy supply and specific activity around the development of markets and supply chain opportunities for biomass[7]. The Northwest's Biomass Woodfuel Strategy contains the vision "to create conditions under which woodfuel can develop as a viable and self sufficient energy source in Northwest England, in order to reduce carbon emissions, diversify energy sources, develop markets and add value to the regional economy"[37].

It is suggested that any woodlands currently sustainably managed for biofuels should be *safeguarded* for this green infrastructure service; whereas in areas with high potential yields of miscanthus or short rotation coppice (figure 8) woodland, this service could be *enhanced*. It should be noted that areas identified as potential high yield may not be suitable for biofuel crops due to transportation issues, proximity of processing facilities, visual impacts of harvesting, and compatibility with other land uses.

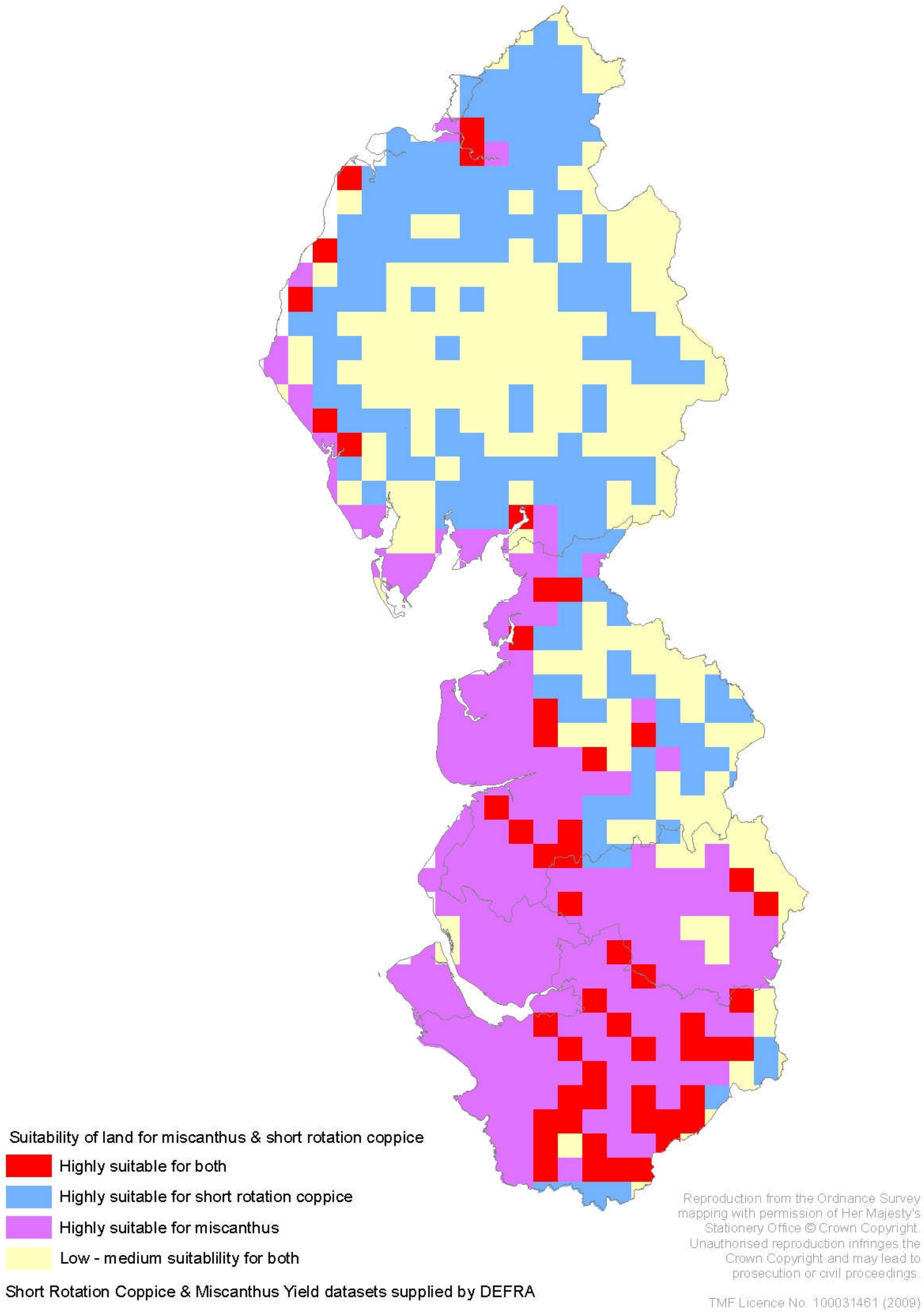
- Although estimates of the amount and type of biomass generation likely to be available by 2020 are uncertain, around 80 million MWh is likely to be needed. This would meet the share of the UK's renewable energy target envisaged for biomass, which would be about 30% of the UK's renewable heat and electricity requirement. If the majority of this was from electricity generated using poor practice feedstocks, moving to good practice would save over $3MtCO_2e$ per year by 2020[38].
- The limited land resource within the UK is a pressing issue in the development of bioenergy crops. Indications are that bioenergy could *potentially* contribute up to 7% of the UK demand for heat and electricity in 2050[39].

[37] Northwest Regional Forestry Framework. Northwest England Biomass Wood Fuel Strategy. www.forestry.gov.uk/pdf/englandnwebiomassstrategy.pdf/$FILE/englandnwebiomassstrategy.pdf

[38] AEA (2009). Biomass: Carbon sink or carbon sinner? http://www.environment-agency.gov.uk/static/documents/Leisure/Biomass__carbon_sink_or_carbon_sinner_summary_report.pdf

[39] Taylor. Bioenergy for heat and electricity in the UK. http://www.foresight.gov.uk/Energy/Bioenergy_for_heat_and_electricity_in_the_UK.pdf

Figure 8. Potential miscanthus and short rotation coppice yield in the Northwest[40]

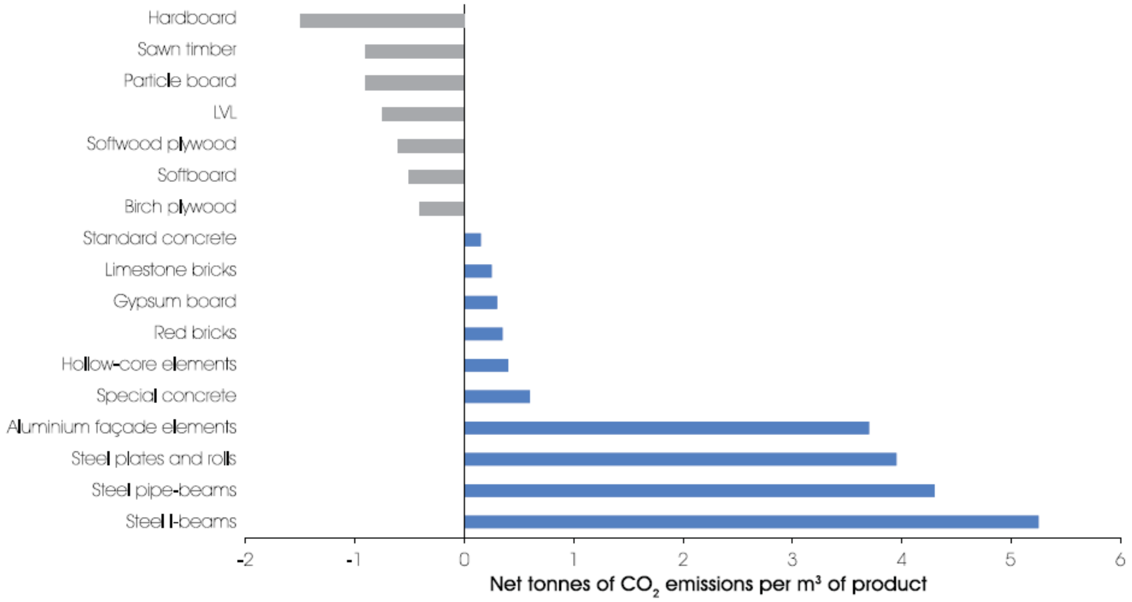


40 www.defra.gov.uk/foodfarm/growing/crops/industrial/energy/opportunities/nw.htm

4.1.3 Material substitution

Green infrastructure can reduce greenhouse gas emissions through material substitution. Wood products can replace more energy intensive construction materials such as concrete and steel, which can result in carbon savings in embodied energy and also increase the carbon storage in buildings (figure 9)[41]. The Northwest Regional Forestry Framework highlights the use of timber as a low energy sustainable construction material[42]. The combination of woodlands providing material substitution, an alternative to fossil fuels (section 4.1.2) and storing and sequestering carbon (section 4.1.1), indicate that they have the potential to deliver significant carbon abatements.

Figure 9. Net CO_2 emissions of construction industry products. Non-woody components are a net source of CO_2; wood-based components are net sinks. (LVL = laminated veneer lumber)[41].

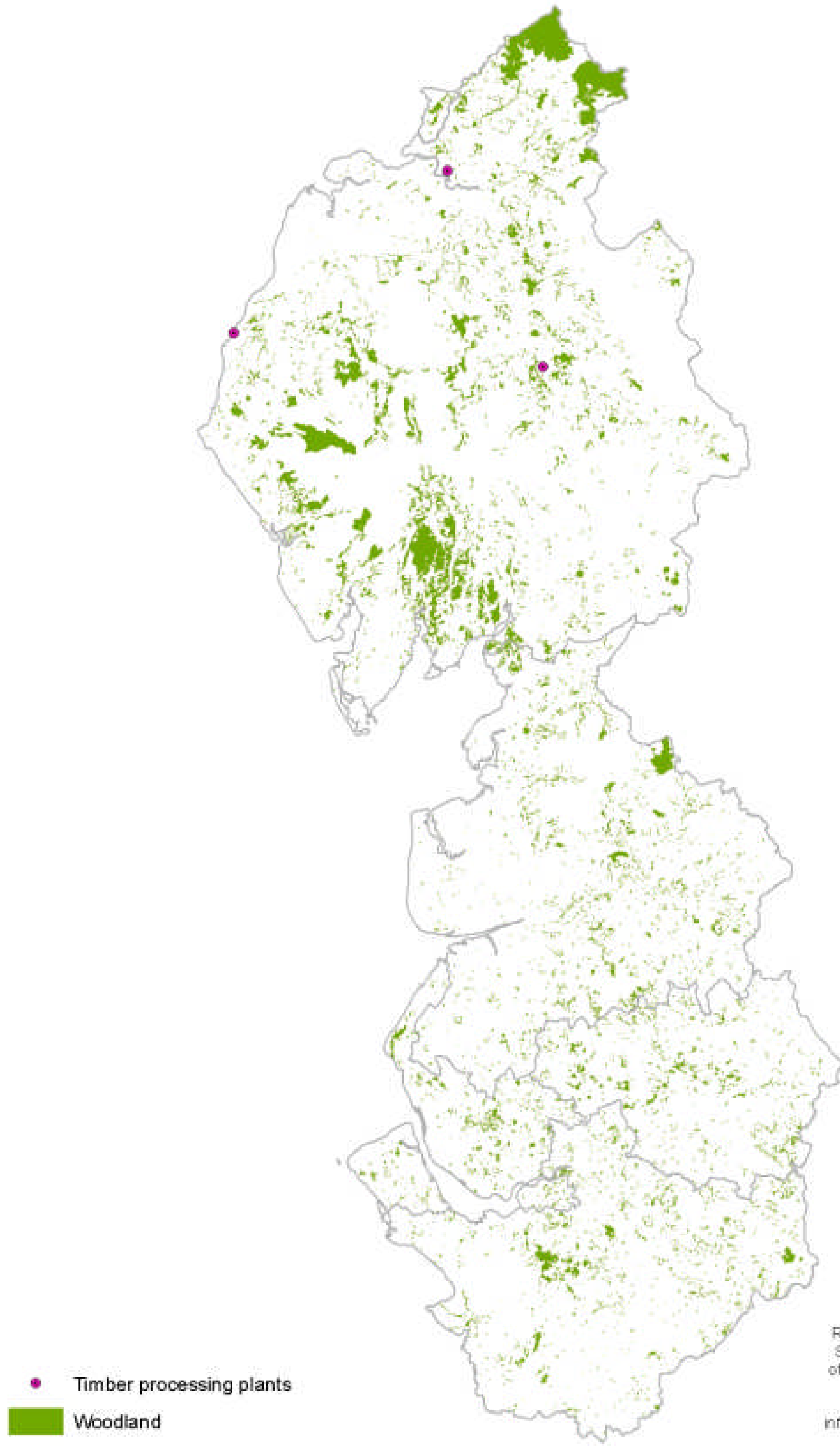


Existing woodlands which are currently managed for timber production could be *safeguarded* for this service, as should local processing plants; whereas the service could be *enhanced* in other existing woodlands by bringing them into management for this purpose and by creating new processing plants (figure 10). It should be noted that not all woodlands identified in figure 10 will be suitable for harvesting wood.

- It is possible to achieve up to an 86% reduction in greenhouse gas emissions by increasing the amount of timber specified in buildings[43].
- The estimated total quantity of carbon stored in wood-based construction products in the UK housing stock in 2009 is 19 MtC. If the market for wood construction products continues to grow at its current rate there is the potential to store an estimated additional 10 MtC in the UK's new and refurbished homes by 2019[35].

[41] Suttie *et al* (2009). Potential of forest products and substitution for fossil fuels to contribute to mitigation. In footnote 35.
[42] Northwest Regional Forestry Framework. (2005). The Agenda for Growth: The Regional Forestry Framework for England's Northwest www.creativeconcern.com/iwood/pdf/IWOOD_Agenda_For_Growth.pdf
[43] Forestry Commission Scotland (2006). Greenhouse Gas Emissions Comparison Carbon benefits of Timber in Construction.
www.forestry.gov.uk/pdf/Carbonbenefitsoftimberinconstruction.pdf/$FILE/Carbonbenefitsoftimberinconstruction.pdf

Figure 10. Woodland areas and timber processing plants in the Northwest



Woodland dataset supplied by Forestry Commission, Woodland Trust and The Mersey Forest
Processing plants dataset supplied by BSW Timber

4.1.4 Food production

Whilst primarily a mitigation service, food production has some adaptation aspects in relation to the following climate change impacts (from table 5):

- Ecological impacts from shifting patterns of agriculture
- Agricultural options will broaden out as new crops and varieties become viable.

Food production is essential, yet it causes greenhouse gas emissions; arising from what is grown, how it is grown, processed, and transported. Altered farming methods can lead to a reduction in emissions. For example, agricultural tillage practices have the potential to significantly contribute to reductions. An increased adoption of conservation tillage[44] will increase carbon sequestration rates in agricultural soils[45]. Organic farming practices provide a practical model for addressing climate-friendly food production; sequestering higher levels of carbon in the soil, and being much less dependent on oil-based fertilisers and pesticides. In northern Europe, organic farming results in soil carbon levels that are 28% higher than in non-organic farming. This represents a soil carbon sequestration rate of about 560 kg C/yr for each hectare of cultivated land converted to organic farming in the UK[46].

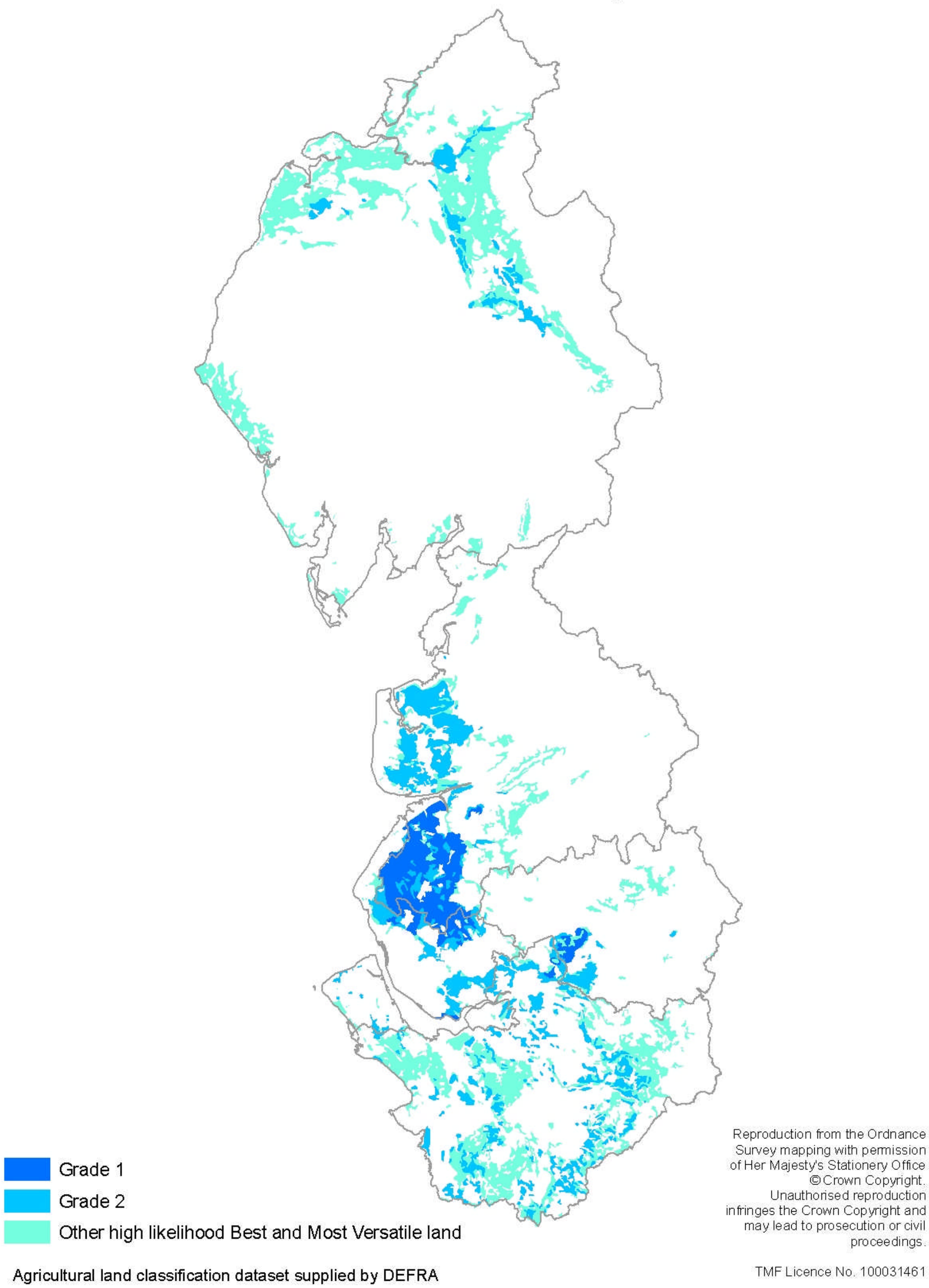
Transportation of food to processing plants and markets also results in carbon emissions. Food travels much further than it did 30 years ago, with an almost 25% increase in average 'food miles' during that time[47]. Reducing 'food miles' by producing food in close proximity to processing plants and markets can decrease emissions. In addition, urban food production offers an option to reduce food miles and use less packaging, and has other benefits for local people and the environment[48].

In the Northwest, 80% of the region is designated as agricultural land; 29,109 ha is grade 1 land and 73,791 ha is grade 2 land. Grade 1, 2 and 3a land is the highest quality and is the most versatile in terms of food production; DEFRA define this as 'best and most versatile' (figure 11). Best and most versatile land should be *safeguarded* for food production; food production should be *enhanced* in urban areas[49].

- The total market value for England for all agricultural produce and activities is £10,316m. The total annual GVA is less than half of that, at £4,369m[36].
- One analysis suggests that arable farming might become unviable on 7% of the Northwest due to flooding[50].

[44] Conservation tillage uses crop residue to serve as mulch to protect and increase the soil organic carbon.
[45] Gregory *et al* (2000). The efficiency of sequestering carbon in agricultural soils. Working Paper 00-WP-246, Iowa State University. www.card.iastate.edu/publications/DBS/PDFFiles/00wp246.pdf
[46] Soil Association (2009). Soil, Carbon and Organic Farming. www.soilassociation.org/Whyorganic/Climatefriendlyfoodandfarming/Soilcarbon/tabid/574/Default.aspx
[47] Soil Association (2009). Food Futures: strategies for resilient food and farming. www.soilassociation.org/LinkClick.aspx?fileticket=aBVYgjxtNOI%3d&tabid=565
[48] Sustain (1999). City Harvest: the feasibility of growing more food in London. www.sustainweb.org/publications/order/134/
[49] The agricultural land classification does not highlight the quality of urban and urban-fringe soils which could be very productive as older settlements were often at the centre of good farmland. They are also subject to planning and development pressures leading to their cumulative loss.
[50] Soil Association (2008). An inconvenient truth about food: Neither secure nor resilient. http://www.soilassociation.org/LinkClick.aspx?fileticket=EttWlupviYA%3D&tabid=387

Figure 11. Best and most versatile agricultural land[51] in the Northwest[52]



[51] It should be noted that agricultural land classification may alter in a changed climate as climatic and soil conditions change, this map is based on current climate and land use data.

[52] Grade 3a areas on this map are derived from a dataset which specifies the 'likelihood' of land being amongst the three grades making up best and most versatile land, i.e. 1, 2 and 3a. We used land categorised as 'high likelihood' best and most versatile, but not as grade 1 or 2, as a proxy for grade 3a.

4.1.5 Reducing the need to travel by car

Road traffic is responsible for a substantial amount of the UK's carbon emissions. In 2004 the transport sector was responsible for around 27% of total UK carbon dioxide emissions[53]; of this, private motor transport generated nearly 43% of emissions[54]. Thus, reducing the need to travel by car will help to decrease carbon dioxide emissions.

Whilst green infrastructure cannot automatically reduce car usage, there are two main mechanisms through which green infrastructure may reduce the need to travel by car: by providing high quality local recreation areas which may reduce the need to travel for recreation purposes (in this respect, this service is linked to the adaptation service of managing visitor pressure (section 4.2.7) as local recreation areas will also be beneficial in reducing visitor pressure on more vulnerable landscapes), and by providing green walking and cycling routes for both recreation and daily commuting which may increase the attractiveness of these modes of travel[55]. It is important to ensure that green cycle and walking paths are safe, secure and offer a real alternative to the private car.

Due to the large numbers of people located in urban areas the potential to reduce car use through green infrastructure is highest here; hence this service is especially important within and near to urban areas, but rural to urban and inter-rural linkages should also be considered (figure 12). In particular, existing green walking and cycling routes and local recreation areas in and near urban areas should be *safeguarded* to help reduce the need to travel by car; these routes and areas should also be improved, linked together better, and new routes and areas created to *enhance* the service provided by green infrastructure in reducing the need to travel by car.

- If 160 journeys of 3.9km are made by bicycle rather than by car in urban areas, this equates to pollution-related savings (such as reduced carbon emissions and improved air quality) of £70 a year. It is estimated that this saves 112,000 grams of CO_2 per person (displaced from single-occupancy car to cycle) or 112 metric tonnes of CO_2 per 1,000 people[56].
- In addition to carbon savings there are also health and economic benefits. There are around 30,000 deaths or serious injuries from road accidents in the UK every year. Air pollution contributes to respiratory diseases and is estimated to reduce life expectancy by 7-8 months. Congestion is estimated to cost the UK economy £20 billion per year[57].

[53] Steer Davies Gleave (2006). Driving up carbon dioxide emissions from road transport: an analysis of current government projections. A report for Transport 2000. www.foe.co.uk/resource/briefings/driving_up_co2_emissions.pdf

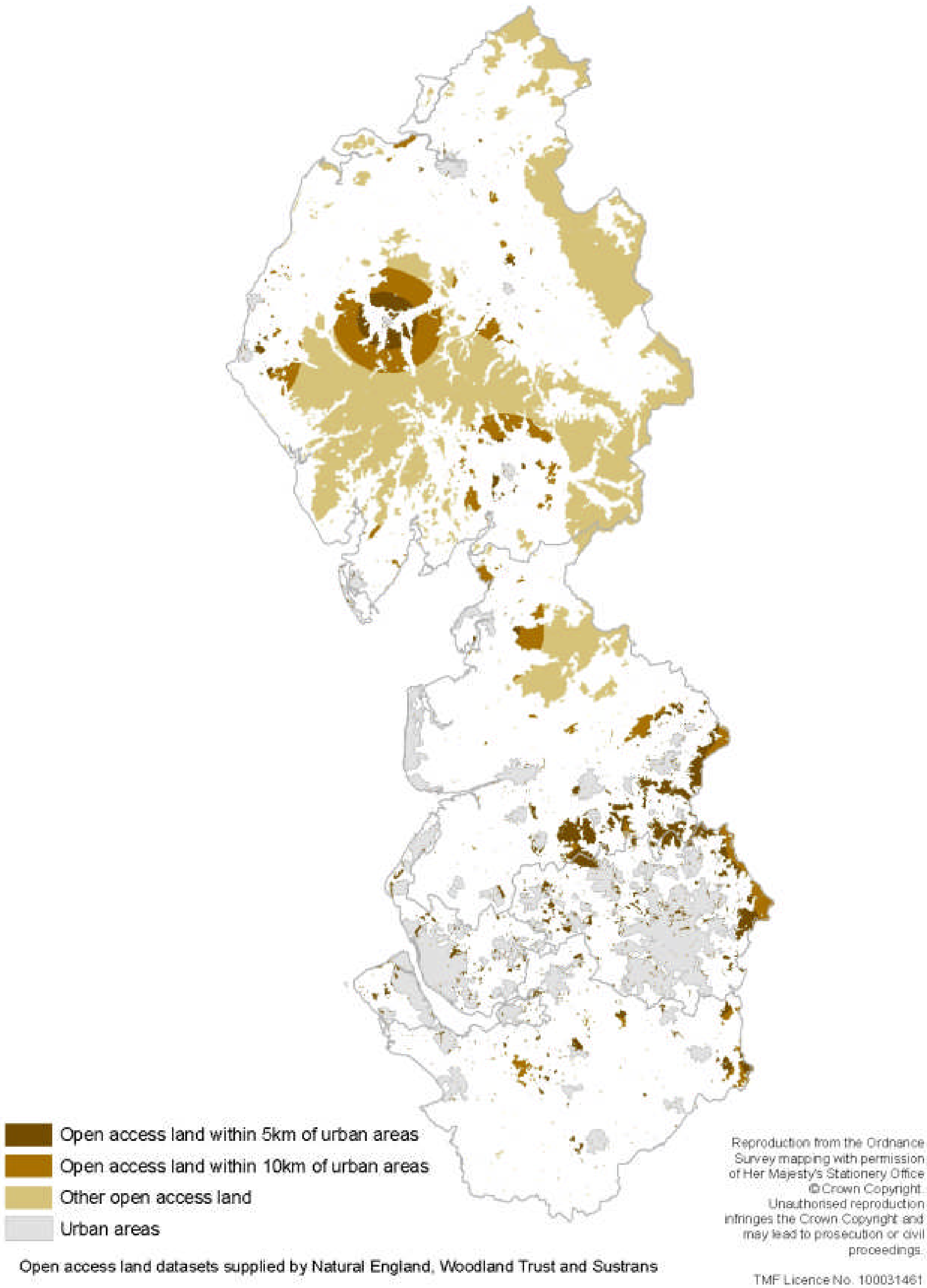
[54] Sustrans (2008). Annual Review. www.sustrans.org.uk/assets/files/Publications/sustrans_annual_review_08.pdf

[55] Town and Country Planning Association (2004). Biodiversity by Design: a guide to sustainable communities. www.tcpa.org.uk/data/files/bd_biodiversity.pdf

[56] SQW (2007). Valuing the benefits of cycling. http://www.dft.gov.uk/cyclingengland/site/wp-content/uploads/2008/08/valuing-the-benefits-of-cycling-full.pdf

[57] http://www.sustainablecities.org.uk/transport/carbon-efficiency/

Figure 12. The proximity of open access land to urban areas in the Northwest, indicating where there may be opportunities to encourage people to commute and recreate locally without using cars[58]



[58] This map is a proxy for local recreation areas. We have not mapped green walking and cycling routes in relation to daily commuting. This issue may be best dealt with at a more local level, using locally available datasets.

4.2 Adaptation services provided by green infrastructure

4.2.1 Managing high temperatures

Using green infrastructure to manage high temperatures could help to address the following climate change impacts (from table 5):

- Increased heat stress and mortality in urban areas for vulnerable populations, and people in poorly designed, insulated and ventilated buildings
- Increased uptake of air conditioning, which uses energy and creates waste heat
- Negative health impacts from an increase in ozone pollution episodes in summer (due to hotter, sunnier days with lower wind speeds)
- Increased water deficit, which will cause stress to vegetation, potentially reducing evapo-transpiration and further increasing temperatures
- Water quality decreases as a result of low water levels in summer (increasing pollutant concentrations) and a warmer climate increasing algal blooms
- Increase in outdoor-oriented lifestyles as a result of hotter, drier summers; bringing positive commercial, social and health impacts.

Green infrastructure has the potential to help urban areas cope with increased temperatures, by providing evaporative cooling and shading. Trees with large mature canopies are especially important for their shade provision. Open spaces which allow air to flow through the city could also help to manage high temperatures; Berlin's digital environmental atlas emphasises the importance of air flows through the city, with planning advice for different areas[59].

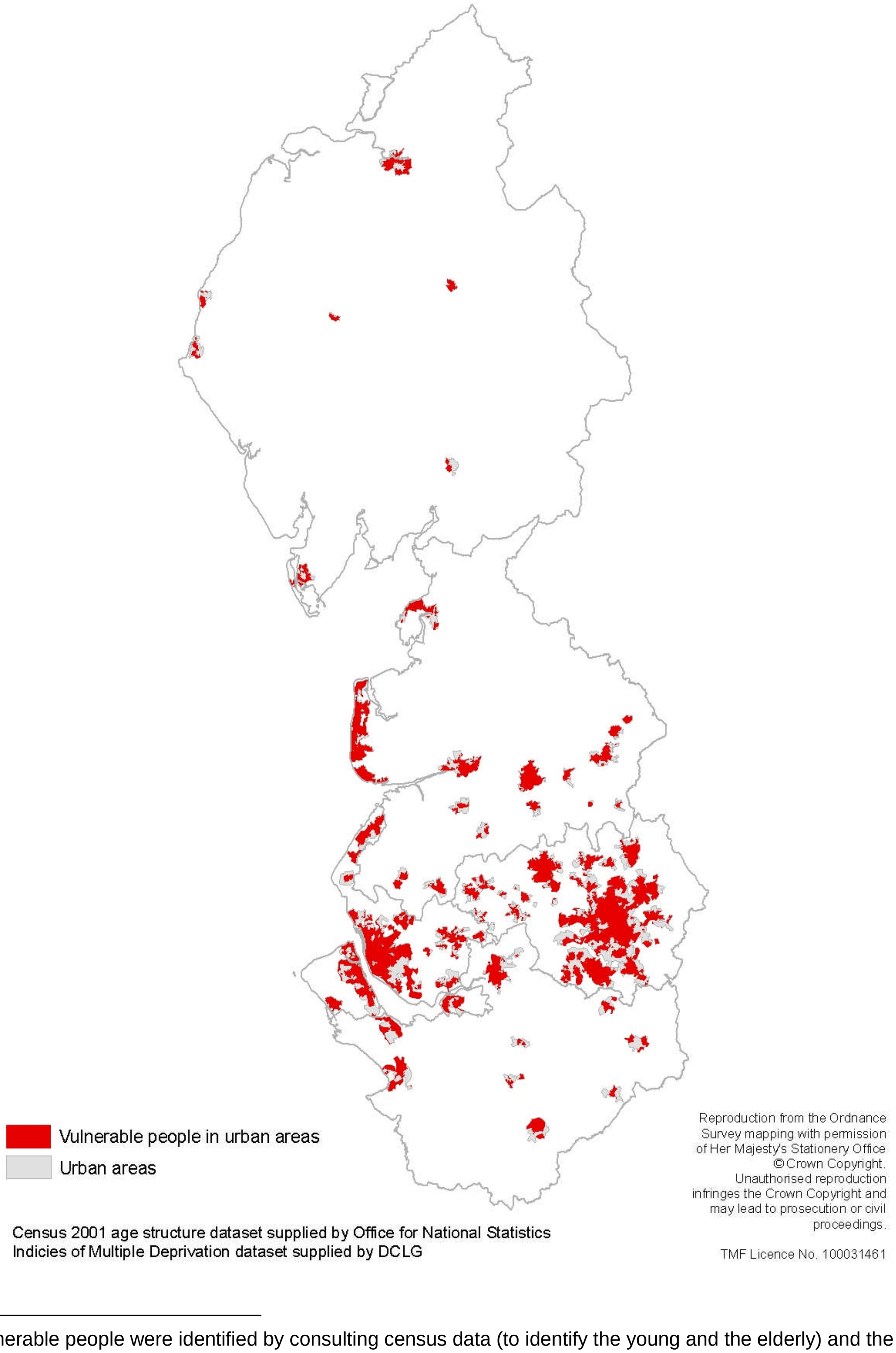
Using green infrastructure to manage high temperatures helps to reduce heat stress and mortality, particularly among vulnerable people. It also ensures that cities continue to be comfortable places to live, work, visit and invest in the future. It should be noted that green infrastructure responses which help to manage high temperatures, can also help mitigate climate change by reducing energy use for cooling buildings.

Urban areas display an 'urban heat island' effect, where they are warmer than the surrounding countryside. It is here where green infrastructure can make the biggest impact in terms of helping manage high temperatures (figure 13); hence green infrastructure in these areas should be *safeguarded* and *enhanced*. Within urban areas, this is especially where vulnerable people live, where green infrastructure levels are currently lowest, and in areas where people congregate.

- In the Northwest there were approximately 60 excess deaths in the heatwave of 16th-28th July 2006, this is approximately 15% above the baseline[60].
- Modelling work has suggested that adding 10% green cover to built-up areas in Greater Manchester keeps surface temperatures at a 1961-1990 baseline level up until the 2080s high emissions scenario[61].

[59] www.stadtentwicklung.berlin.de/umwelt/umweltatlas/edua_index.shtml
[60] Department of Health (2010). Heatwave plan for England. http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/@ps/documents/digitalasset/dh_114423.pdf
[61] Gill *et al* (2007). Adapting cities for climate change: the role of the green infrastructure. Built Environment, 33(1), 115-133.

Figure 13. Urban areas and concentrations of vulnerable populations[62]



[62] Vulnerable people were identified by consulting census data (to identify the young and the elderly) and the index of multi deprivation.

4.2.2 Managing water supply

Using green infrastructure to manage water supply could help to address the following climate change impacts (from table 5):

- Increased water deficit, which will cause stress to vegetation, potentially reducing evapo-transpiration and further increasing temperatures
- Water quality decreases as a result of low water levels in summer (increasing pollutant concentrations) and a warmer climate increasing algal blooms
- Reduced water availability during prolonged droughts; manufacturing may be particularly affected.

The River Basin Management Plan for the Northwest[63] highlights a number of challenges including: diffuse pollution from agricultural activities; point source pollution from water industry sewage works; diffuse pollution from urban sources; physical modification of water bodies; point source pollution from industrial discharges; water abstraction and artificial flow regulation. The Northwest is highly dependent on surface water sources for drinking water, accounting for 85% of the total demand.

Green infrastructure can help manage water supply by maintaining quantity and quality. A recent report suggests that a range of habitats play a role in the provision, regulation and purification of water[80]. Green infrastructure provides a permeable surface which helps to sustain infiltration to aquifers, recharges groundwater and maintains base flow in rivers. Extensive woodland planting (especially of conifers), due to its high water use, can reduce catchment yields and so will require careful evaluation particularly over significant aquifers[64]. Vegetation removes and filters pollutants from soils and water.

Maintaining water quantity is important as climate change alters precipitation patterns, with significantly less rainfall in summer. In combination with existing uses of water, including by the manufacturing industry, there is considerable housing growth planned for the region which will increase demand. In the Northwest, 22% of the 162 catchments are currently over-abstracted or over-licensed at low flows[65]. Maintaining water quality will help to achieve Water Framework Directive targets[66]. In the Northwest, there are a number of catchment management initiatives including United Utilities' Sustainable Catchment Management Programme and the work of Peatscapes in the North Pennines to protect and improve the management of peatlands[65].

We are currently exploring the potential use of the wealth of information available under the Water Framework Directive[63] (e.g. figure 14) for mapping where green infrastructure may be most important for managing the water supply. When available these maps will be accessible via www.ginw.co.uk/climatechange.

- Restoration of peat bogs in the Northwest was estimated to provide annual benefits of £1.2-2.6 million (based on costs of 'end of pipe' water treatment expected to be avoided)[67].

[63] Environment Agency (2009). Water for life and livelihoods: River Basin Management Plan North West River Basin District. http://wfdconsultation.environment-agency.gov.uk/wfdcms/en/northwest/Intro.aspx

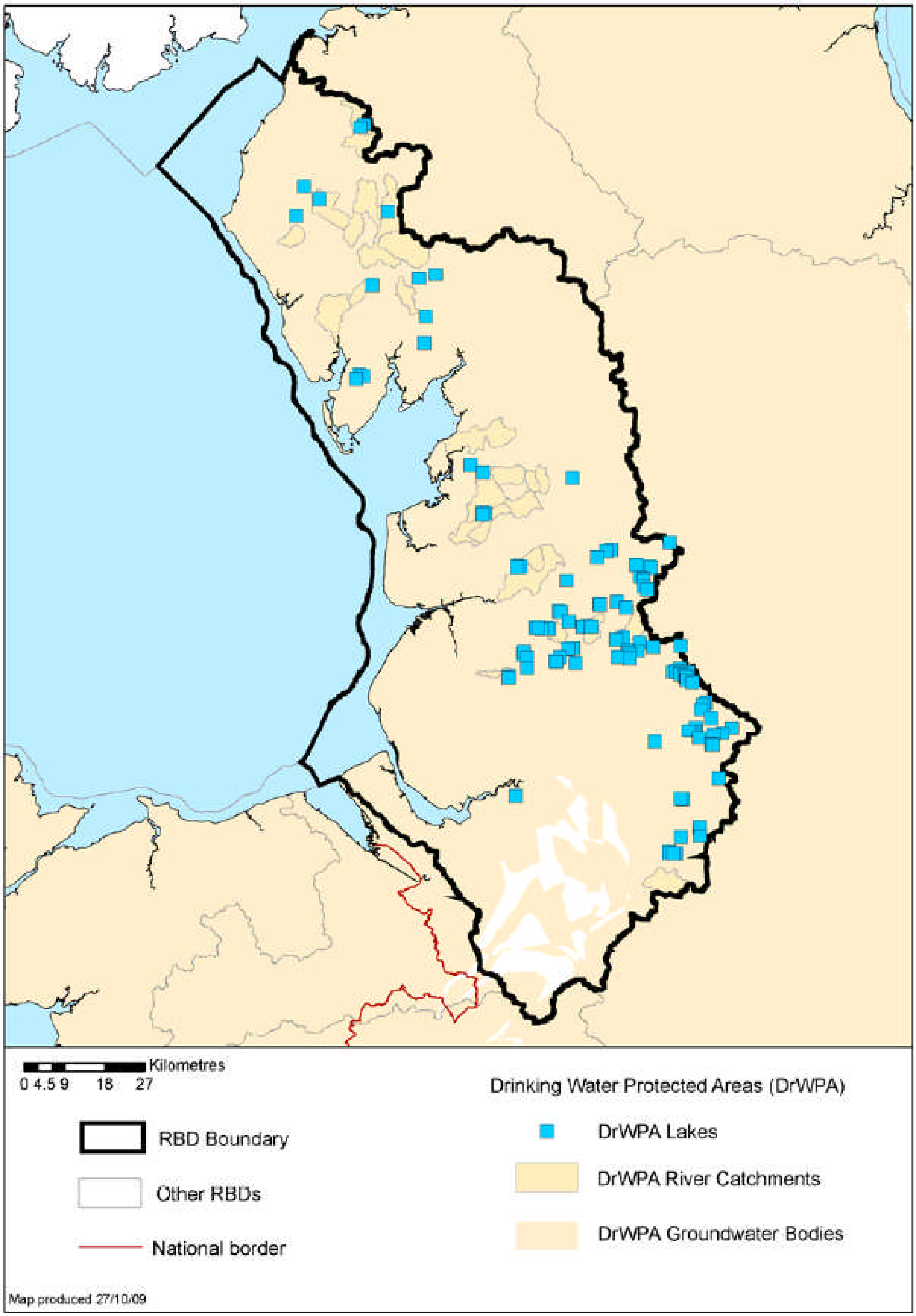
[64] Handley and Gill (2009). Woodlands helping society to adapt. In Read *et al*. (2009). Combating climate change: a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. The Stationery Office. www.tsoshop.co.uk/gempdf/Climate_Change_Main_Report.pdf

[65] Environment Agency (2009). Water Resources Strategy: Regional Action Plan for Northwest Region. http://publications.environment-agency.gov.uk/pdf/GEHO1209BRLA-e-e.pdf

[66] http://ec.europa.eu/environment/water/water-framework/index_en.html

[67] Institute for European Environmental Policy (2006), Value of Biodiversity: Documenting EU examples where biodiversity loss has led to the loss of ecosystem services http://www.conservationfinance.org/Documents/CF_related_papers/Value_of_biodiversity-June_06.pdf

Figure 14. Location of drinking waters (groundwater and surface water) in the Northwest[63]



4.2.3 Managing riverine flooding

Using green infrastructure to manage riverine flooding could help to address the following climate change impacts (from table 5):

- Increased flood risk from streams, rivers and sewers.

Riverine flooding can have severe negative impacts, damaging property, and affecting peoples' health and well being. Climate change, with increased winter rainfall and higher intensity events throughout the year increase flood risk.

The Northwest is ranked seventh out of the nine English regions in relation to the number of properties at significant risk of flooding (greater than a 1.3%, or 1 in 75, chance of flooding in any year), Warrington is ranked tenth out of local authorities (with around 6,500 properties at significant risk)[68]. A recent study estimated that, for the baseline case with existing flood defences, annual average damages to Northwest businesses is £43m; increasing to £138m (223%) with climate change, assuming that flood defences are maintained at current levels[69].

Flooding cannot be wholly prevented, yet its impacts can be reduced[70]. The Pitt Review advocates working with natural processes to manage flooding[71]. Green infrastructure and land use management in the wider catchment reduce the frequency of floods, but in extreme rainfall events this is less significant. Land use management has a significant effect on runoff at local levels; wetlands and riparian and floodplain woodlands help to reduce peak flood volumes[72,64], and provide areas where rivers can flood without causing damage.

Existing green infrastructure within flood zones should be *safeguarded* to manage riverine flooding. This service can be *enhanced* by re-naturalisation and taking opportunities to create new green infrastructure (figure 15). Green infrastructure outside of flood zones will also help; there may be significant opportunities for wetland creation in the predominantly rural areas designated as 'policy option 6' within Catchment Flood Management Plans[73,74].

- Upland and lowland management to restore floodplains and improve water quality has demonstrated benefit-cost ratios of up to 4:1[75].
- Urban wetlands have a value that is significantly higher than rural wetlands[36].
- Flood control and storm buffering benefits provided by a subset of the Northwest's habitats is valued at £194m per annum[36].
- Floodplain woodlands are valued at £1-4k for their flood water management properties[36].
- An average annual value of wetlands for flood control and storm buffering benefits is estimated to be £3,900/ha[76].

[68] Environment Agency (2009). Flooding in England: a national assessment of flood risk. http://publications.environment-agency.gov.uk/pdf/GEHO0609BQDS-E-E.pdf.

[69] The climate change scenario used is for a 20% increase in river flows by 2100; URS (2009). Economic impacts of increased flood risk associated with climate change in the North West. www.climatechangenorthwest.co.uk/assets/_files/documents/oct_09/cli__1256311710_URS_Ecoimpact_report_finalOct2.pdf

[70] DCLG (2006). Planning Policy Statement 25: Development and flood risk. www.communities.gov.uk/documents/planningandbuilding/pdf/planningpolicystatement25.pdf

[71] Pitt (2008). Learning lessons from the 2007 floods. http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html

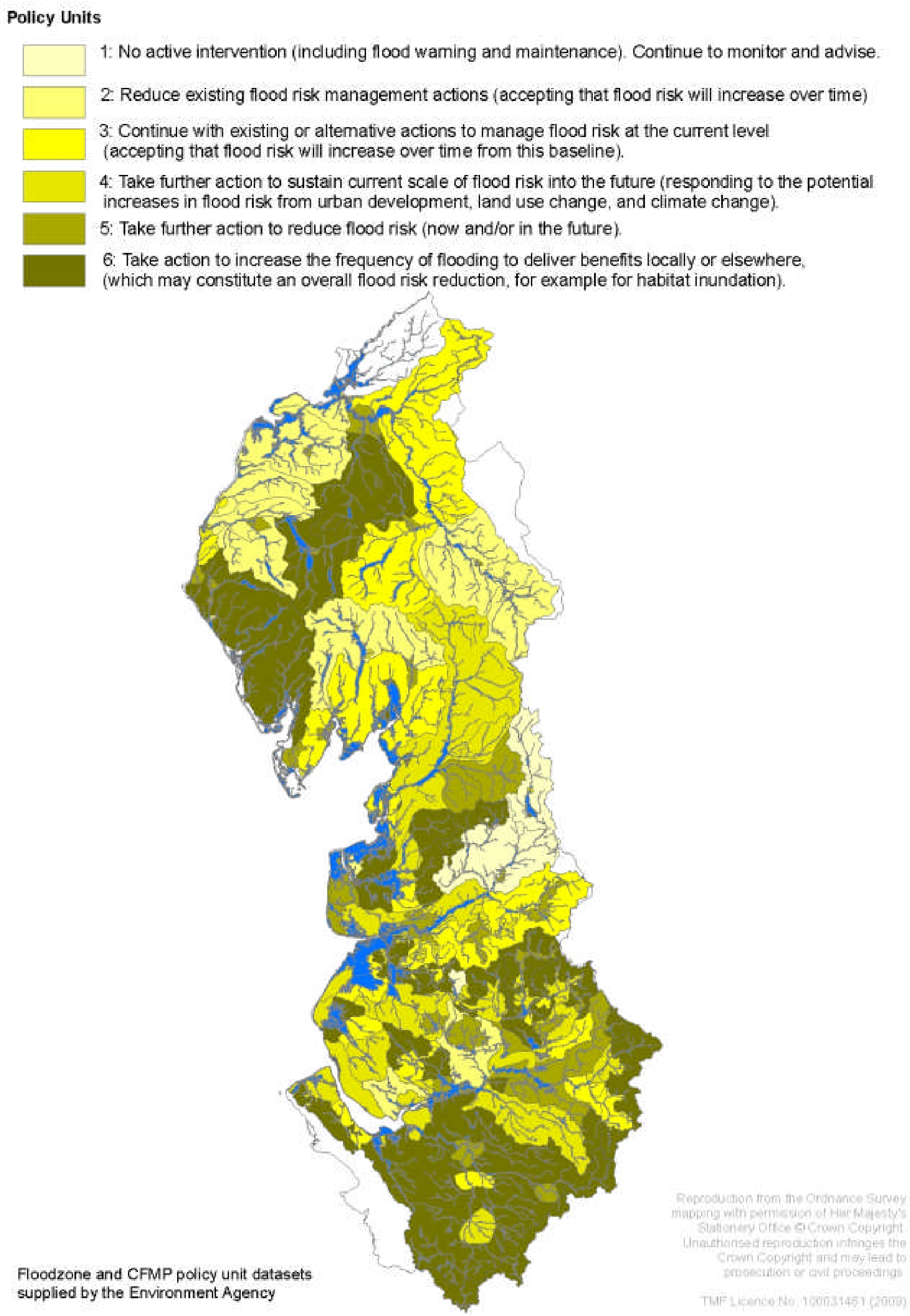
[72] Thomas and Nisbet (2006). An assessment of the impact of floodplain woodland on flood flows. Forest Research. Water and Environment Journal. 21, 114–126.

[73] www.environment-agency.gov.uk/research/planning/114513.aspx

[74] Environment Agency analysis suggests that policy option 6 is the policy with the most actions regarding the creation of green infrastructure (34% of total), there are also green infrastructure actions in areas of policy option 4 (27% of total).

[75] Natural England (2009). No charge? Valuing the natural environment. http://naturalengland.etraderstores.com/NaturalEnglandShop/NE220

Figure 15. Northwest flood zones in relation to Catchment Flood Management Plan policy units[77]



[76] Brander *et al* (2003). The Empirics of Wetland Valuation: A comprehensive summary and a meta-analysis of the literature. http://www.cbd.int/doc/external/academic/wetland-bramder-2003-en.pdf
[77] This map includes both fluvial and tidal flood risk.

4.2.4 Managing coastal flooding

Using green infrastructure to manage coastal flooding could help to address the following climate change impacts (from table 5):

- Loss of mudflats and salt marshes due to sea level rise, disrupting internationally significant bird-feeding grounds
- Increased coastal flooding risk from increased wave heights (as a result on increased wind speeds) combined with sea level rise.
- Inundation of coastal aquifers as sea level rise and hydrology changes.

Coastal flooding occurs when storm surges reach the shore. It could occur more often as sea levels rise and is projected to increase under future climate scenarios[78]. Coastal flooding impacts on people, buildings and infrastructure.

The draft Shoreline Management Plan for Northwest England examines coastal flooding and erosion risks[79]. It proposes policy options: hold the line, advance the line, managed realignment, and no active intervention.

Just as natural floodplains, which allow rivers to over-bank and flood their land temporarily, help to manage riverine flooding, naturally occurring green infrastructure along the coast provides a service that help to manage coastal flooding. Actions will include protecting wetlands and salt marshes which provide natural habitats which can accommodate coastal floodwaters, thereby protecting other areas from flooding. Hesketh Out Marshes on the south shores of the Ribble estuary, is an example of working with nature to manage coastal flooding. Here, the coast has been allowed to realign and a large area of salt marsh has been restored, this protects other infrastructure inland. Similarly, dune systems provide a natural buffer against coastal flooding.

Green infrastructure interventions to manage coastal flooding would, to a large extent, involve *safeguarding* existing habitats which provide this natural buffer[80] (figure 17). This would include appropriate management of these habitats, for example, employing soft engineering solutions to stabilise sand dune systems. In some instances, the service provided by green infrastructure in managing coastal flooding could be *enhanced* by the creation of new habitats for this purpose, including marshes and wetland habitats.

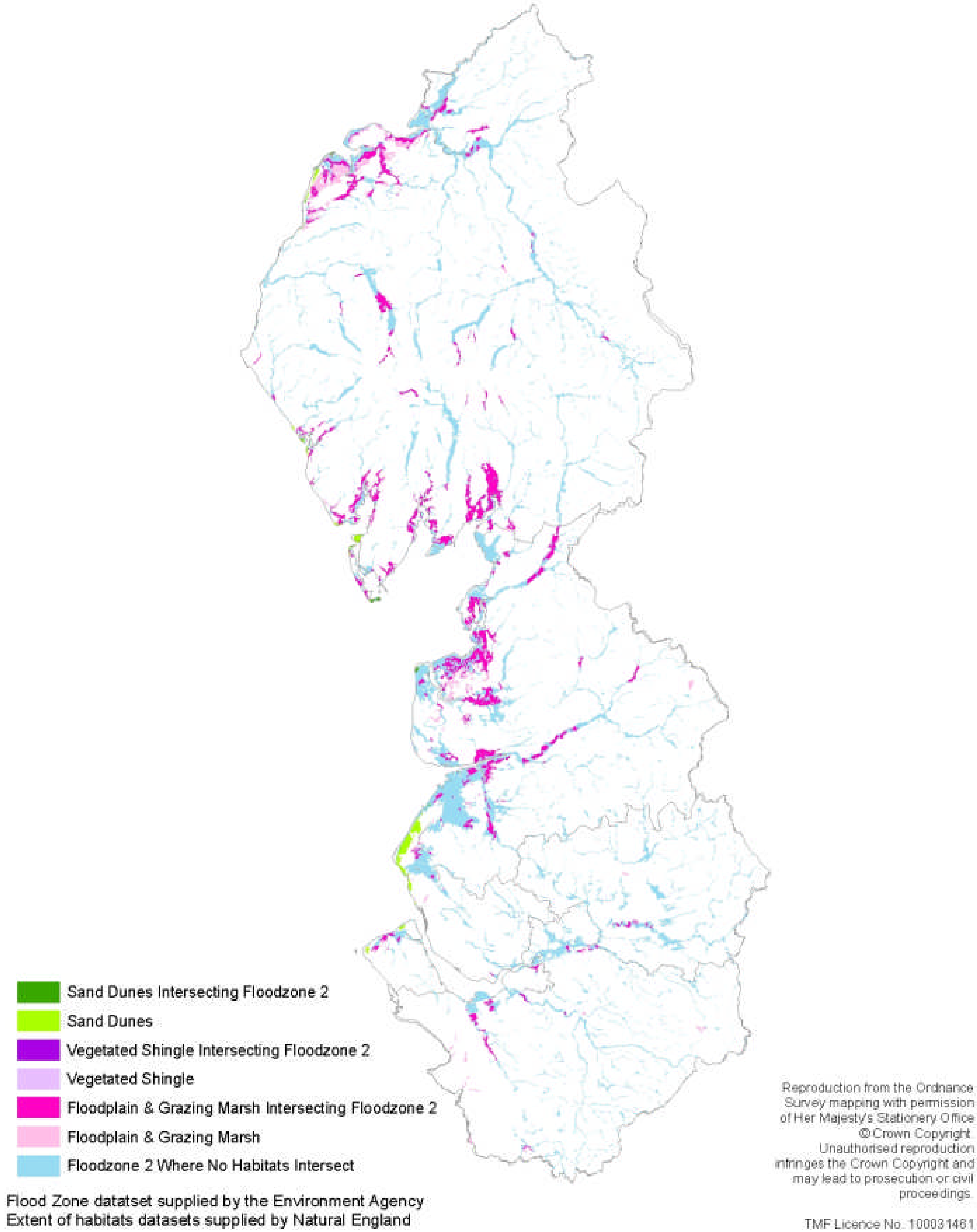
- Using a benefits transfer of willingness to pay values, it is estimated that the possible (as opposed to actual) flood control and storm buffering benefits provided by a subset of England's habitats (coastal & floodplain grazing marsh; coastal sand dunes; coastal vegetated shingle; mudflats; saline lagoons) are worth £1.2 billion a year[36].

[78] Met Office (2008). Coastal Flooding Fact Sheet. www.metoffice.gov.uk/publications/brochures/coastal_flooding.pdf

[79] North West and North Wales Coastal Group (2009). North West England and North Wales Shoreline Management Plan – Consultation Draft. http://mycoastline.org/index.php?option=com_content&task=view&id=163&Itemid=149

[80] Habitats were identified from Haines-Young and Potschin (2008). England's Terrestrial Ecosystem Services and the Rationale for an Ecosystem Approach. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14751

Figure 17. Flood zone 2 and habitats that can help manage coastal flooding in the Northwest



4.2.4 Managing surface water

Using green infrastructure to manage surface water could help to address the following climate change impacts (from table 5):

- Increased flood risk from streams, rivers and sewers.

We are concerned here with managing water, particularly within urban areas, so as to reduce the risk of surface water and sewer flooding. This type of flooding is increasingly common, largely as a result of the increase in sealed surfaces within urban areas. This means that when rain reaches the ground it moves quickly across built surfaces and enters the sewers. During intense rainfall, the volume of water exceeds the capacity of the sewers and leads to flooding; in areas where there is a combined sewer system, the flood waters can include sewerage. It is anticipated that, as a result of more intense rainfall events, climate change will make such flooding even more common.

The Pitt Review found that surface water flooding was a major issue in the major flooding experienced in the UK in the summer of 2007 and that it will remain a significant problem in the future[71]. Whilst increasing the capacity of the sewers and other hard engineering solutions can help to tackle this problem, such solutions could be expensive. Soft engineering approaches, that manage water on the surface, are being given increasing attention; in particular, the use of sustainable urban drainage systems (SUDS)[81]. Green infrastructure can help to manage surface water as part of SUDS system. The Northwest's Regional Flood Risk Appraisal encourages the use of green infrastructure or open space to provide a sustainable drainage role where appropriate[82].

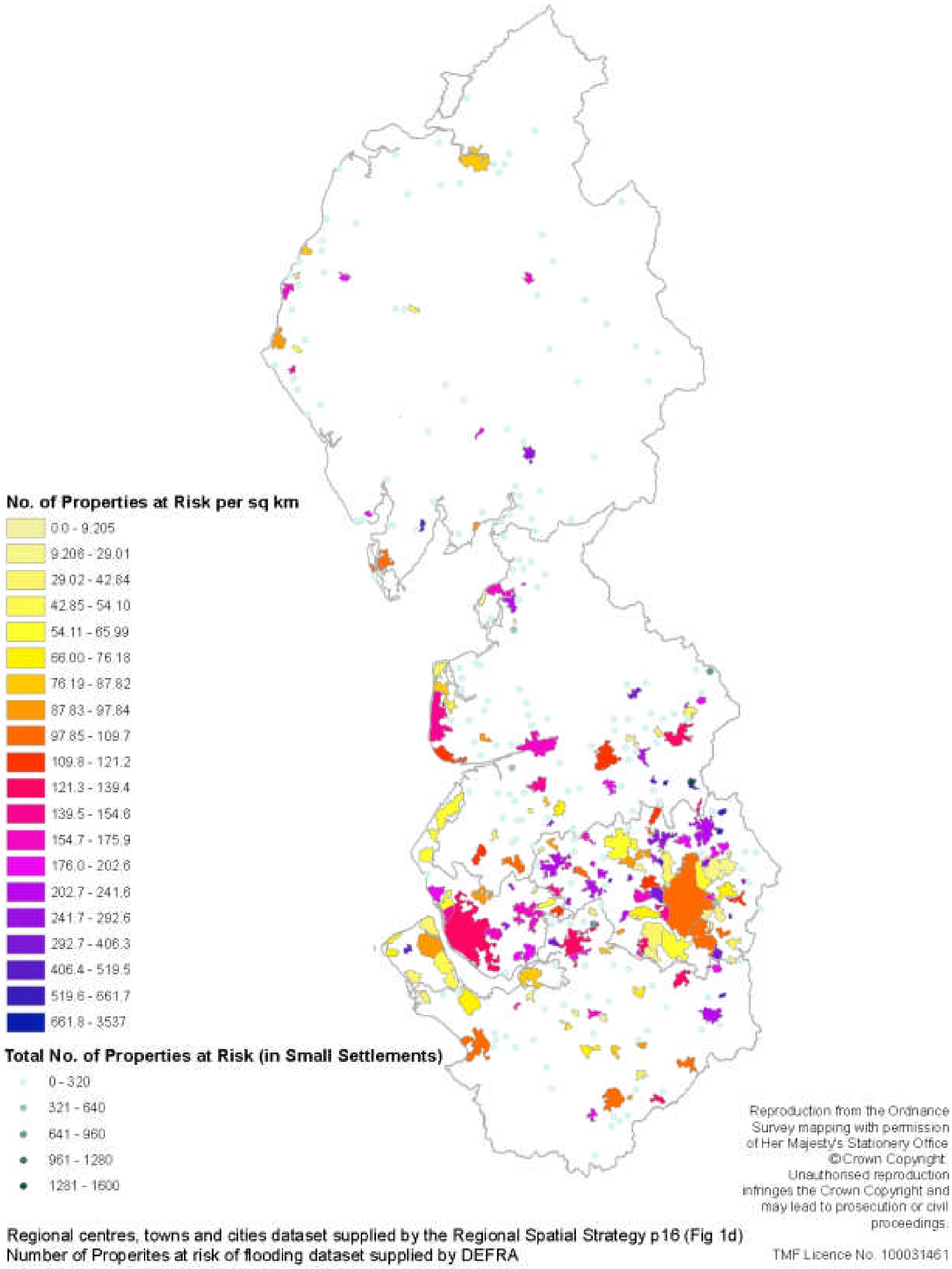
Vegetation intercepts rainwater before it reaches the ground; permeable surface allows it to infiltrate into the soil, rather than immediately being converted into surface water runoff; depressions in the ground can form temporary or permanent storage areas; and the roughness of the ground surface compared to a smooth paved surface slows down the speed at which water moves across it. This all reduces the volume and slows the rate of water entering the sewers, meaning that they are less likely to be overwhelmed. In addition, excess rainwater stored in depressions on the surface could then be used for other purposes such as irrigating vegetation; this then helps to manage surface water, water supply, and high temperatures.

Existing green infrastructure in urban areas should be *safeguarded* for managing surface water. This service should be *enhanced*, particularly in settlements at the greatest risk of surface water flooding (figure 18). This could be by increasing the functionality of the existing green infrastructure or by the creation of new green infrastructure.

- Modelling for Greater Manchester showed that a 10% increase in green cover can result in a 5% reduction in surface water run off[61].
- Where property holders avoid discharging surface water to the combined sewer network water companies provide a discount for wastewater bills. In the Northwest the discount is £35.33pa for residential properties and varies for commercial properties according to the 'chargeable area' (area of premises, discounting permeable areas), e.g. £918pa for a 0.15-0.3ha site and £15,313pa for a 2.5-5ha site[83].

[81] CIRIA (2007). The SUDS Manual. www.ciria.org.uk/suds/publications.htm
[82] 4NW (2008). Northwest Regional Spatial Strategy: Regional Flood Risk Appraisal. www.4nw.org.uk/downloads/documents/oct_08/nwra_1225456013_Final_Regional_Flood_Risk_Appr.pdf
[83] Genecon (2010). Green Infrastructure: Building Natural Value for Sustainable Economic Development. Valuation Toolbox: User Guide Draft V4.4.

Figure 18. Number of properties at risk of surface water flooding in the Northwest, normalised by area of the settlement[84]



84 www.defra.gov.uk/environment/flooding/documents/manage/surfacewater/sw-settlement-order.pdf; 'properties' includes all buildings with an address point, so this refers to residential, retail and business units.

4.2.5 Reducing soil erosion

Using green infrastructure to reduce soil erosion could help to address the following climate change impacts (from table 5):

- Greater soil erosion as the intensity of rainfall increases
- Pressures on vulnerable landscapes from increased visitors and soil erosion.

Some soils are more vulnerable to erosion than others, for example peat soils, soils on steep slopes and soils with limited vegetation cover[85]. Soil erosion can be exacerbated by some agricultural practices and visitor pressure.

Climate change could increase soil erosion as a result of more intense rainfall, and, if the climate is more favourable for outdoor recreation, increased visitor numbers and trampling could also increase erosion (this latter issue is covered in section 4.2.7).

Land cover and management can help to reduce soil erosion. For example, woodland has the potential to reduce soil erosion at source, limit the delivery of sediment to water courses, protect river banks from erosion, and encourage sediment deposition within the floodplain. Woodland provides this service as its canopy reduces the intensity of the rain when it reaches the ground, it acts as a windbreak, and its roots help to bind the soil together[86]. In this way, reducing soil erosion will also help to manage water supply as it reduces sediment in water courses, thereby improving water quality.

Green infrastructure needs to be *safeguarded* to help reduce soil erosion and *enhanced* to perform this service better in areas where soil erosion risk has been classified as very high and high (figure 19). This is especially important in upland areas[87], along the coast, and along the banks and floodplains of stream and rivers. It will be important in any area where soil is on a slope.

- It has been estimated from Local Authority data that the impacts on property and roads from soil erosion has cost UK society up to £30m/year in recent years[88].
- In a case study of the Bassenthwaite Lake catchment area existing woodland occupied 12% of the catchment. Only 1% of the high soil erosion vulnerability class was under woodland. Similarly, only 12% of the river length identified as highly vulnerable to bank erosion is occupied by riparian woodland[86].

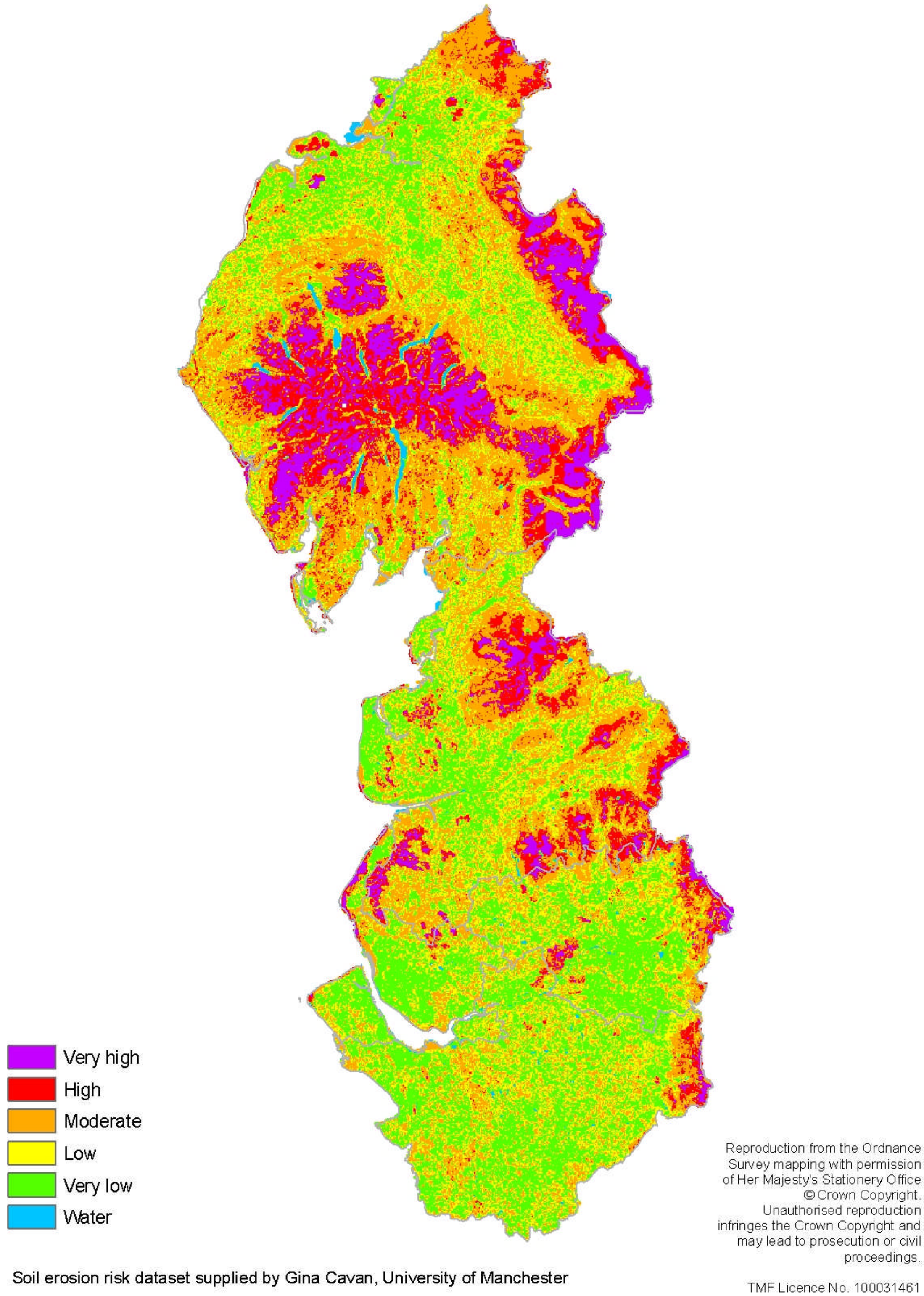
[85] DEFRA (2005). Controlling soil erosion: incorporating former advisory leaflets on grazing livestock, wind, outdoor pigs and the uplands. www.defra.gov.uk/environment/quality/land/soil/documents/soilerosion-combinedleaflets.pdf

[86] Nisbet *et al* (2004). A Guide to Using Woodland for Sediment Control. www.forestresearch.gov.uk/pdf/englandwoodlandforsedimentcontroljune04.pdf/$FILE/englandwoodlandforsedimentcontroljune04.pdf

[87] Natural England (2009). Responding to the impacts of climate change on the natural environment: The Cumbria high fells. http://naturalengland.etraderstores.com/NaturalEnglandShop/NE115

[88] Evans (1995). Soil Erosion and Land Use. Towards a Sustainable Policy. www.wwf.org.uk/filelibrary/pdf/soilerosionengwales.pdf

Figure 18. Soil erosion risk in the Northwest[89]



[89] Soil erosion risk here combines soil erodability (taking into account soil texture and slope), soil erosivity (taking into account precipitation and temperature) and land cover vulnerability. Presentation by Cavan *et al* on Climate change, tourism and landscape impacts: a regional analysis.

4.2.6 Helping other species to adapt

Using green infrastructure to help other species to adapt could help to address the following climate change impacts (from table 5):

- Ecological impacts from shifting patterns of agriculture
- Expansion northwards and upwards in the ranges of species (may be limited by habitat fragmentation and urban development, and species' dispersal ability)
- Loss of mudflats and salt marshes due to sea level rise and coastal squeeze between sea defences, disrupting internationally significant bird-feeding grounds
- Additional stress for remnant semi-natural habitats and loss of niche habitats in uplands
- Migration of species into the region.

As the climate changes, the range of species may shift northwards and upwards to higher altitudes as they seek new 'climate spaces'. A number of factors will limit their ability to do this, including their own dispersal ability and the nature of the landscape through which they are moving (i.e. the fragmentation of existing habitats and the permeability of the landscape between habitats)[90]. The management of linear features and corridors (e.g. river corridors, and road, railway and canal verges) for species movement may become increasingly important. Features oriented north-south may aid species movement, whereas east-west features could act as barriers unless appropriately designed[91].

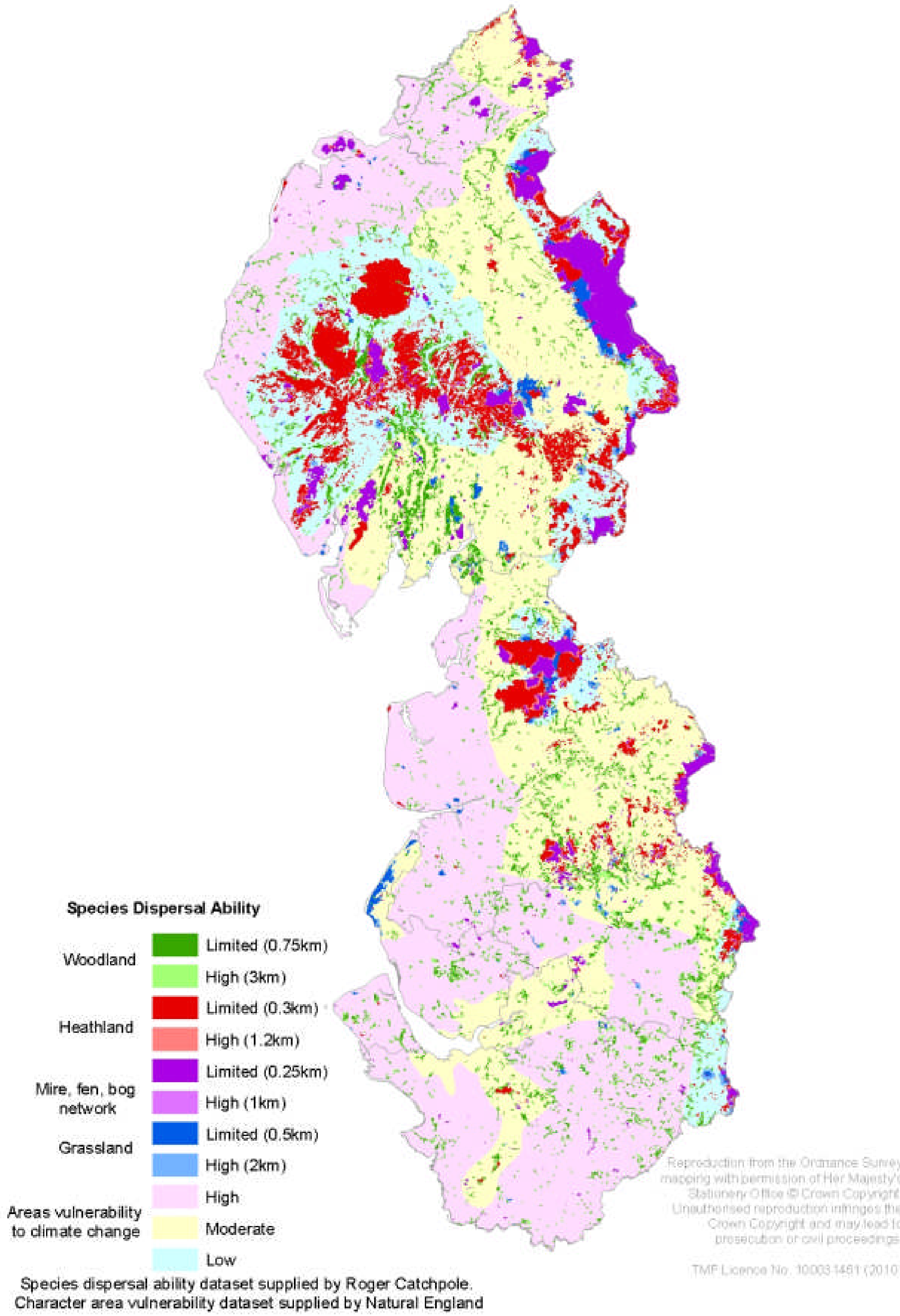
A recent study assessed and mapped the vulnerability of the Northwest's natural environment to climate change according to character areas. It found that our protected landscapes are often the most resilient, whilst areas of highest risk correspond with built up areas and act as a barrier to movement of species through the North West[92].

Green infrastructure can help other species to adapt to climate change as it provides existing habitats; these need to be *safeguarded*. In addition, the functionality of the wider landscape needs to be *enhanced* especially in the character areas mapped as having a high vulnerability to climate change (figure 20). This could be by creating new habitat to connect fragmented areas, or by increasing the wider landscape permeability through, for example, the planting of appropriate species and management of linear corridors.

- The cost of global biodiversity decline under a business-as-usual scenario is estimated to be as much €14 trillion by 2050 (7% of global GDP)[75].
- By 2080, out of the 32 species studied in the MONARCH programme, 15 are projected to gain substantial potential climate space with no significant loss, 8 will lose space with no significant gain, 3 show no significant gain or loss, and 6 both gain and lose potential climate space resulting in a northward shift[90].
- Biodiversity can have an economic value as a visitor attraction. Around 100,000 people visit the ospreys in the Lake District each season; a 2003 study found they spent £1.7m, of which £420,000 was directly attributable to the ospreys[93].
- The expected loss of biodiversity by 2050 is about 10-15% decline in the mean abundance of the original species of an ecosystem for all of the world's biomes[94].

[90] MONARCH (Modelling Natural Resource Responses to Climate Change) was a seven year phased programme to assess impacts of projected climate change on wildlife in Britain and Ireland. www.ukcip.org.uk/images/stories/Pub_pdfs/Monarch_summary.pdf
[91] Personal communication with Anna Gilchrist, University of Manchester.
[92] Natural England and NWDA (2010). An Assessment of the vulnerability of the Natural Environment in the North West to climate change at the National Character Area scale. Final draft version for circulation.
[93] http://www.ospreywatch.co.uk/downloads/nenwldopcasestudy.pdf
[94] The economics of ecosystems and biodiversity (2008). http://www.cbd.int/iyb/doc/prints/teeb-en.pdf

Figure 20. Species dispersal range for a variety of habitat networks across the Northwest[95]



[95] www.rogercatchpole.net. Some species are better able to move or disperse than others. For example, in this mapping it is assumed that a woodland species with a high dispersal ability could reach 3km from existing habitat, compared to only 0.75km for a woodland species with a low dispersal ability.

4.2.7 Managing visitor pressure

Using green infrastructure to manage visitor pressure could help to address the following climate change impacts (from table 5):

- Greater fire risk in upland areas due to drought and high temperatures
- Pressures on vulnerable landscapes from increased visitors and soil erosion
- New and expanding markets for some sectors, for example, for recreation and tourism
- Increase in outdoor-oriented lifestyles as a result of hotter, drier summers; bringing positive commercial, social and health impacts
- Increased coastal recreation will provide opportunities for coastal zone regeneration.

The Northwest has a thriving natural visitor economy[96], with much of the focus on the National Parks, including the Lake and Peak Districts. Natural tourism increases appreciation of the environment, yet it also places these environments under increased pressure.

Climate change could be positive for the Northwest visitor economy. Warmer, drier summers and an extended UK season, combined with a decreasing popularity of Mediterranean locations and increasingly hot urban areas, could lead to increased outdoor-based recreation and water-based activities. This might reduce carbon emissions from flights. Cumbria Tourism aspires to 'have an unrivalled reputation for outdoor adventure, heritage and culture with a year round programme of events' by 2018[97]. Some landscapes, such as the National Parks, the rural uplands and the coast, will be vulnerable both to climate change itself, as well as to the increased visitor pressure placed on them. Careful management will be needed to make the most of the opportunities provided by increased tourism whilst managing the potential adverse effects of increasing visitor pressure on these landscapes[96].

It is important to *safeguard* areas with a low or very low capacity to accommodate visitors, by carefully managing visitor pressure. Conversely, areas with a high or very high capacity to accommodate visitors could be *enhanced* as a tourism resource to divert pressure from more vulnerable landscapes. This is especially important within or close to urban areas, or near good public transport links, as this will also help reduce the need to travel by car (section 4.1.5) and thereby help mitigate climate change. Woodlands could provide a robust visitor attraction as they can accommodate a lot of users[96]. Woodlands have a high-recreational 'carrying capacity' and that this should be exploited[98]. Northwest examples include Grizedale and Whinlatter in the Lake District, Delamere Forest in Cheshire, and the emerging 'Forest Parks' in the Mersey Belt.

- The annual value of forests in the UK in terms of recreation and landscape value equates to some £400m; in the Northwest the value has been estimated at £35m[99].
- The total economic valuation of walking trips in England is estimated to be £3,158m per year. This activity is estimated to generate £742m in income (equivalent to GVA) per year[36].
- The environmental economy sustains 26% (or £2.8b) of the Northwest region's tourism sector with rural tourism supporting £0.7b[83].

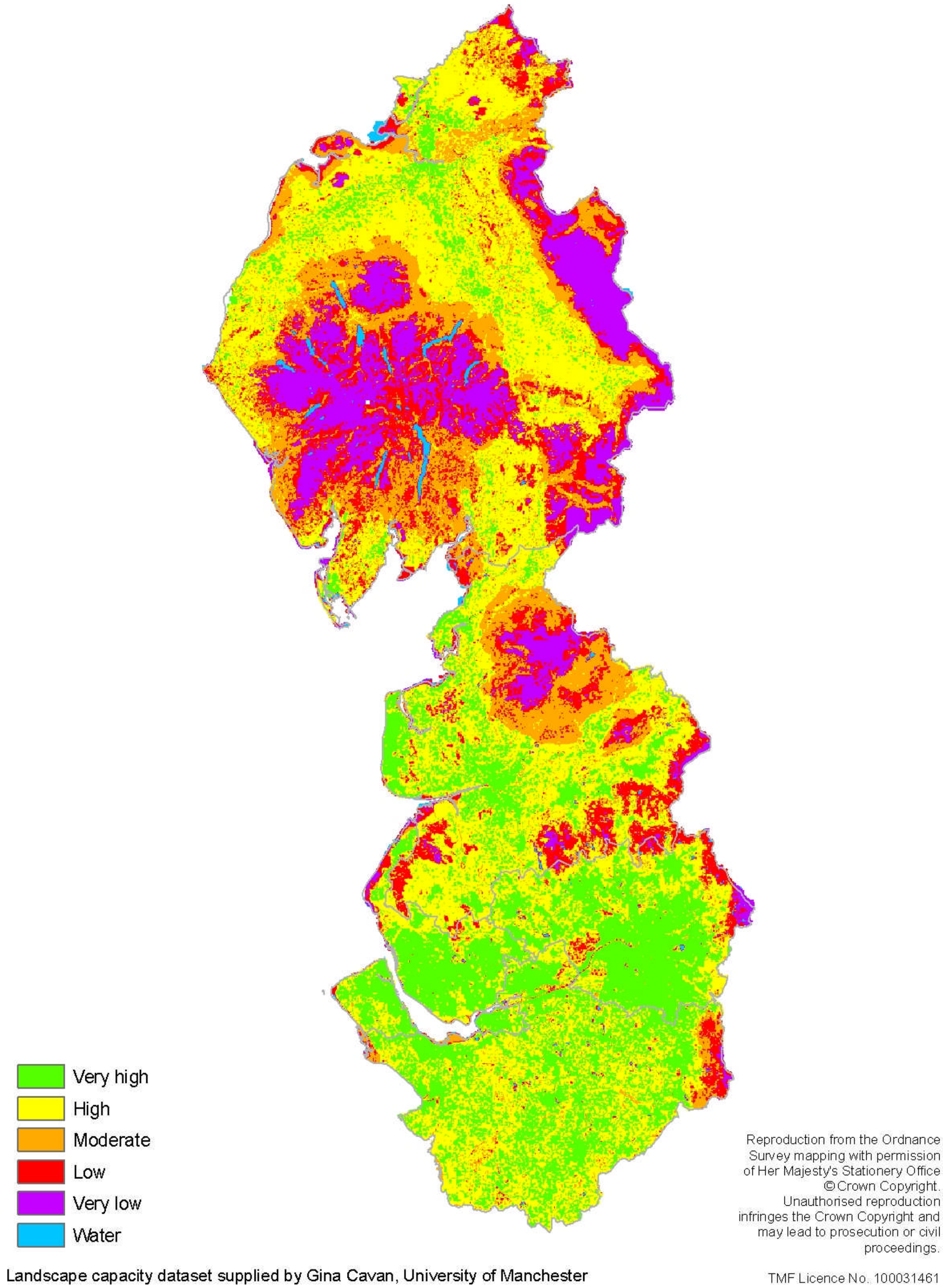
[96] McEvoy *et al* (2006). Climate Change and the Visitor Economy: the challenges and opportunities for England's Northwest. Sustainability Northwest and UKCIP.
www.snw.org.uk/tourism/downloads/CCVE_Challenges_And_Opportunities.pdf

[97] Making the Dream a Reality: The Tourism Strategy for Cumbria 2008 – 2018.
http://mediafiles.thedms.co.uk/Publication/CU-CTB/cms/pdf/tourism-strategy-2008-2018.pdf

[98] Forestry Commission (2007-2008). Corporate Plan: England and Great Britain Activities.
http://www.forestry.gov.uk/pdf/gbengcorp2007.pdf/$FILE/gbengcorp2007.pdf

[99] AMION (2008). The Economic Value of Green Infrastructure.
http://www.nwda.co.uk/PDF/EconomicValueofGreenInfrastructure.pdf

Figure 21. Capacity of the landscape to accommodate use by walkers in the Northwest[100]



[100] This map combines: landscape character sensitivity (using soil erosion vulnerability – see figure 19), visual sensitivity (using tranquillity), and landscape value (using designated sites). It does not take into account rights of way and access. Presentation by Cavan *et al* on Climate change, tourism and landscape impacts: a regional analysis.

5. Targeting where action is needed

5.1 Where each service is considered important

The previous section set out where each climate change service provided by green infrastructure is considered to be the most important across the Northwest; suggesting where each service should be *safeguarded* and where it should be *enhanced* (table 8). If a particular organisation was interested in only one (or a few) of these services, then table 8 (and the detail presented in section 4) would be a good place to start for targeting activity.

Table 8. Summary of where each climate change service provided by green infrastructure is most important in the Northwest; suggesting where to safeguard and enhance it

Service	Where to safeguard	Where to enhance
Carbon storage and sequestration	Highest density areas, e.g. where carbon density is greater than the regional average of 178 tC/ha	Everywhere
Fossil fuel substitution	Woodlands currently managed for biofuels production	Areas of high potential yields of miscanthus or short rotation coppice
Material substitution	Woodlands currently managed for timber production and local processing plants	Other existing woodlands could be brought into management for this purpose and new processing plants created
Food production	Best and most versatile agricultural land	Urban areas
Reducing the need to travel by car	Existing green walking and cycling routes and local recreation areas in and near (e.g. within 5 km of) urban areas	Improving and linking existing green walking and cycling routes and local recreation areas in and near (e.g. within 5 km of) urban areas
Managing high temperatures	In urban areas, especially where vulnerable people live, where green infrastructure levels are currently low, and where people congregate	In urban areas, especially where vulnerable people live, where green infrastructure levels are currently low, and where people congregate
Managing water supply	Areas where water is currently available	Areas where the water resource is over-licensed or over-abstracted
Managing riverine flooding	Within flood zones and strategic locations in the catchment, especially areas designated as 'policy option 6' within Catchment Flood Management Plans	Within flood zones and strategic locations in the catchment, especially areas designated as 'policy option 6' within Catchment Flood Management Plans
Managing coastal flooding	Existing coastal habitats which provide a natural buffer	Where natural flood defence / realignment is suitable
Managing surface water	Existing green infrastructure in urban areas	In settlements at the greatest risk of surface water flooding
Reducing soil erosion	Where soil erosion risk is high or very high	Where soil erosion risk is high or very high
Helping other species to adapt	Existing habitats	Around existing habitat taking into account species' dispersal ability. In landscape character areas assessed as having a high vulnerability to climate change. Increasing the permeability of the wider landscape and linear corridors
Managing visitor pressure	Low or very low capacity to accommodate visitors	High or very high capacity to accommodate visitors, especially where these are within or close to urban areas, or to good public transport links

This way of targeting is valid, yet it does not capture the multifunctional nature of green infrastructure and the multiple services it provides. If an organisation, interested in only one (or a few) of these services, targets activity specifically for this service then, at the very least, we would advocate that they also consider the other services that are also important in that area and take the opportunity offered by any intervention to maximise these services. This could be by working in partnership with other organisations which have a specific interest in these other services.

5.2 Where a number of services are considered important

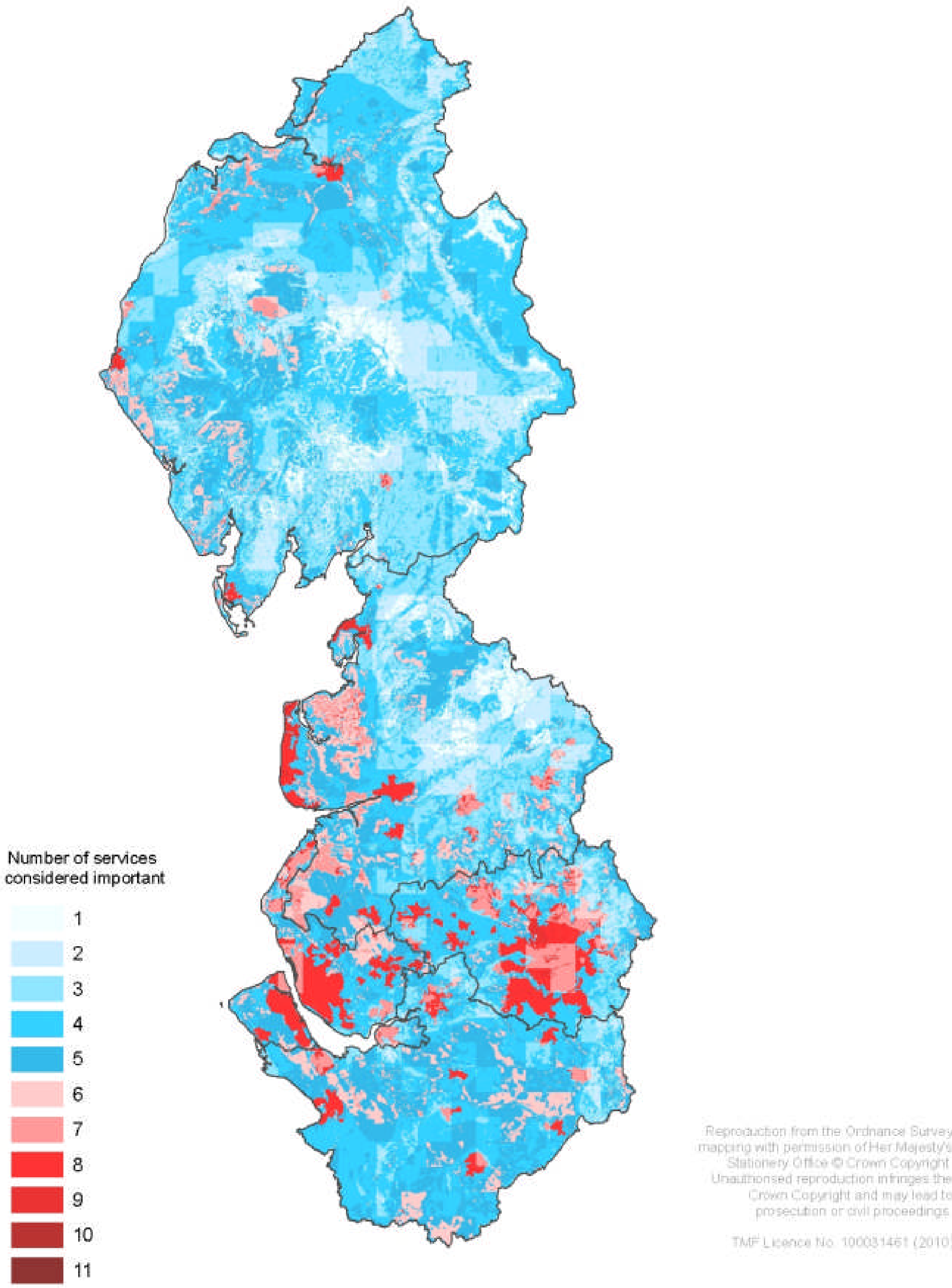
We have seen that green infrastructure provides a number of climate change services and that the areas where each of these are most important can overlap[101]. One way to target where investment in green infrastructure should take place is to focus on areas which are important for the greatest number of services (figure 22; see appendix B for sub-regional versions of this map). Any activity taking place should then seek to optimise the services considered important in that area. Perhaps unsurprisingly, urban areas tend to come out strongly as being important for the greatest number of climate change services.

The extent to which the services can be optimised in a given area will depend on their compatibility. Figure 23 attempts to compare each climate change services provided by green infrastructure alongside every other service and determine how compatible the two are (Appendix C sets out the reasoning behind theses scores). Whilst some services are considered to be generally incompatible with each other, many are considered to be generally compatible. The compatibility of the services on a given site often depends on considered and careful design and management. It should be possible to create and manage green infrastructure for more than one service; this is what tends to happen in practice.

Again, this way of targeting is valid. It will mean that investment in green infrastructure takes place in areas where it can perform the greatest number of services to help combat climate change. That said, it assumes that these services are all of equal importance to each other. In fact, some services may be considered to be of a higher priority than others; targeting areas which are important for the greatest number of services will disregard areas which are important for only a few services, yet those few could be of utmost priority.

[101] These areas will also be important for other, non-climate change related, benefits of green infrastructure. Considering these other benefits is beyond the scope of this report.

Figure 22. Number of services considered important[102, 103]



[102] This draws on information in table 8 where suitable datasets were available for each service. The following was not mapped in this instance: (a) Fossil fuel substitution – where to safeguard; (b) Material substitution – where to safeguard and enhance; (c) Managing water supply – where to safeguard and enhance.

[103] To view this map in more detail at a sub-regional level, see Appendix B.

Figure 23. Compatibility of climate change related services[104]

1. Carbon storage & sequestration	2. Fossil fuel substitution	3. Material substitution	4. Food production	5. Reducing the need to travel by car	6. Managing high temperatures	7. Managing water supply	8. Managing riverine flooding	9. Managing coastal flooding	10. Managing surface water	11. Reducing soil erosion	12. Helping other species to adapt	13. Managing visitor pressure	
	+	++	o	++	++	+	++	++	+	++	++	o	1. Carbon storage & sequestration
		o	--	o	o	-	o	o	o	o	o	o	2. Fossil fuel substitution
			--	o	o	-	o	o	o	o	o	o	3. Material substitution
				+	+	-	-	-	-	-	o	o	4. Food production
					++	+	++	+	+	-	+	++	5. Reducing the need to travel by car
						++	++	+	++	++	+	++	6. Managing high temperatures
							++	+	+	+	o	+	7. Managing water supply
								++	++	+	+	++	8. Managing riverine flooding
									++	+	+	++	9.Managing coastal flooding
										++	++	++	10. Managing surface water
											++	-	11. Reducing soil erosion
												-	12. Helping other species to adapt
													13. Managing visitor pressure

++	Generally compatible
+	
o	
-	
--	Generally incompatible

[104] This is based on the authors' best judgement. We welcome any comments on this matrix and intend to develop it further in the future, posting updates on www.ginw.co.uk/climatechange.

5.3 Where prioritised services are considered important

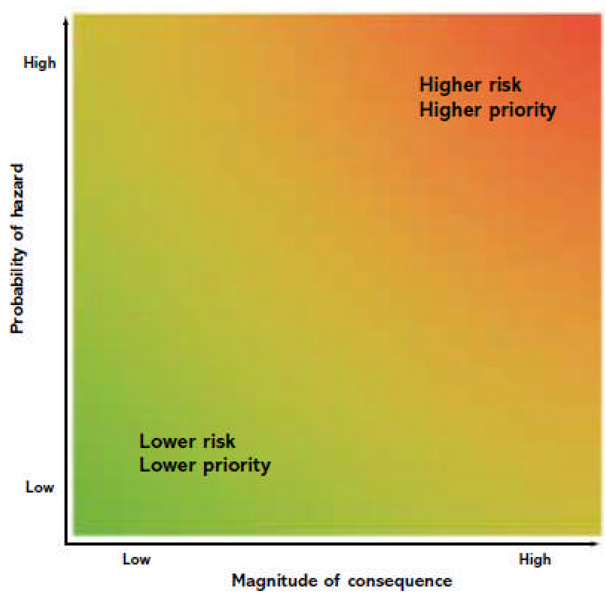
Some of the climate change related services identified may be considered to be of a higher priority than others. In practice it is very difficult to prioritise these services, especially when considering both mitigation and adaptation services side by side. However, we have attempted such a prioritisation using the following method[105]. This approach is useful as it helps to tease out some of the different factors to consider when prioritising. It provides a starting point for a wider regional and sub-regional discussion of the issues.

Each climate change related service is assigned 4 scores (see appendix D for the reasoning behind the scores) from 1-3 (1 being the lowest priority and 3 being the highest priority) which are then summed to give the priority ranking (table 9). The scores relate to:

(a) The need for mitigation or adaptation – This is prioritising the need for action. For adaptation services we consider the climate change impacts that the service addresses (section 4.2). We use a risk-based approach (figure 24) to determine two scores for probability and magnitude.

i. *Probability* – A score of 3 is where a hazard is considered the most likely, whereas 1 is less likely.
ii. *Magnitude* – A score of 3 is where the impacts are considered the most severe, whereas 1 is less severe.

Figure 24. An approach for prioritising according to risk[106]



(b) The potential for green infrastructure as a solution – This is prioritising the potential for green infrastructure to provide a mitigation or adaptation solution by assigning two scores the

[105] This method is adapted from the COAP (Climate Outcomes, Adaptation Potential) index used by Cavan *et al* (2009). Supermarket Adaptation to Future Environments. University of Manchester. www.sci.manchester.ac.uk/medialibrary/SAFE_Final_Jan09_reduced.pdf
[106] Willows and Connell (eds.) (2003). Climate Adaptation: Risk, Uncertainty and Decision Making. UKCIP Technical Report. www.ukcip.org.uk/images/stories/Pub_pdfs/Risk.pdf

first for how effective a green infrastructure solution is, and the second for how practical a green infrastructure solution is.

iii. *Effectiveness* – A score of 3 is where green infrastructure provides a highly effective solution, whereas 1 indicates a less effective solution.

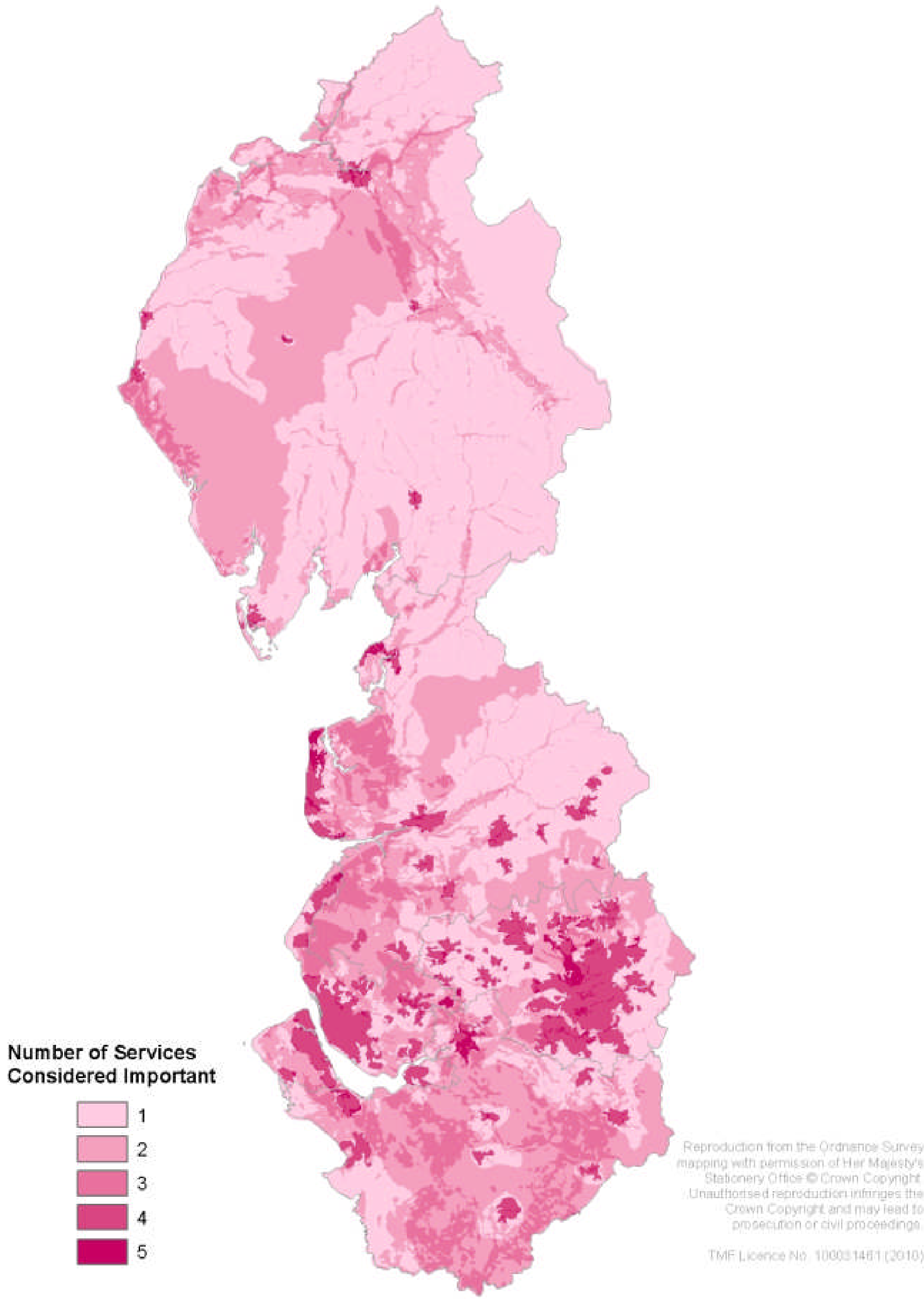
iv. *Practicality* – This takes into account issues of cost, feasibility, land requirements, public perception, etc. A score of 3 is a highly practical solution, whereas 1 indicates a less practical solution.

Table 9. Prioritised climate change services provided by green infrastructure (see appendix D for the reasoning behind the scores)

Service	Need for mitigation / adaptation		Potential for green infrastructure as a solution		Final Score
	Probability	Magnitude	Effectiveness	Practicality	
Managing surface water	3	3	3	3	12
Managing high temperatures	2	3	3	3	11
Carbon storage and sequestration	3	3	3	2	11
Managing riverine flooding	3	3	2	2	10
Food production	3	3	2	2	10
Material substitution	3	3	2	1	9
Fossil fuel substitution	3	3	2	1	9
Reducing the need to travel by car	3	3	1	2	9
Helping other species to adapt	2	2	2	2	8
Managing visitor pressure	1	1	2	3	7
Reducing soil erosion	1	1	3	2	7
Managing water supply	2	2	1	2	7
Managing coastal flooding	1	2	2	1	6

Table 9 suggests that the priority services for using green infrastructure to combat climate change are managing surface water, managing high temperatures, carbon storage and sequestration, managing riverine flooding, and food production. Areas where these services are considered to be the most important could be targeted for action (figure 25; see appendix B for sub-regional versions of this map). Urban areas and floodplains tend to come out as important for the priority services. We would strongly advocate that interventions in these areas should also consider the non-priority services that are important there and take the opportunity offered by any intervention to maximise these. It could be that these services are highly compatible with, or the intervention could be designed and managed to be compatible with, the priority service (section 5.2).

Figure 25. Number of priority services considered important[107, 108]

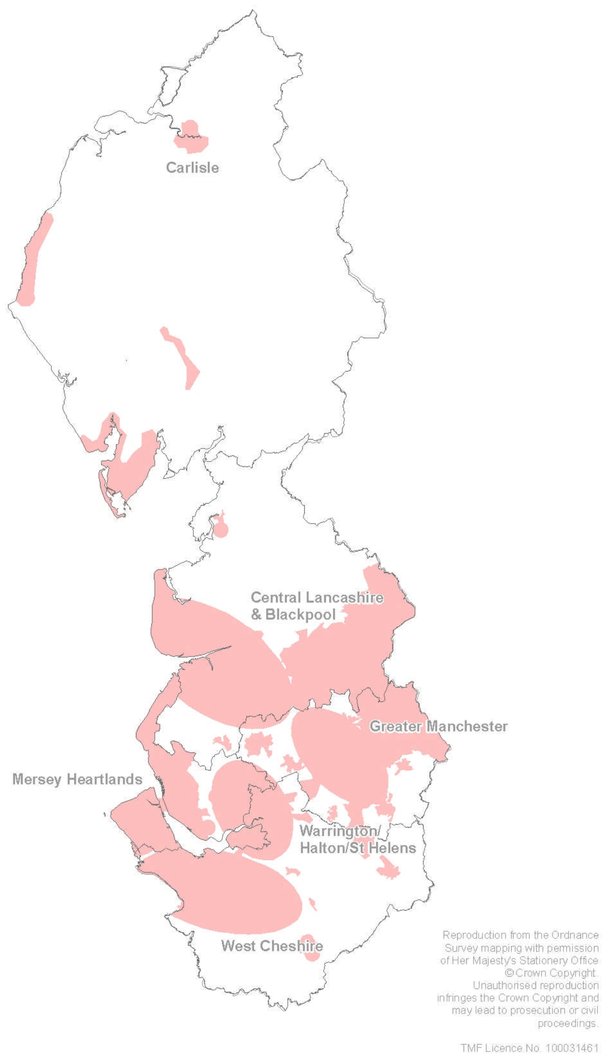


[107] The priority services mapped are managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding and food production. The mapping, as in figure 22, draws on information in table 8.
[108] To view this map in more detail at a sub-regional level, see Appendix B.

5.4 Where change or investment is taking place

In practice, there is a good deal of structural change, new development and investment taking place across the Northwest (figure 26). This is a crucial opportunity to increase the functionality of green infrastructure, including the climate change related services it provides. This is especially important given the long lifetime of the built environment. Such investment and changes must *safeguard* and *enhance* climate change services considered important for an area. This should help to ensure that the development itself helps to mitigate and is well adapted to climate change[109]. It should also ensure that opportunities are taken which help wider society to mitigate and adapt to climate change.

Figure 26. Areas which may experience restructuring and new development over the next 3-5 years[110]



[109] Northwest Green Infrastructure Unit (2008). Green Infrastructure Solutions to Pinch Point Issues in Northwest England. www.ginw.co.uk/resources/Exec_sum_23rd_March_lores.pdf

[110] Includes growth point partnerships, housing market renewal areas, regional town centres, areas of regionally specific economic investment, and strand 1 areas. Data drawn from: Natural Economy Northwest (2008). The policy framework for Green Infrastructure in England's Northwest (as of December 2007) and the opportunities for Green Infrastructure to contribute to sub-regional economic growth. www.naturaleconomynorthwest.co.uk/resources+reports.php

6. Using the information in the report

This report has explored how and where green infrastructure can help the Northwest to both mitigate and adapt to climate change. It is intended to raise awareness in the Northwest of the climate change services that green infrastructure can provide, and to start to target where these may be considered to be the most important; highlighting that it may be possible to get multiple services from the same piece of land and the need to take opportunities as they arise to do this.

There is a wealth of information held in this report, including regional scale mapping. At this scale broad conclusions about areas where the climate change services of green infrastructure are most important can be made as a way of targeting and getting more out of regional interventions. Whilst maps at this scale are useful, decision makers may also need to interrogate them at a finer resolution. Appendix B includes mapping and analysis of the data for the sub-regions of the Northwest, including lists at a ward level of potential areas to target intervention. It also includes some local scale mapping, for example for Liverpool Knowledge Quarter. Due to the datasets used the maps become coarser at local scales, where they should be used as a starting point and supplemented by more detailed local data and knowledge[111]. Although it is currently outside the remit of this work, the mapping could be further developed as an interactive online tool, allowing decision makers to interrogate it at their chosen level.

At a regional level, this report will be used to help develop a forthcoming action plan, which will set out green infrastructure actions to be taken to mitigate and adapt to climate change. This should set out green infrastructure actions to be taken for each climate change service, where these should be taken, delivery mechanisms and organisations who could lead on each.

[111] Please refer to www.ginw.co.uk/climatechange for the latest mapping and to contact us to discuss the presentation of more detailed mapping for selected areas.

Appendix A. Supporting evidence for the services

Below is a list of evidence for each service identified in the report. It was compiled in October 2009 from www.ginw.co.uk/climatechange/search_start.php. This searchable evidence base continues to be updated and should be referred to for an updated list of supporting information.

Carbon storage and sequestration

RESEARCH	Date	Author/Organisation
International		
ForeStClim Trans-national forestry management strategies in response to regional climate change impacts	2008	ForeStClim
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Adapt or die: Climate change and woodland	2006	Woodland Trust
Climate change and British woodland	2005	Forestry Commission
Carbon in the vegetation and soils of Great Britain	1997	Milne & Brown
Climate change and British woodland	2005	Forestry Commission
Climate regulation by carbon storage and sequestration	2008	Natural England
Code of good practice for forest carbon projects	2009	Forestry Commission
Forests, carbon and climate change: The UK contribution	2003	Forestry Commission
Natural England research report: Carbon management by land and marine managers	2008	Natural England
The essential role of green infrastructure: Eco-towns green infrastructure worksheet - Advice to promoters and planners	2008	TCPA
Trees and climate change information pack	2009	Forestry Commission
Regional		
Assessment of potential of carbon saving achievable in the Northwest region by 2020	2008	4NW
Climate change in the Northwest: A summary document	2005	Sustainability Northwest
Green infrastructure solutions to pinch point issues in Northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Restoring floodplain woodland for flood alleviation	2008	DEFRA
Re-engaging with the land: Our most precious asset	2008	NWDA
The economic value of green infrastructure	2008	Natural Economy Northwest
Sub/city-regional		
Ecocities	2009	University of Manchester
Opportunity mapping for woodland to reduce flooding in the Yorkshire and Humber region	2009	Forest Research
Local		
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	Date	Author/Organisation
International		
EU white paper: Adapting to climate change - Towards a European framework for action	2009	European Commission
National		
Adapting to climate change in England: A framework for action	2008	DEFRA
Be aware, be prepared, take action: How to integrate climate change adaptation strategies into local government	2008	Environment Agency
Biodiversity by design: A guide to sustainable communities	2004	TCPA
Climate change policy	2008	Natural England
Climate change: Adapting for tomorrow	2009	Environment Agency
Conserving biodiversity in a changing climate: Guidance on building capacity to adapt	2007	DEFRA
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Green infrastructure: Connected and multi-functional landscapes	2009	Landscape Institute
Heatwave plan for England: protecting health and reducing harm from extreme heat and heatwaves	2009	DOH

Landscape Architecture and the challenge of climate change	2008	Landscape Institute
The UK low carbon transition plan: national strategy for climate and energy	2009	DECC
Regional		
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Rising to the challenge: A climate change action plan for the Northwest	2006	NWDA
Sub/city regional		
The London climate change adaptation strategy: Draft report	2008	Greater London Authority
Local		
The Weaver valley climate change action plan	2008	The Mersey Forest

DELIVERY	**Date**	**Author/Organisation**
National		
Woodland carbon project	2009	Woodland Trust
Regional		
Foundation: the Northwest climate fund	2009	NWDA
Sub/city-regional		
Garden for a living London	2008	London Wildlife Trust
Green Streets: Greater Manchester	2001	Red Rose Forest
Green Streets: Merseyside	2007	The Mersey Forest

Fossil fuel substitution

RESEARCH	**Date**	**Author/Organisation**
International		
ForeStClim: Trans-national forestry management strategies in response to regional climate change impacts	2008	ForeStClim
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Climate change and British Woodland	2005	Forestry Commission
Forests, carbon and climate change: The UK contribution	2003	Forestry Commission
Hallmarks of a sustainable city	2009	CABE
Natural England research report: Carbon management by land and marine managers	2008	Natural England
Stern Review: Economics of climate change	2006	Stern
The essential role of green infrastructure: Eco-towns green infrastructure worksheet - Advice to promoters and planners	2008	TCPA
Regional		
Assessment of potential carbon savings achievable in the Northwest region by 2020	2008	4NW
Green infrastructure solutions to pinch point issues in Northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Of chips and logs… Making the most of arboricultural arisings in the Mersey Belt	2006	Red Rose Forest and The Mersey Forest
Re-engaging with the land: Our most precious asset	2008	NWDA
The economic value of green infrastructure	2008	Natural Economy Northwest
Local		
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	**Date**	**Author/Organisation**
National		
A strategy for England's woods, trees and forests	2007	DEFRA
England's trees, woods and forests: A delivery plan 2008 – 2012	2008	Forestry Commission
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Green infrastructure: Connected and multi-functional landscapes	2009	Landscape Institute
Regional		
Northwest regional coastal strategy	2008	Northwest Coastal Forum
Northwest England biomass wood fuel strategy		Northwest Regional Forestry Framework

Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Regional forestry framework for England's northwest: Agenda for Growth	2005	Forestry Commission
Sub/city-regional		
The Mersey Forest Plan	2001	The Mersey Forest
Local		
The Weaver Valley climate change action plan	2008	The Mersey Forest

DELIVERY	Date	Author/Organisation
National		
Green day: Climate change activity kit for schools	2009	CABE
Regional		
Foundation: northwest climate fund	2009	NWDA
Local		
The Nottingham declaration	2009	Energy Saving Trust

Material substitution

RESEARCH	Date	Author/Organisation
International		
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Climate change and British woodland	2005	Forestry Commission
Forests, carbon and climate change: the UK contribution	2003	Forestry Commission
Natural England research report: Carbon management by land and marine managers	2008	Natural England
Stern Review: The economics of climate change	2006	Stern
Trees and climate change information pack	2009	Forestry Commission
Regional		
Re-engaging with the land: Our most precious asset	2008	NWDA
Local		
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	Date	Author/Organisation
National		
A strategy for England's trees, woods and forests	2007	DEFRA
England's trees, woods and forests: A delivery plan 2008 – 2012	2008	Forestry Commission
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Landscape architecture and the challenge of climate change	2008	Landscape Institute
Regional		
Northwest Regional economic strategy	2006	NWDA
The regional forestry framework for England's northwest: Agenda for growth	2005	Forestry Commission
Sub/city-regional		
The Mersey Forest plan	2001	The Mersey Forest

Food production

RESEARCH	Date	Author/Organisation
International		
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Hallmarks of a sustainable city	2009	CABE
Natural England Research Report: Carbon management by land marine managers	2008	Natural England
Stern Review: Economics of climate change	2006	Stern
Regional		
Climate change and the visitor economy: Challenges and opportunities for England's northwest	2006	McEvoy *et al*.
GI solutions to pinch point issues in northwest England: How can GI	2008	The Mersey Forest

enable sustainable development		
Re-engaging with the land: Our most precious asset	2008	NWDA
Local		
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	**Date**	**Author/Organisation**
National		
Appraisal of flood and coastal erosion risk management	2009	DEFRA
Green Infrastructure: connected and multi functional landscapes	2009	Landscape Institute
Landscape architecture and the challenge of climate change	2008	Landscape Institute
Regional		
Climate change and agriculture in northwest England: Impacts, adaptations and mitigations	2008	Environment Agency
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional delivery plan: Sustainable farming and food strategy	2003	GONW
Sub/city-regional		
Leading to a greener London: An environment programme for the capital	2009	Greater London Authority
Local		
The Weaver Valley climate change action plan	2008	The Mersey Forest

DELIVERY	**Date**	**Author/Organisation**
National		
Green day: Climate change activity kit for schools	2009	CABE
National indicators for local authorities and local authority partnerships	2007	DEFRA

Reducing the need to travel by car

RESEARCH	**Date**	**Author/Organisation**
National		
Adaptation and Resilience in a changing climate	2009	UKCIP
Carbon regulation by carbon storage and sequestration	2008	Natural England
Hallmarks of a sustainable city	2009	CABE
Health effects of climate change in the UK	2002	DOH
The essential role of green infrastructure: Ecotowns green infrastructure worksheet: Advice to promoters and planners	2008	TCPA
Regional		
Assessment of potential carbon savings achievable in the Northwest region by 2020	2008	4NW
Climate change and the visitor economy: Challenges and opportunities for England's Northwest	2006	McEvoy *et al*.
Green infrastructure solutions to pinch point issues in northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit

POLICY	**Date**	**Author/Organisation**
National		
Biodiversity by design: A guide to sustainable communities	2004	TCPA
Climate change policy	2008	Natural England
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Green infrastructure: connected and multifunctional landscapes	2009	Landscape Institute
PPG17: Planning for open space, sport and recreation	2002	DEFRA
PPS25: Planning for development and flood risk	2006	DEFRA
Securing the future: Delivering UK sustainable development strategy	2005	DEFRA
Supplement to PPS1: Planning and climate change	2007	DEFRA
Towards a sustainable transport system: supporting economic growth in a low carbon world	2007	DFT
Winning a tourism strategy for 2012 and beyond	2007	DCMS
Regional		

Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional economic strategy	2006	NWDA
Sub/city-regional		
Leading to a greener London: An environmental programme for the capital	2009	Greater London Authority
The Mersey Forest plan	2001	The Mersey Forest
Local		
The Weaver Valley climate change action plan	2008	The Mersey Forest

DELIVERY	Date	Author/Organisation
National		
Green day: Climate change activity kit for schools	2009	CABE
Sustrans annual review	2008	Sustrans
Regional		
Economic and Regenerative Value of the Natural Environment	2003	NWDA
Foundation: The Northwest climate fund	2009	NWDA
Local		
The Nottingham declaration	2009	Energy Saving Trust

Managing high temperatures

RESEARCH	Date	Author/Organisation
International		
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Adaptation and Resilience in a changing climate	2009	UKCIP
Climate change adaptation by design: A guide for sustainable communities	2007	TCPA
Climate change and British woodland	2005	Forestry Commission
Green infrastructure report to the royal commission on environmental pollution	2006	Royal Commission on Environmental Pollution
Hallmarks of a sustainable city	2009	CABE
Health effects of climate change in the UK 2002	2002	DOH
Public space lessons: Adapting public space for climate change	2009	CABE
Supermarket adaptation to future environments	2009	University of Manchester
The essential role of green infrastructure: Ecotowns green infrastructure worksheet: A guide for promoters and planners	2008	TCPA
The urban environment	2007	Royal Commission on Environment Pollution
Trees and climate change information pack	2009	Forestry Commission
Regional		
Assessment of potential of carbon savings achievable in the Northwest region by 2020	2008	4NW
Climate change and the visitor economy: Challenges and opportunities for England's northwest	2006	McEvoy *et al*.
Climate change impacts and responses for key business sectors and public services in the Northwest	2009	Arup
Green infrastructure solutions to pinch point issues in northwest England: How green infrastructure can enable sustainable development	2008	The Mersey Forest
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
The economic value of green infrastructure	2008	Natural Economy Northwest
Sub/city-regional		
A review of roof greening in Greater Manchester	2007	Natural Economy Northwest
Adapting cities for climate change: The role of green infrastructure	2007	University of Manchester
City cooling development proposal		Environment Agency
Crazy paving: The environmental importance of London's front gardens	2005	Greater London Authority
Ecocities	2009	University of Manchester
Sustainable cities website: Green infrastructure pages	2009	CABE

Local		
Benefits and well being perceived by people visiting green spaces in periods of heat stress	2009	Lafortezza *et al.*
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	Date	Author/Organisation
National		
Adapting to climate change in England: A framework for action	2008	DEFRA
Be aware, be prepared, take action: How to integrate climate change adaptation strategies into local government	2008	Environment Agency
Biodiversity by design a guide for sustainable communities	2004	TCPA
Climate change policy	2008	Natural England
Climate change: Adapting for tomorrow	2009	Environment Agency
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Green infrastructure: connected and multifunctional landscapes	2009	Landscape Institute
Guidance for local authorities for implementing biodiversity duty	2007	DEFRA
Heat wave plan for England: Protecting health and reducing harm from extreme heat and heat waves	2009	DOH
Landscape architecture and the challenge of climate change	2008	Landscape Institute
Supplement to PPS1: Planning and climate change	2007	DEFRA
The UK low carbon transition plan: National strategy for climate and energy	2009	DECC
Regional		
Climate change and agriculture in Northwest England: Impacts adaptations and mitigations	2008	Environment Agency
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Sub/city-regional		
Leading to a greener London: An environment programme for the capital	2009	Greater London Authority
London: Adapting to climate change: Creating natural resilience	2009	London Climate Change Partnership
No trees, no future: Trees in the urban realm	2008	Trees and Design Action Group
The London climate change adaptation strategy: Draft report	2008	Greater London Authority
Local		
The Weaver Valley climate change action plan	2008	The Mersey Forest

DELIVERY	Date	Author/Organisation
National		
Adapting to climate change: A checklist for development: Guidance on designing developments in a changing climate	2005	London Climate Change Partnership
Natural indicators for local authorities and local authority partnerships	2007	DEFRA
Right tree, right place website	2009	Arbor Day Foundation
Woodland carbon project	2009	Woodland Trust
Sub/city-regional		
Berlin digital environmental atlas	2005	Senate Department for Urban Development, Berlin
Chiswick park, west London	1999	CABE
Garden for a living London	2008	London Wildlife Trust
Green alleys, Chicago	2008	CABE
Green streets, Greater Manchester	2001	Red Rose Forest
Green streets, Merseyside	2007	The Mersey Forest
Green streets, Portland	2005	CABE
iTrees	2008	Manchester City Council
Local		
Chavasse park, Liverpool	2000	BDP

Managing water supply

RESEARCH	Date	Author/Organisation

International		
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Adaptation and resilience in a changing climate	2009	UKCIP
Climate change adaptation by design: A guide for sustainable communities	2007	TCPA
Climate regulation by carbon storage and sequestration	2008	Natural England
Health effects of climate change in the UK	2008	DOH
The essential role of green infrastructure: Ecotowns green infrastructure worksheet: Advice for promoters and planners	2008	TCPA
The urban environment	2007	Royal Commission on Environmental Pollution
Regional		
Green infrastructure solutions to pinch point issues in northwest England: How green infrastructure can enable sustainable development	2008	The Mersey Forest
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
Restoring floodplain woodland for flood alleviation	2008	DEFRA
Sub/city-region		
Opportunity mapping for woodland to reduce flooding in the Yorkshire and Humber region	2009	Forest Research
Sustainable cities website: Green infrastructure web pages	2009	CABE
Sustainable management of urban rivers and floodplains	2002	Environment Agency
Local		
Benefits and well being perceived by people visiting green spaces in periods of heat stress	2009	Lafortezza *et al*.

POLICY	Date	Author/Organisation
International		
EU water framework directive 2000 EC	2000	European Commission
EU white paper adapting to climate change: Towards a European framework for action	2009	European Commission
National		
A strategy for England's trees, woods and forests	2007	DEFRA
Climate change policy	2008	Natural England
Climate change: Adapting for tomorrow	2009	Environment Agency
England's trees, woods and forests: Delivery plan 2008 – 2012	2008	Forestry Commission
Future water: The government's water strategy for England	2008	DEFRA
Green infrastructure: connected and multifunctional landscape	2009	Landscape Institute
Landscape architecture and the challenge of climate change	2008	Landscape Institute
PPS25 Development and flood risk	2006	DEFRA
Supplement to PPS1 Planning and climate change	2007	DEFRA
The UK low carbon transition plan: National strategy for climate and energy	2009	DECC
Regional		
Climate change and agriculture in Northwest England: Impacts, adaptations and mitigations	2008	Environment Agency
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Sub/city-regional		
London: Adapting to climate change: Creating natural resilience	2009	London Climate Change Partnership
The London climate change adaptation strategy: Draft report	2008	Greater London Authority

DELIVERY	Date	Author/Organisation
National		
Adapting to climate change: A checklist for development: guidance on designing developments in a changing climate	2005	London Climate Change Partnership
Woodland carbon project	2009	Woodland Trust
Sub/city regional		
Berlin digital environmental atlas	2005	Senate Department for

		Urban Development, Berlin
Chiswick park, West London	1999	CABE
Local		
The SUDS manual	2007	CIRIA

Managing riverine flooding

RESEARCH	Date	Author/Organisation
International		
ForeStClim: Trans-national forestry management strategies in response to Regional climate impacts	2008	ForeStClim
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
A guide to using woodlands for sediment control	2004	Forest Research
Adapt or die: Climate change and woodland	2006	Woodland Trust
Adaptation and resilience in a changing climate	2009	UKCIP
An assessment of the impact of floodplain woodland on flood flows	2006	Forest Research
Climate change adaptation by design: A guide for sustainable communities	2007	TCPA
Climate change and British woodland	2005	Forestry Commission
Combating climate change: A role for UK forests: A synthesis report	2009	Forestry Commission
Grey to green: How to shift funding and skills to green our cities	2009	CABE
Green Infrastructure report to Royal Commission on Environmental Pollution	2006	Royal Commission on Environmental Pollution
Hallmarks of a sustainable city	2009	CABE
Pitt Review: Learning lessons form the 2007 floods	2008	Pitt
Planning space for water	2008	University of Liverpool
Public opinion of forestry, 2009, UK	2009	Forestry Commission
Public space lessons: Adapting public space to climate change	2009	CABE
The essential role of green infrastructure: Ecotowns green infrastructure worksheet: Advice for promoters and planners	2008	TCPA
The urban environment	2007	Royal Commission on Environmental Pollution
Trees and climate change information pack	2009	Forestry Commission
Regional		
Climate change in the Northwest: A summary document	2005	Sustainability Northwest
Green infrastructure solutions to pinch point issues in Northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Nature's place for water: Working with nature to reduce flooding		Wildlife Trusts
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
Restoring floodplain woodland for flood alleviation	2008	DEFRA
Re-engaging with the land: Our most precious asset	2008	NWDA
The economic contributions of The Mersey Forest's objective one-funded investments	2009	Regeneris
The economic value of green infrastructure	2008	Natural Economy Northwest
Sub/city-region		
Greater Manchester green roof guidance	2009	NWDA
Opportunity mapping for woodland to reduce flooding in the Yorkshire and Humber region	2009	Forest Research
Sustainable cities website: Green infrastructure web pages	2009	CABE
Sustainable management of urban rivers and floodplains	2002	Environment Agency

POLICY	Date	Author/Organisation
International		
EU water framework directive	2000	European Commission
EU white paper: Adapting to climate change: Towards a European framework for action	2009	European Commission
National		
A strategy for England's trees, woods and forests	2007	DEFRA

A strategy for promoting an integrated approach to the management of coastal areas in England	2008	DEFRA
Adapting to climate change in England: A framework for action	2008	DEFRA
Adapting to climate change: Flooding and coastal erosion		Environment Agency
Appraisal of flood and coastal erosion risk management	2009	DEFRA
Be aware, be prepared, take action: How to integrate climate change adaptation strategies into local government	2008	Environment Agency
Biodiversity by design: A guide for sustainable communities	2004	TCPA
Climate change adapting for tomorrow	2009	Environment Agency
Conserving biodiversity in a changing climate: Guidance on building capacity to adapt	2007	DEFRA
England biodiversity strategy: Towards adaptation to climate change	2007	DEFRA
England's trees, woods and forests: Delivery plan 2008 – 2012	2008	Forestry Commission
Flooding in England a national assessment of flood risk	2009	Environment Agency
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Future water: The government's water strategy for England	2008	DEFRA
Green infrastructure: Connected and multi-functional landscapes	2009	Landscape Institute
Guidance for local authorities for implementing biodiversity duty	2007	DEFRA
PPS25 Development and flood risk: A practice guide	2008	DEFRA
PPS25 Development and flood risk	2006	DEFRA
Supplement to PPS1 Planning and climate change	2007	DEFRA
The UK low carbon transition plan: National strategy for climate and energy	2009	DECC
Regional		
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional delivery plan: Sustainable farming and food strategy	2003	GONW
Northwest regional spatial strategy: Regional flood risk appraisal	2008	4NW
Northwest regional economic strategy:	2006	NWDA
Rising to the Challenge: A climate change action plan for England's Northwest	2006	NWDA
Sub/city-regional		
Leading to a greener London: An environment programme for the capital	2009	Greater London Authority
London: Adapting to climate change: Creating natural resilience	2009	London Climate Change Partnership
The Lancashire climate change strategy 2009 - 2020	2009	London Climate Change Partnership
The London climate change adaptation strategy: Draft report	2008	Greater London Authority
Local		
The Weaver valley climate change action plan	2008	The Mersey Forest

DELIVERY	**Date**	**Author/Organisation**
National		
A living landscape: A call to restore the UK's battered ecosystems for wildlife and people	2008	The Wildlife Trust
Adapting to climate change: A checklist for development: Guidance for designing developments in a changing climate	2005	London Climate Change Partnership
National indicators for local authorities and local authority partnerships	2007	DEFRA
Wetland vision	2005	Environment Agency
Woodland carbon project	2009	Woodland Trust
Regional		
Economic and regenerative value of the natural environment	2003	NWDA
Sub/city-regional		
Berlin digital environmental atlas	2005	Senate Department for Urban Development, Berlin
Garden for a living London	2008	London Wildlife Trust
River Irwell flood control scheme	2005	CABE
Local		
Quaggy river, Lewisham	2000	CABE

Managing coastal flooding

RESEARCH	Date	Author/Organisation
International		
BRANCH project: Biodiversity requires action in North West Europe under a changing climate: Final Report	2009	Natural England
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Adaptation and resilience in a changing climate	2009	UKCIP
Climate change adaptation by design: A guide for sustainable communities	2007	TCPA
Grey to green: How to shift funding and skills to green our cities	2009	CABE
Health effects of climate change in the UK	2002	DOH
Pitt Review: Learning lessons form the 2007 floods.	2008	Pitt
Public opinion of forestry, 2009, UK	2009	Forestry Commission
The essential role of green infrastructure: Ecotowns green infrastructure worksheet: Advice for promoters and planners	2008	TCPA
Regional		
Climate change in the Northwest: A summary document	2005	Sustainability Northwest
Green infrastructure solutions to pinch point issues in Northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
The economic value of green infrastructure	2008	Natural Economy Northwest
Sub/city-region		
Sustainable cities website: Green infrastructure web pages	2009	CABE

POLICY	Date	Author/Organisation
International		
EU white paper: Adapting to climate change: Towards a European framework for action	2009	European Commission
National		
A strategy for England's trees, woods and forests	2007	DEFRA
A strategy for promoting an integrated approach to the management of coastal areas in England	2008	DEFRA
Adapting to climate change in England: A framework for action	2008	DEFRA
Adapting to climate change: Flooding and coastal erosion		Environment Agency
Appraisal of flood and coastal erosion risk management	2009	DEFRA
Be aware, be prepared, take action: How to integrate climate change adaptation strategies into local government	2008	Environment Agency
Climate change policy	2008	Natural England
Climate change, adapting for tomorrow	2009	Environment Agency
Conserving biodiversity in a changing climate: Guidance on building capacity to adapt	2007	DEFRA
England biodiversity strategy: Towards adaptation to climate change	2007	DEFRA
Flooding in England a national assessment of flood risk	2009	Environment Agency
Future water: The government's water strategy for England	2008	DEFRA
Green infrastructure: Connected and multi-functional landscapes	2009	Landscape Institute
Guidance for local authorities for implementing biodiversity duty	2007	DEFRA
Landscape architecture and the challenge of climate change	2008	Landscape Institute
PPS25 Development and flood risk: A practice guide	2008	DEFRA
PPS25 Development and flood risk	2006	DEFRA
Regional		
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional coastal strategy: Consultation draft	2008	Northwest Coastal Forum
Northwest regional delivery plan: Sustainable farming and food strategy	2003	GONW
Northwest regional economic strategy:	2006	NWDA
Rising to the Challenge: A climate change action plan for England's	2006	NWDA

Northwest		
Sub/city-regional		
The London climate change adaptation strategy: Draft report	2008	Greater London Authority
Local		
The Weaver valley climate change action plan	2008	The Mersey Forest

DELIVERY	Date	Author/Organisation
National		
A living landscape: A call to restore the UK's battered ecosystems for wildlife and people	2008	The Wildlife Trust
Adapting to climate change: A checklist for development: Guidance for designing developments in a changing climate	2005	London Climate Change Partnership
National indicators for local authorities and local authority partnerships	2007	DEFRA
Wetland vision	2005	Environment Agency

Managing surface water

RESEARCH	Date	Author/Organisation
International		
ForeStClim: Trans-national forestry management strategies in response to regional climate change impacts	2008	ForeStClim
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Adapt or die: Climate change and woodland	2006	Woodland Trust
Adaptation and resilience in a changing climate	2009	UKCIP
An assessment of the impact of floodplain woodland on flood flows	2006	Forest Research
Climate change adaptation by design: A guide for sustainable communities	2007	TCPA
Climate change and British woodland	2005	Forestry Commission
Combating climate change: A role for UK forests: The synthesis report	2009	Forestry Commission
Green infrastructure report to the Royal commission on Environmental Pollution	2006	Royal Commission on Environmental Pollution
Grey to green: How to shift funding and skills to green our cities	2009	CABE
Hallmarks of a sustainable city	2009	CABE
Pitt review: Learning lessons from the 2007 floods	2008	Pitt
Public opinion of forestry	2009	Forestry Commission
Public space lessons: Adapting public space to climate change	2009	CABE
Supermarket adaptation to future environments	2009	University of Manchester
The essential role of green infrastructure: Ecotowns and green infrastructure worksheet: Advice to promoters and planners	2008	TCPA
The green information gap: Mapping the nations greenspaces	2009	CABE
The urban environment	2007	Royal Commission on Environmental Pollution
Trees and climate change information pack	2009	Forestry Commission
Regional		
Climate change impacts and responses for key business sectors and public services in the Northwest	2009	Arup
Climate change in the Northwest: A summary document	2005	Sustainability Northwest
Nature's place for water: Working with nature to reduce flooding		Wildlife Trusts
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
The economic contributions of The Mersey Forest's objective one-funded investments	2009	Regeneris
The economic value of green infrastructure	2008	Natural Economy Northwest
Sub/city-regional		
A review of roof greening in Manchester	2007	Natural Economy Northwest
Adapting cities for climate change: The role of green infrastructure	2007	University of Manchester
Crazy paving: The environmental importance of London's front gardens	2005	Greater London Authority
Ecocities	2009	University of Manchester
Greater Manchester green roof guidance	2009	NWDA

Opportunity mapping for woodland to reduce flooding in the Yorkshire and Humber region	2009	Forest Research
Sustainable cities: Green infrastructure web pages	2009	CABE

POLICY	**Date**	**Author/Organisation**
International		
EU water framework directive	2000	European Commission
EU white paper: Adapting to climate change: Towards a European framework for action	2009	European Commission
National		
A strategy for England's trees, woods and forests	2007	DEFRA
A strategy for promoting an integrated approach to the management of coastal areas in England	2008	DEFRA
Adapting to climate change in England: A framework for action	2008	DEFRA
Adapting to climate change: Flooding and coastal erosion		Environment Agency
Biodiversity by design: A guide to sustainable communities	2004	TCPA
Climate change policy	2008	Natural England
Climate change adapting for tomorrow	2009	Environment Agency
Conserving biodiversity in a changing climate: Guidance on building capacity to adapt	2007	DEFRA
England biodiversity strategy: Towards adaptation to climate change	2007	DEFRA
England's trees, woods and forests delivery plan 2008 – 2012	2008	Forestry Commission
Flood and water management bill draft & consultation paper	2009	DEFRA
Flooding in England a national assessment of flood risk	2009	Environment Agency
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Future water: The government's water strategy for England	2008	DEFRA
Green infrastructure: Connected and multifunctional landscapes	2009	Landscape Institute
Guidance for local authorities for implementing biodiversity duty	2007	DEFRA
Guidance on permeable surfacing of front gardens	2009	DCLG
Landscape architecture and the challenge of climate change	2008	Landscape Institute
PPS25 Development and flood risk: A practice guide	2008	DEFRA
PPS25 Development and flood risk	2006	DEFRA
Supplement to PPS1 Planning and climate change	2007	DEFRA
The UK low carbon transition plan: National strategy for climate and energy	2009	DECC
Regional		
Climate change and agriculture in Northwest England: Impacts, adaptations and mitigations	2008	Environment Agency
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional spatial strategy flood risk appraisal	2008	4NW
Northwest regional economic strategy	2006	NWDA
Rising to the challenge: A climate change action plan for England's Northwest	2006	NWDA
Sub/city regional		
Leading to a greener London: An environment programme for the capital	2009	Greater London Authority
London adapting to climate change: creating natural resilience	2009	London Climate Change Partnership
No trees, no future: Trees in the urban realm	2008	Trees and Design Action Group
The Lancashire climate change strategy 2009-2020	2009	Lancashire Climate Change Partnership
The London climate change adaptation strategy: Draft report	2008	Greater London Authority
Local		
Code for sustainable homes: A step-change in sustainable home building practice	2006	DEFRA
The Weaver Valley climate change action plan	2008	The Mersey Forest

DELIVERY	**Date**	**Author/Organisation**
National		
A living landscape: A call to restore the UK's battered ecosystems for	2008	Wildlife Trusts

wildlife and people		
Adapting to climate change: A checklist for development: guidance on designing developments in a changing climate	2005	London Climate Change Partnership
National indicators for local authorities and local authority partnerships	2007	DCLG
Wetland vision	2005	Environment Agency
Woodland carbon project	2009	Woodland Trust
Regional		
Economic and regenerative value of the natural environment	2003	NWDA
Sub/city-regional		
Berlin digital environmental atlas	2005	Senate Department for Urban Development, Berlin
Chiswick park, west London	1999	CABE
Garden for a living London	2008	London Wildlife Trust
Green alleys, Chicago	2008	CABE
Green streets, Portland	2005	CABE
River Irwell flood control scheme	2005	CABE
Delivery: Local		
Chavasse Park, Liverpool	2000	BDP
The SUDS manual	2007	CIRIA

Reducing soil erosion

RESEARCH	Date	Author/Organisation
International		
ForeStClim: Trans-national forestry management strategies in response to regional climate change impacts	2008	ForeStClim
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
A guide to using woodlands for sediment control	2004	Forest Research
Adapt or die: Climate change and woodland	2006	Woodland Trust
Climate change adaptation by design: A guide for sustainable communities	2007	TCPA
Climate change and British woodland	2005	Forestry Commission
The urban environment	2007	Royal Commission on Environmental Pollution
Trees and climate change information pack	2009	Forestry Commission
Regional		
Climate change and the visitor economy: Challenges and opportunities for England's Northwest	2006	McEvoy *et al*.
Climate change in the Northwest: A summary document	2005	Sustainability Northwest
Green infrastructure solutions to pinch point issues in Northwest England: how can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
Sub/city-regional		
Sustainable cities website: Green infrastructure web pages	2009	CABE

POLICY	Date	Author/Organisation
International		
EU white paper: Adapting to climate change: Towards a European framework for action	2009	European Commission
National		
A strategy for England's trees, woods and forests	2007	DEFRA
Adapting to climate change in England: A framework for action	2008	DEFRA
Appraisal of flood and coastal erosion risk management	2009	DEFRA
Biodiversity by design: A guide to sustainable communities	2004	TCPA
Conserving biodiversity in a changing climate: Guidance on building capacity to adapt	2007	DEFRA
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Regional		

Climate change and agriculture in Northwest England: Impacts, adaptations and mitigations	2008	Environment Agency
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW

DELIVERY	**Date**	**Author/Organisation**
National		
Adapting to climate change: A checklist for development: Guidance on designing developments in a changing climate	2005	London Climate Change Partnership
Woodland carbon project	2009	Woodland Trust

Helping other species to adapt

RESEARCH	**Date**	**Author/Organisation**
International		
BRANCH Project: Biodiversity requires adaptation in Northwest Europe under a changing climate	2009	Natural England
ForeStClim: Trans-national forestry management strategies to regional climate change impacts	2008	ForeStClim
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Adapt or die: Climate change and woodland	2006	Woodland Trust
Climate change and biodiversity adaptation: the role of the spatial planning system	2009	Natural England
Green infrastructure report to the royal commission for environmental pollution	2006	Royal Commission on Environmental Pollution
Hallmarks of a sustainable city	2009	CABE
Modelling natural resource responses to climate change (MONARCH)	1999	UKCIP
Natural England research report NERR026: Carbon management by land and marine managers	2008	Natural England
Public space lessons: Adapting public space to climate change	2009	CABE
Supermarket adaptation to future environments	2009	University of Manchester
The essential role of green infrastructure: Ecotowns and green infrastructure worksheet: Advice to promoters and planners	2008	TCPA
The urban environment	2007	Royal Commission on Environmental Pollution
Trees and climate change information pack	2009	Forestry Commission
Regional		
Green infrastructure solutions to pinch point issues in Northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
Restoring floodplain woodland for flood alleviation	2008	DEFRA
Re-engaging with the land: Our most precious asset	2008	NWDA
The economic value of green infrastructure	2008	Natural Economy Northwest
Sub/city Regional		
A review of roof greening in Manchester	2007	Natural Economy Northwest
Crazy paving: The environmental importance of London's front gardens	2005	Greater London Authority
Ecocities	2009	University of Manchesterr
Opportunity mapping for woodland to reduce flooding in the Yorkshire and Humber region	2009	Forest Research
Sustainable cities website: green infrastructure web pages	2009	CABE
Sustainable management of urban rivers and floodplains	2002	Environment Agency
The Red Rose and Mersey community forest timber stations: demonstrating that high quality products can be made from local waste timber	2003	Red Rose Forest
Local		
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	Date	Author/Organisation
National		
A strategy for England's trees, woods and forests	2007	DEFRA
A strategy for promoting an integrated approach to the management of coastal areas in England	2008	DEFRA
Adapting to climate change in England: A Framework for action	2008	DEFRA
Appraisal of flood and coastal erosion risk management	2009	DEFRA
Be aware, be prepared, take action: How to integrate climate change adaptation strategies into local government	2008	Environment Agency
Biodiversity by design: A guide to sustainable communities	2004	TCPA
Climate change policy	2008	Natural England
Climate change adapting for tomorrow	2009	Environment Agency
Conserving biodiversity in a changing climate: guidance on building capacity adapt	2007	DEFRA
England's trees, woods and forests: Delivery plan 2008 – 2012	2008	Forestry Commission
Flooding in England a national assessment of flood risk	2009	Environment Agency
Forests and climate change guidelines: Consultation draft	2009	Forestry Commission
Green infrastructure connected and multi-functional landscapes: Landscape Institute position statement	2009	Landscape Institute
Guidance for local authorities for implementing biodiversity duty	2007	DEFRA
Landscape architecture and the challenge of climate change	2008	Landscape Institute
PPG17 Planning for open space, sport an recreation	2002	DEFRA
PPS9 Planning for biodiversity and geological conservation	2005	DEFRA
PPS25 Development and flood risk: A practice guide	2008	DEFRA
PPS25 Development and flood risk	2006	DEFRA
Supplement to PPS1 Planning and climate change	2007	DEFRA
Towards a sustainable transport system: Supporting economic growth in a low carbon world	2007	DFT
Regional		
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional coastal strategy: Consultation draft	2008	Northwest Coastal Forum
The regional forestry framework for England's Northwest: Agenda for growth	2005	Forestry Commission
Sub/city-region		
Leading to a greener London: An environment programme for the capital	2009	Greater London Authority
London: Adapting to climate change: Creating natural resilience	2009	London Climate Change Partnership
The London climate change adaptation strategy draft report	2008	Greater London Authority
The Mersey Forest plan	2001	The Mersey Forest
Local		
The Weaver valley climate change action plan	2008	The Mersey Forest

DELIVERY	Date	Author/Organisation
National		
A living landscape: A call to restore the UK's battered ecosystems for wildlife and people	2008	The Wildlife Trust
Green day: Climate change activity kit for schools	2009	CABE
National indicators for local authorities and local authority partnerships	2007	DEFRA
Right tree in the right place website	2009	Arbor Day Foundation
Wetland vision	2005	Environment Agency
Woodland carbon project	2009	Woodland Trust
Regional		
Economic and regenerative value of the natural environment	2003	NWDA
Sub/city-regional		
Berlin digital environmental atlas	2005	Senate Department for Urban Development, Berlin
Chiswick park, west London	1999	CABE
Garden for a living London	2005	London Wildlife Trust
Local		

Quaggy river, Lewisham	2000	CABE
The SUDS manual	2007	CIRIA

Managing visitor pressure

RESEARCH	Date	Author/Organisation
International		
Mediterranean tourism: Exploring the future with the tourism climatic index	2006	Amelung & Viner
The economics of ecosystems and biodiversity climate issues update	2009	Sukhdev *et al*.
National		
Climate regulation by carbon storage and sequestration	2008	Natural England
The urban environment	2007	Royal Commission on Environmental Pollution
Regional		
Climate change and the visitor economy: Challenges and opportunities for England's Northwest	2006	McEvoy *et al*.
Green infrastructure solutions to pinch point issues in Northwest England: How can green infrastructure enable sustainable development	2008	North West Green Infrastructure Unit
Northwest green infrastructure guide: Version 1.1	2008	Green Infrastructure Think Tank
Re-engaging with the land: Our most precious asset	2008	NWDA
The economic value of green infrastructure	2008	Natural Economy Northwest
Local		
Responding to the impacts of climate change on the natural environment: The Cumbria high fells	2009	Natural England

POLICY	Date	Author/Organisation
National		
A strategy for England's trees, woods and forests	2007	DEFRA
Adapting to climate change in England: A framework for action	2008	DEFRA
Climate change policy	2008	Natural England
England's trees, woods and forests: Delivery plan 2008 – 2012	2008	Forestry Commission
PPG17 Planning for open space, sport and recreation	2002	DEFRA
Winning: A tourism strategy for 2012 and beyond	2007	DCMS
Regional		
Northwest of England plan: Regional spatial strategy to 2021	2008	GONW
Northwest regional economic strategy	2006	NWDA
The regional forestry framework for England's Northwest: Agenda for growth	2005	Forestry Commission
Sub/city-regional		
London: Adapting to climate change: Creating natural resilience	2009	London Climate Change Partnership
The Mersey Forest plan	2001	The Mersey Forest
Local		
The Weaver Valley climate change action plan	2008	The Mersey Forest

DELIVERY	Date	Author/Organisation
National		
National indicators for local authorities and local authority partnerships	2007	DEFRA
Regional		
Economic and regenerative potential of the natural environment	2003	NWDA

Appendix B. Sub-regional mapping and analysis

The regional mapping (figures 22 and 25) is presented here for the Northwest's sub-regions, alongside a table listing wards where 8 or more services are considered important. An area is highlighted for each sub-region to demonstrate possible interpretation at this scale. It should be noted that managing water supply and material substitution were not included in the regional mapping and therefore are never highlighted as of importance here.

B.1 Cheshire

The number of services and priority services considered important in Cheshire are shown in figures 27 and 28, respectively. The table which follows highlights the Cheshire wards where 8 or more services OR all 5 priority services are considered important.

Figure 27. Number of services considered important: Cheshire

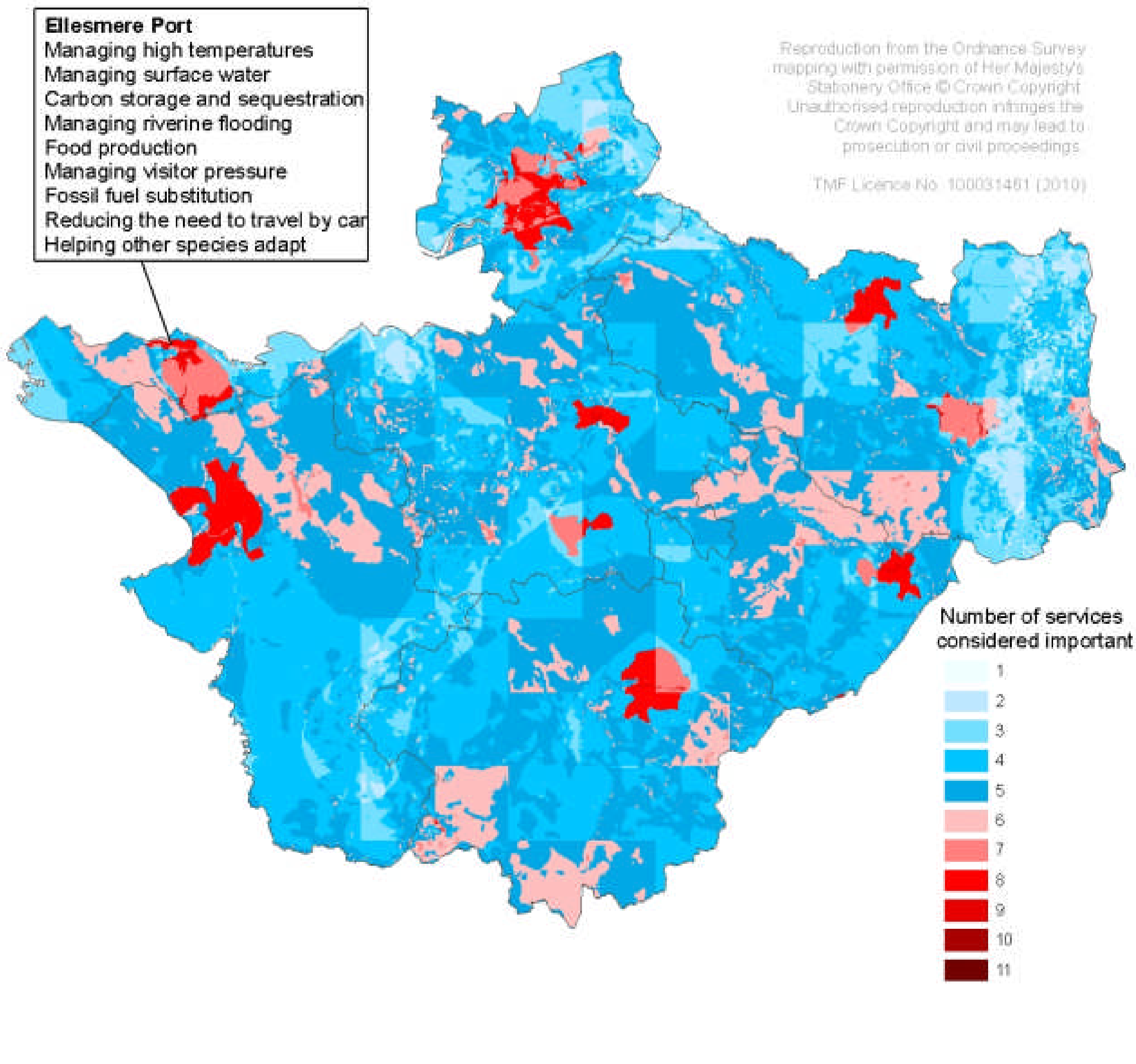
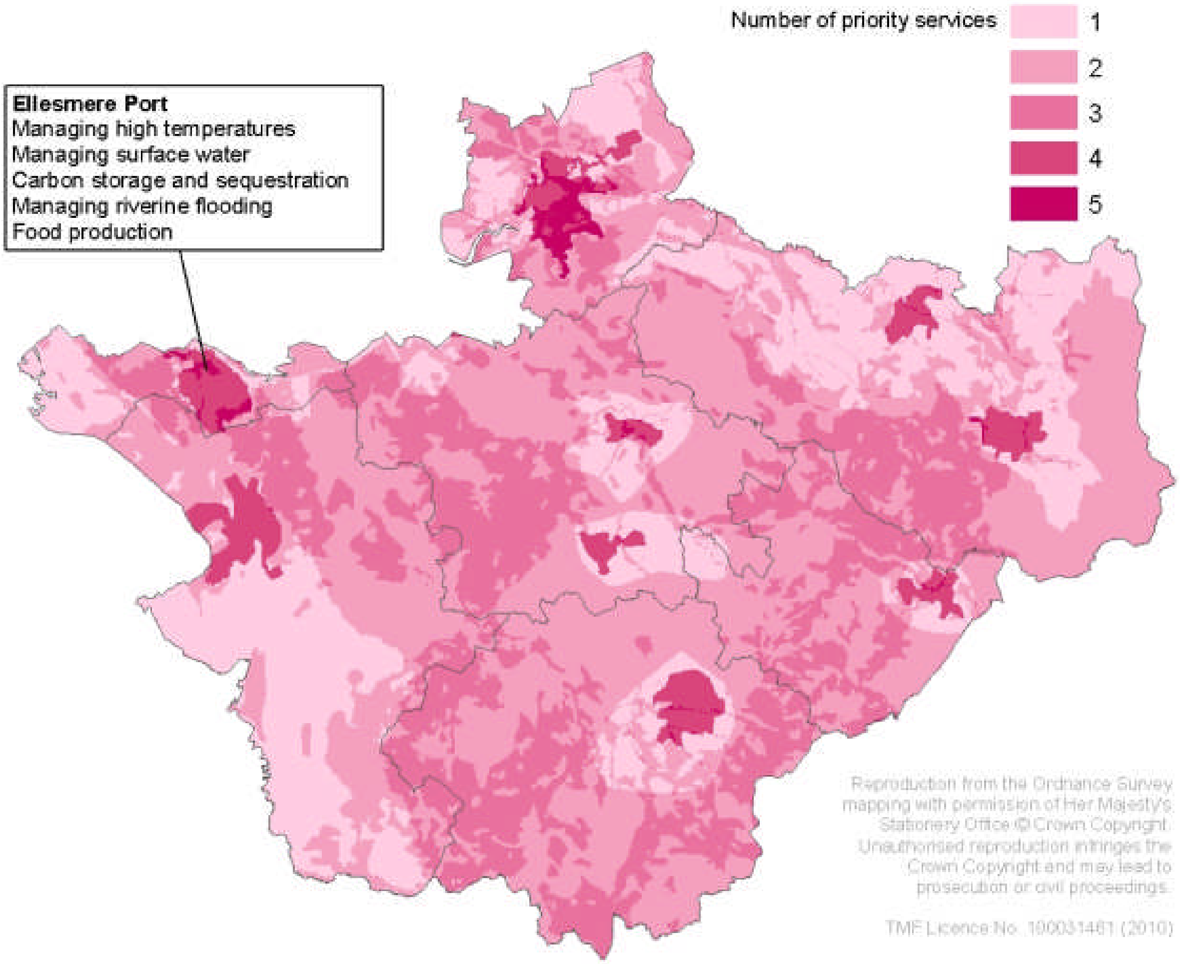


Figure 28. Number of priority services considered important: Cheshire



Cheshire wards where 8 or more services OR all 5 priority services are considered important

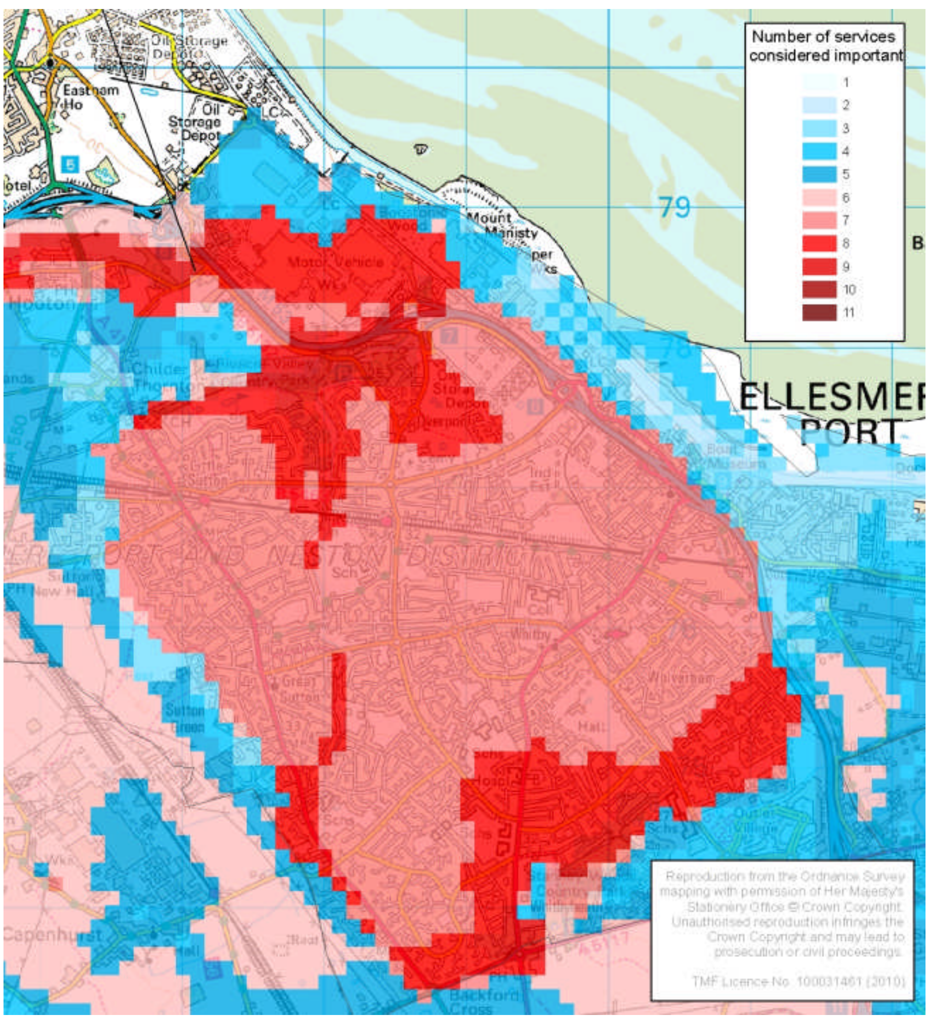
Local Authority	Ward	≥ 8 services	5 priority services
Cheshire East	Alexandra		
Cheshire East	Astbury		
Cheshire East	Buglawton		
Cheshire East	Congleton Central		
Cheshire East	Congleton North		
Cheshire East	Congleton North West		
Cheshire East	Congleton South		
Cheshire East	Congleton West		
Cheshire East	Coppenhall		
Cheshire East	Dean Row		
Cheshire East	Delamere		
Cheshire East	Fulshaw		
Cheshire East	Gawsworth		
Cheshire East	Grosvenor		
Cheshire East	Handforth		
Cheshire East	Henbury		
Cheshire East	Hough		
Cheshire East	Lacey Green		
Cheshire East	Lawton		
Cheshire East	Leighton		
Cheshire East	Macclesfield East		
Cheshire East	Macclesfield Bollin Brook		
Cheshire East	Macclesfield Broken Cross		
Cheshire East	Macclesfield Central		
Cheshire East	Macclesfield Hurdsfield		
Cheshire East	Macclesfield Ryles		
Cheshire East	Macclesfield South		
Cheshire East	Macclesfield Tytherington		
Cheshire East	Macclesfield West		
Cheshire East	Maw Green		
Cheshire East	Minshull		
Cheshire East	Morley & Styal		
Cheshire East	Prestbury		
Cheshire East	St Barnabas		
Cheshire East	St John's		
Cheshire East	St Mary's		
Cheshire East	Sutton		
Cheshire East	Valley		
Cheshire East	Waldron		
Cheshire East	Wells Green		
Cheshire East	Wistaston Green		
Cheshire East	Wrenbury		
Cheshire West and Chester	Astbury		
Cheshire West and Chester	Blacon Hall		
Cheshire West and Chester	Blacon Lodge		
Cheshire West and Chester	Boughton		
Cheshire West and Chester	Boughton Heath		
Cheshire West and Chester	Christleton		
Cheshire West and Chester	City & St Anne's		
Cheshire West and Chester	College		
Cheshire West and Chester	Congleton West		

Local Authority	Ward	≥ 8 services	5 priority services
Cheshire West and Chester	Curzon & Westminster		
Cheshire West and Chester	Dodleston		
Cheshire West and Chester	Elton		
Cheshire West and Chester	Frodsham		
Cheshire West and Chester	Grange		
Cheshire West and Chester	Groves		
Cheshire West and Chester	Handbridge & St Mary's		
Cheshire West and Chester	Hoole All Saints		
Cheshire West and Chester	Hoole Groves		
Cheshire West and Chester	Huntington		
Cheshire West and Chester	Lache Park		
Cheshire West and Chester	Leftwich & Kingsmead		
Cheshire West and Chester	Mickle Trafford		
Cheshire West and Chester	Milton Weaver		
Cheshire West and Chester	Mollington		
Cheshire West and Chester	Newton Brook		
Cheshire West and Chester	Newton St Michaels		
Cheshire West and Chester	Northwich Castle		
Cheshire West and Chester	Northwich Winnington		
Cheshire West and Chester	Northwich Witton		
Cheshire West and Chester	Pooltown		
Cheshire West and Chester	Rivacre		
Cheshire West and Chester	Rossmore		
Cheshire West and Chester	Rudheath & South Witton		
Cheshire West and Chester	Saughall		
Cheshire West and Chester	Stanlow and Wolverham		
Cheshire West and Chester	Strawberry Fields		
Cheshire West and Chester	Sutton		
Cheshire West and Chester	Sutton Green and Manor		
Cheshire West and Chester	Upton Grange		
Cheshire West and Chester	Upton Westlea		
Cheshire West and Chester	Vicars Cross		
Cheshire West and Chester	Waverton		
Cheshire West and Chester	Westminster		
Cheshire West and Chester	Whitby		
Cheshire West and Chester	Willaston & Thornton		
Cheshire West and Chester	Winsford Dene		
Cheshire West and Chester	Winsford Gravel		
Cheshire West and Chester	Winsford Verdin		
Cheshire West and Chester	Winsford Wharton		
Warrington	Appleton		
Warrington	Bewsey and Whitecross		
Warrington	Birchwood		
Warrington	Fairfield and Howley		
Warrington	Grappenhall and Thelwall		
Warrington	Great Sankey South		
Warrington	Hatton, Stretton and Walton		
Warrington	Latchford East		
Warrington	Latchford West		
Warrington	Orford		
Warrington	Poplars and Hulme		
Warrington	Poulton North		
Warrington	Poulton South		

Local Authority	Ward	≥ 8 services	5 priority services
Warrington	Rixton and Woolston		
Warrington	Stockton Heath		
Warrington	Westbrook		
Warrington	Whittle Hall		

Ellesmere Port is a large industrial town and port in Cheshire. The services considered important in Ellesmere Port are: managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding, food production, managing visitor pressure, fossil fuel substitution, reducing the need to travel by car, and helping other species to adapt. The services of less importance are: reducing soil erosion and managing coastal flooding. In parts of Ellesmere Port, particularly in the ward of Rossmore, all five priority services (managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding and food production) are important; some areas are considered less important for managing riverine flooding. The areas where the most services are considered important are along the arterial roads into the town (figure 29), especially alongside the Rivacre Valley country park in Rossmore. Any development and investment in Ellesmere Port should focus on *safeguarding* and *enhancing* the priority services present or any other services considered important.

Figure 29. Number of services considered important: Ellesmere Port



B.2 Cumbria

The number of services and priority services considered important in Cumbria are shown in figures 30 and 31, respectively. The table which follows highlights the Cumbria wards where 8 or more services OR all 5 priority services are considered important.

Figure 30. Number of services considered important: Cumbria

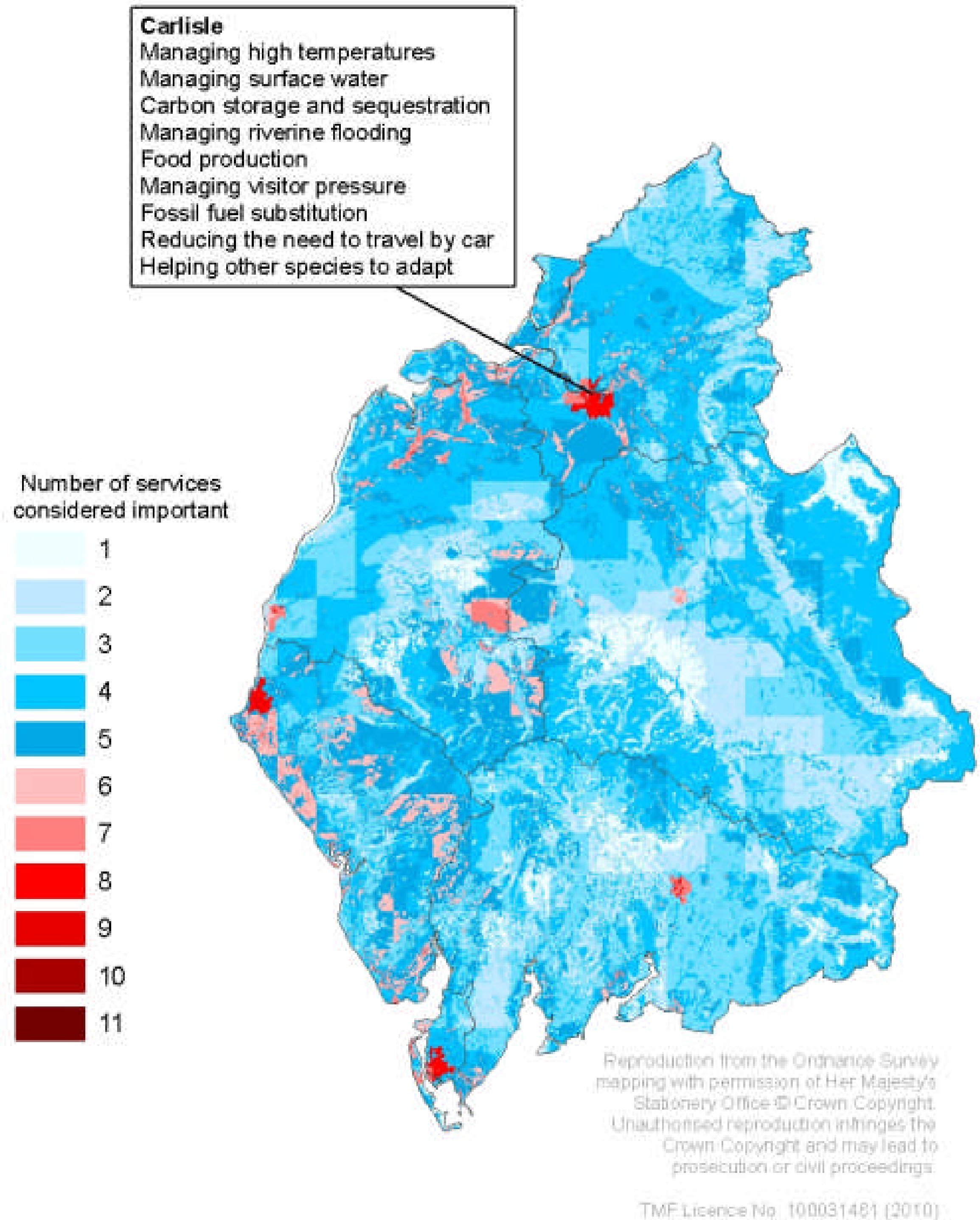
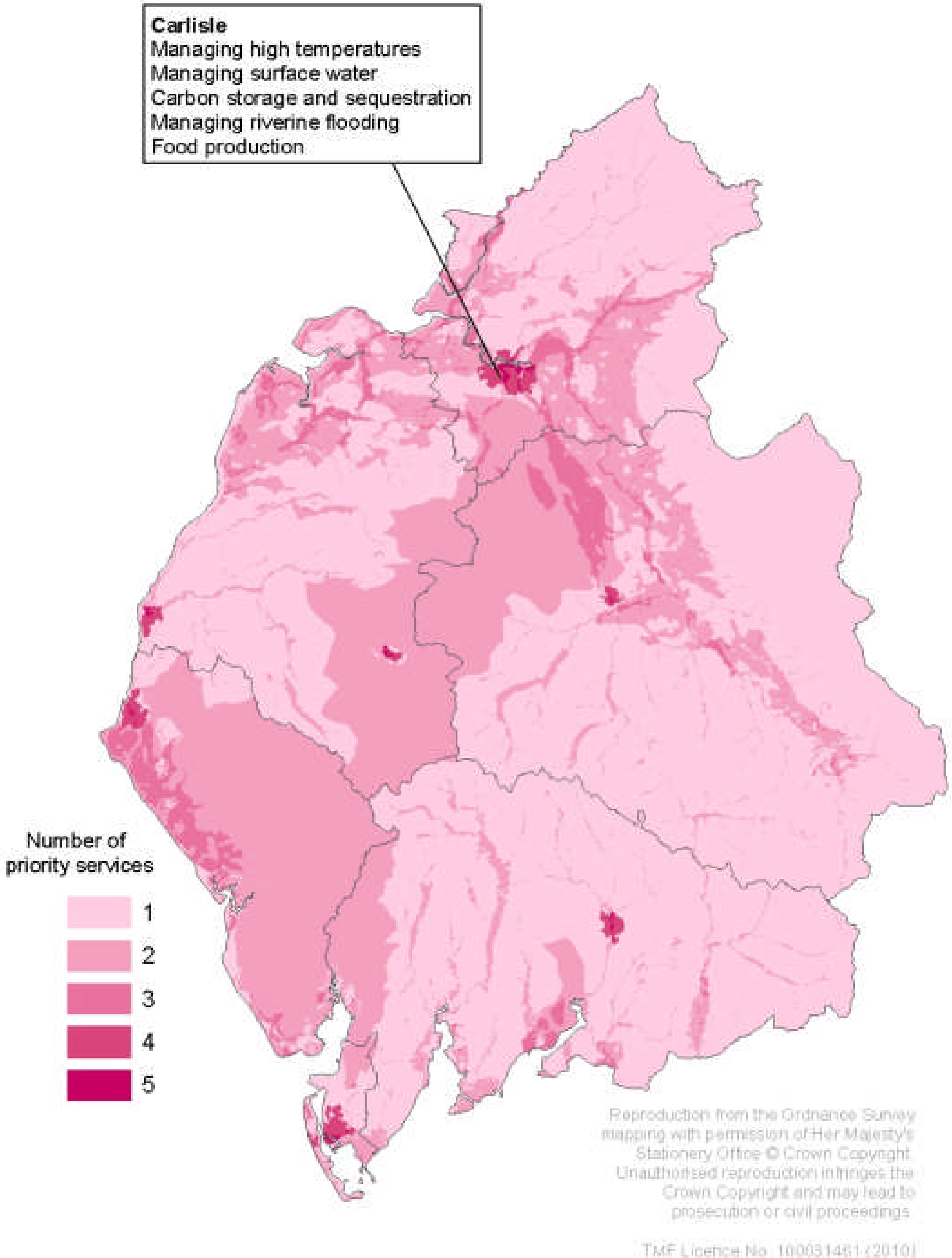


Figure 31. Number of priority services considered important: Cumbria



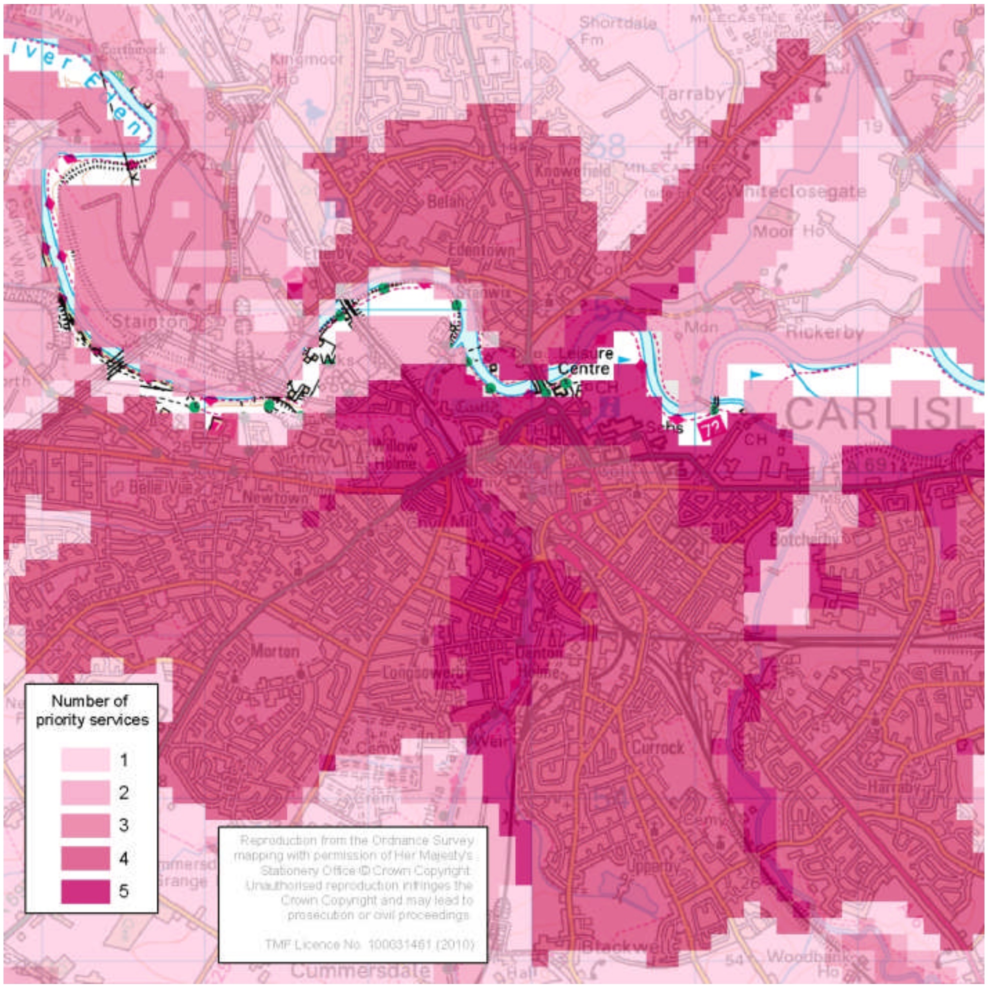
Cumbria wards where 8 or more services OR all 5 priority services are considered important

Local Authority	Ward	≥ 8 services	5 priority services
Allerdale	Boltons		
Allerdale	Harrington		
Allerdale	Holme		
Allerdale	Keswick		
Allerdale	Marsh		
Allerdale	Moss Bay		
Allerdale	Solway		
Allerdale	St John’s		
Allerdale	St Michael’s		
Allerdale	Waver		
Barrow-in-Furness	Barrow Island		
Barrow-in-Furness	Central		
Barrow-in-Furness	Hawcoat		
Barrow-in-Furness	Hindpool		
Barrow-in-Furness	Newbarns		
Barrow-in-Furness	Ormsgill		
Barrow-in-Furness	Parkside		
Barrow-in-Furness	Risedale		
Barrow-in-Furness	Roosecote		
Barrow-in-Furness	Walney South		
Barrow-in-Furness	Walney North		
Carlisle	Belah		
Carlisle	Belle Vue		
Carlisle	Botcherby		
Carlisle	Burgh		
Carlisle	Castle		
Carlisle	Currock		
Carlisle	Denton Holme		
Carlisle	Dalston		
Carlisle	Harraby		
Carlisle	Morton		
Carlisle	St Aidans		
Carlisle	Stanwix Rural		
Carlisle	Stanwix Urban		
Carlisle	Upperby		
Carlisle	Wetherall		
Carlisle	Yewdale		
Copeland	Arlecdon		
Copeland	Beckermet		
Copeland	Bransty		
Copeland	Egremont North		
Copeland	Harbour		
Copeland	Haverigg		
Copeland	Hensingham		
Copeland	Hillcrest		
Copeland	Kells		
Copeland	Millom Without		
Copeland	Mirehouse		
Copeland	Moresby		
Copeland	Sandwith		
Copeland	Seascale		

Local Authority	Ward	≥ 8 services	5 priority services
Copeland	St Bees	■	
Eden	Penrith North		■
Eden	Penrith West		■
Eden	Penrith South		■
Eden	Penrith Pategill		■
Eden	Penrith East		■
South Lakeland	Arnside and Beetham	■	
South Lakeland	Burneside	■	
South Lakeland	Kendal Farcross	■	
South Lakeland	Kendal Fell	■	■
South Lakeland	Kendal Glebelands	■	■
South Lakeland	Kendal Heron Hill	■	
South Lakeland	Kendal Highgate	■	■
South Lakeland	Kendal Kirkland	■	■
South Lakeland	Kendal Mintsfeet	■	■
South Lakeland	Kendal Nether	■	■
South Lakeland	Kendal Oxenholme	■	■
South Lakeland	Kendal Strickland	■	■
South Lakeland	Kendal Underley	■	
South Lakeland	Lyth Valley	■	

Carlisle is the largest urban area in Cumbria, located at the confluence of the rivers Eden, Caldew and Petteril, ten miles south of the Scottish border. The services considered important in Carlisle are: managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding, food production, managing visitor pressure, fossil fuel substitution, reducing the need to travel by car, helping other species to adapt. There is a small area of floodplain and grazing marsh in the east of the town where managing coastal flooding is considered important, local knowledge could verify if this was the case. Reducing soil erosion is considered less important in Carlisle. The number of services considered important is slightly higher in the east of the town and along the A69 at the edge of the urbanised area at the border of the wards Botcherby and Wetherall. To the north of the river Eden, in the ward of Stanwix Urban there is a large area where a high number of services are considered important. There are parts of the city where all five priority services (managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding and food production) are considered important; these areas are along the rivers Caldew and Eden (figure 32) in the wards of Castle and Denton Holme. Any development in Carlisle should focus on *safeguarding* and *enhancing* these priority services, or any other services which are considered important.

Figure 32. Number of priority services considered important: Carlisle



B.3 Greater Manchester

The number of services and priority services considered important in Greater Manchester are shown in figures 33 and 34, respectively. The table which follows highlights the Greater Manchester wards where 8 or more services OR all 5 priority services are considered important.

Figure 33. Number of services considered important: Greater Manchester

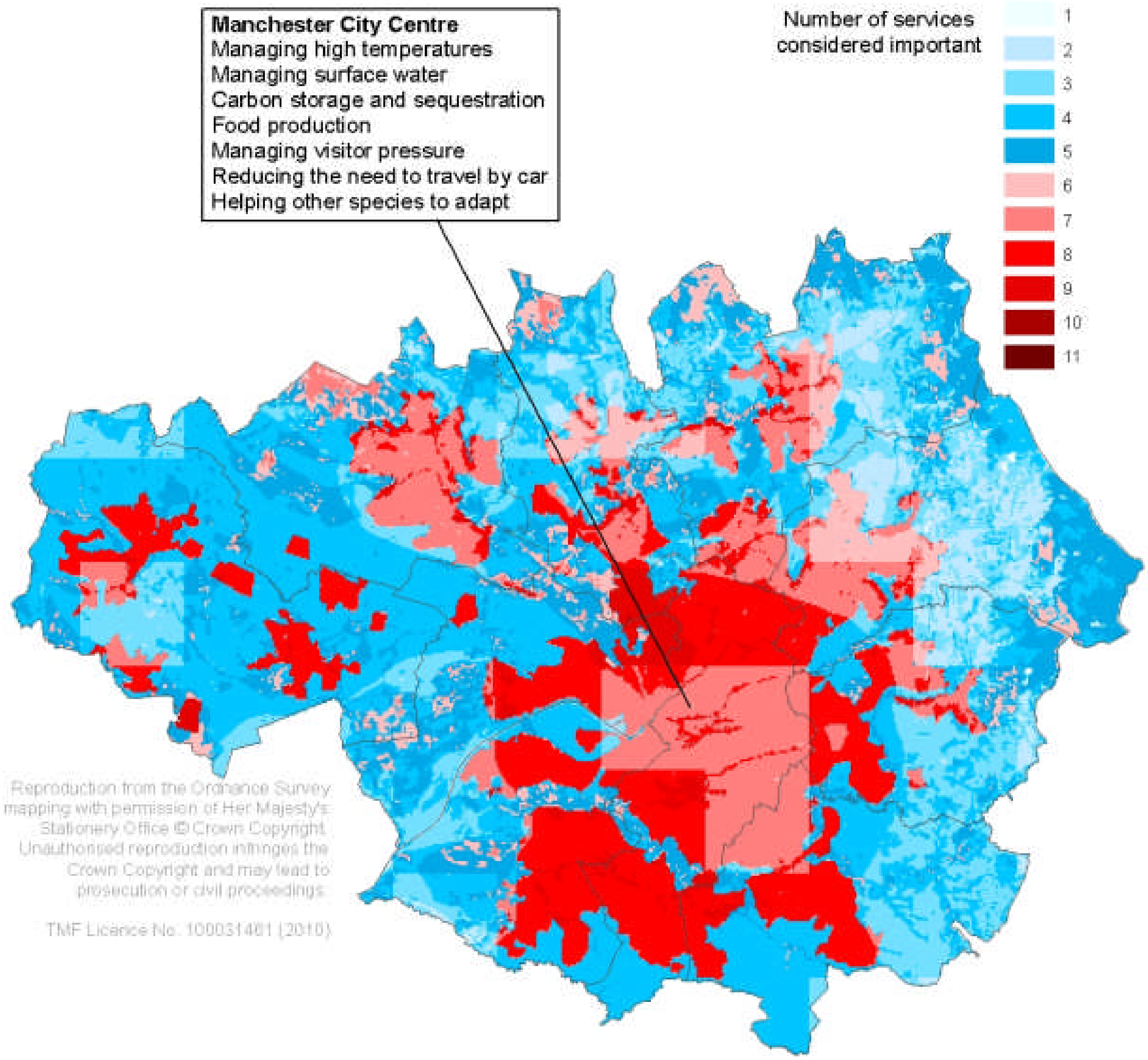
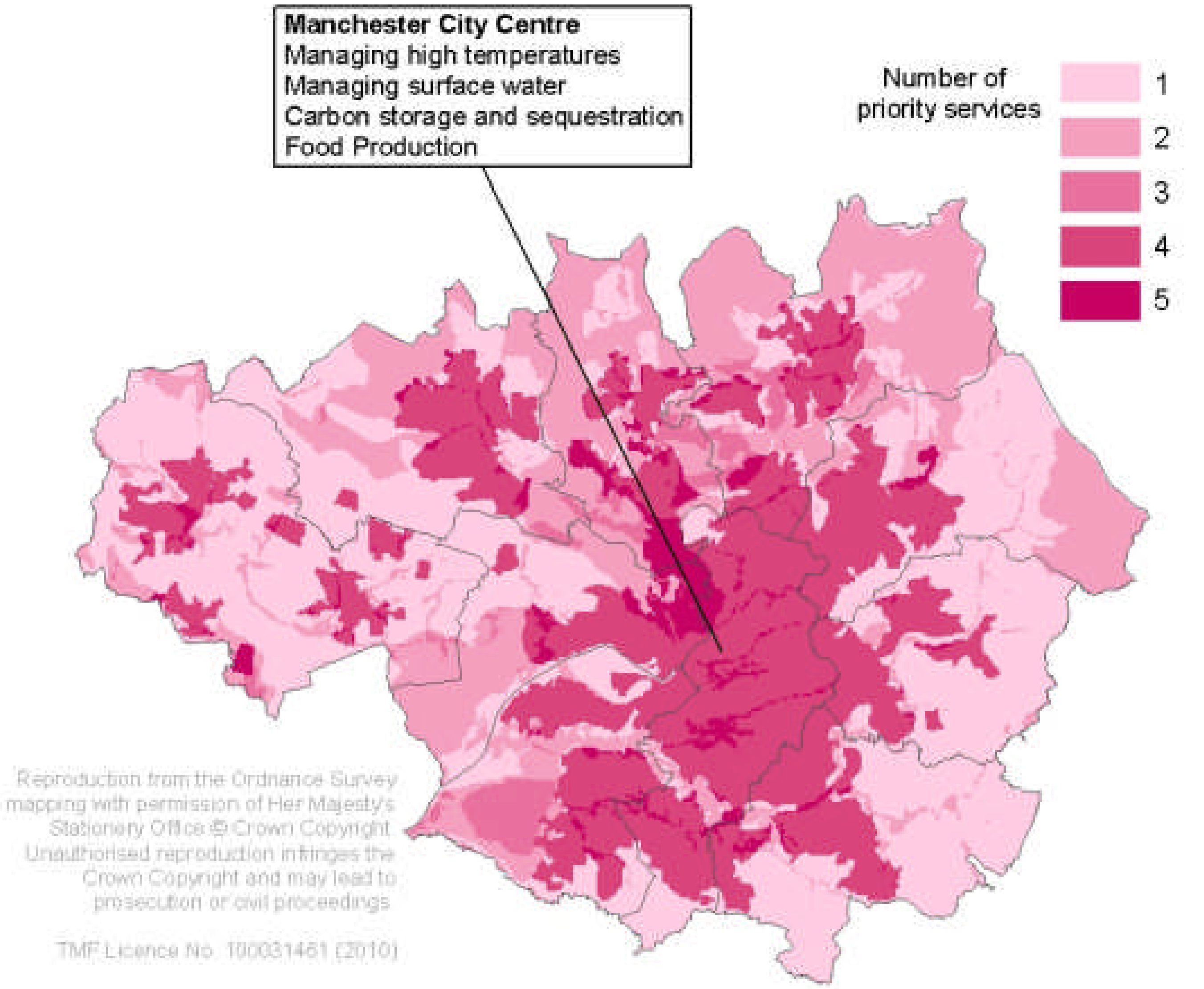


Figure 34. Number of priority services considered important: Greater Manchester



Greater Manchester wards where 8 or more services OR all 5 priority services are considered important

Local Authority	Ward	≥ 8 services	5 priority services
Bolton	Astley Bridge		
Bolton	Bradshaw		
Bolton	Breightmet		
Bolton	Bromley Cross		
Bolton	Crompton		
Bolton	Farnworth		
Bolton	Great Lever		
Bolton	Harper Green		
Bolton	Halliwell		
Bolton	Heaton and Lostock		
Bolton	Horwich and Blackrod		
Bolton	Hulton		
Bolton	Kearsley		
Bolton	Little Lever and Darcy Lever		
Bolton	Rumworth		
Bolton	Smithills		
Bolton	Tonge with the Haulgh		
Bolton	Westhoughton North and Chew Moor		
Bolton	Westhoughton South		
Bury	Besses		
Bury	Church		
Bury	East		
Bury	Elton		
Bury	Holyrood		
Bury	Moorside		
Bury	Pilkington Park		
Bury	Radcliffe East		
Bury	Radcliffe North		
Bury	Radcliffe West		
Bury	Redvales		
Bury	Sedgley		
Bury	St Mary's		
Bury	Unsworth		
Manchester	Ancoats and Clayton		
Manchester	Ardwick		
Manchester	Baguley		
Manchester	Bradford		
Manchester	Brooklands		
Manchester	Charlestown		
Manchester	Cheetham		
Manchester	Chorlton		
Manchester	Chorlton Park		
Manchester	City Centre		
Manchester	Crumpsall		
Manchester	Didsbury East		
Manchester	Didsbury West		
Manchester	Fallowfield		
Manchester	Gorton North		
Manchester	Gorton South		
Manchester	Harpurhey		
Manchester	Higher Blackley		

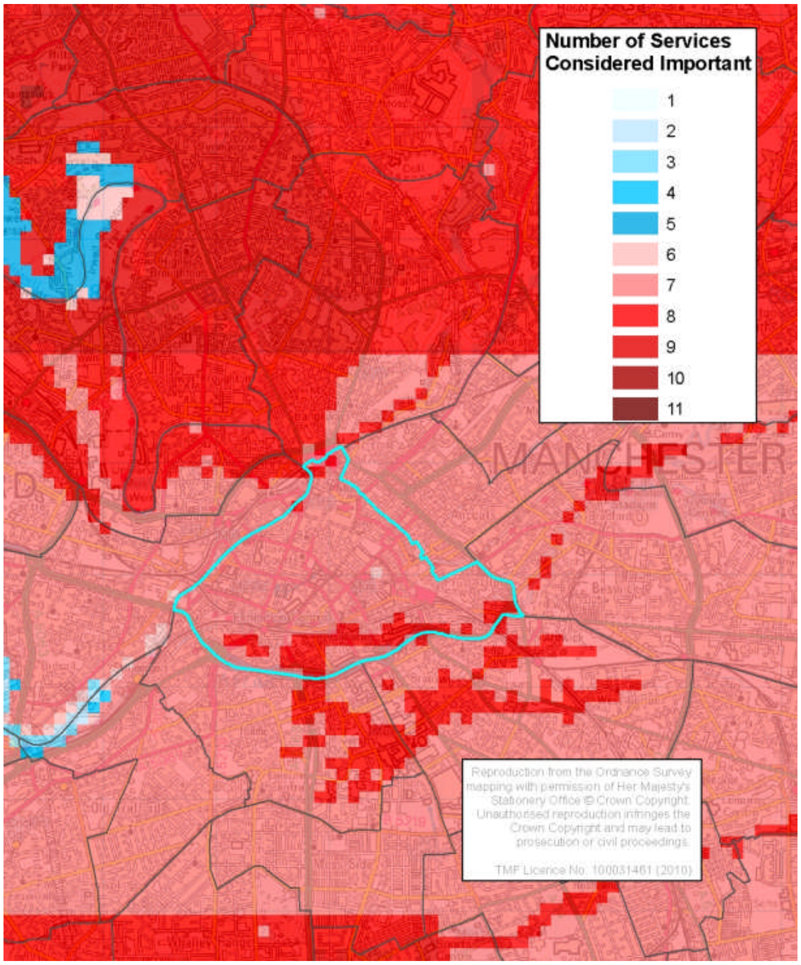
Local Authority	Ward	≥ 8 services	5 priority services
Manchester	Hulme		
Manchester	Levenshulme		
Manchester	Longsight		
Manchester	Miles Platting and Newton Heath		
Manchester	Moss Side		
Manchester	Moston		
Manchester	Northenden		
Manchester	Old Moat		
Manchester	Rusholme		
Manchester	Sharston		
Manchester	Whalley Range		
Manchester	Withington		
Manchester	Woodhouse Park		
Oldham	Alexandra		
Oldham	Chadderton Central		
Oldham	Chadderton North		
Oldham	Chadderton South		
Oldham	Coldhurst		
Oldham	Failsworth East		
Oldham	Failsworth West		
Oldham	Hollinwood		
Oldham	Medlock Vale		
Oldham	Royton North		
Oldham	Royton South		
Oldham	Saddleworth North		
Oldham	Sadleworth West and Lees		
Oldham	St James'		
Oldham	St Mary's		
Oldham	Waterhead		
Oldham	Werneth		
Rochdale	Balderstone and Kirkholt		
Rochdale	Bamford		
Rochdale	Castleton		
Rochdale	Central Rochdale		
Rochdale	East Middleton		
Rochdale	Kingsway		
Rochdale	Healey		
Rochdale	Hopwood Hall		
Rochdale	Milkstone and Deeplish		
Rochdale	Norden		
Rochdale	North Heywood		
Rochdale	North Middleton		
Rochdale	Small Bridge and Firgrove		
Rochdale	South Middleton		
Rochdale	Spotland and Falinge		
Rochdale	Wardle and West Littleborough		
Rochdale	West Heywood		
Rochdale	West Middleton		
Salford	Barton		
Salford	Boothstown and Ellenbrook		
Salford	Broughton		
Salford	Claremont		
Salford	Eccles		

Local Authority	Ward	≥ 8 services	5 priority services
Salford	Irlam		
Salford	Irwell Riverside		
Salford	Kersal		
Salford	Langworthy		
Salford	Ordsall		
Salford	Pendlebury		
Salford	Swinton South		
Salford	Walkden North		
Salford	Walkden South		
Salford	Weaste and Seedley		
Salford	Winton		
Salford	Worsley		
Stockport	Bramhall North		
Stockport	Bredbury and Woodley		
Stockport	Brinnington and Central		
Stockport	Cheadle and Gatley		
Stockport	Cheadle Hulme North		
Stockport	Davenport and Cale Green		
Stockport	Edgeley and Cheadle Heath		
Stockport	Hazel Grove		
Stockport	Heald Green		
Stockport	Heatons South		
Stockport	Manor		
Stockport	Marple South		
Stockport	Offerton		
Stockport	Reddish North		
Stockport	Reddish South		
Stockport	Stepping Hill		
Tameside	Ashton Hurst		
Tameside	Ashton St Michael’s		
Tameside	Ashton Waterloo		
Tameside	Audenshaw		
Tameside	Denton North East		
Tameside	Denton South		
Tameside	Denton West		
Tameside	Droylesden East		
Tameside	Droylesden West		
Tameside	Dukinfield		
Tameside	Dukinfield Stalybridge		
Tameside	Hyde Godley		
Tameside	Hyde Newton		
Tameside	Hyde Werneth		
Tameside	Stalybridge North		
Tameside	Stalybridge South		
Tameside	St Peter’s		
Trafford	Altrincham		
Trafford	Ashton upon Mersey		
Trafford	Bowdon		
Trafford	Broadheath		
Trafford	Brooklands		
Trafford	Bucklow-St Martins		
Trafford	Clifford		
Trafford	Davyhulme East		

Local Authority	Ward	≥ 8 services	5 priority services
Trafford	Davyhulme West		
Trafford	Flixton		
Trafford	Gorse Hil		
Trafford	Hale Barns		
Trafford	Hale Central		
Trafford	Longford		
Trafford	Priory		
Trafford	Sale Moor		
Trafford	St Mary's		
Trafford	Stretford		
Trafford	Timperley		
Trafford	Urmston		
Trafford	Village		
Wigan	Ashton		
Wigan	Aspull New Springs Whelley		
Wigan	Atherleigh		
Wigan	Atherton		
Wigan	Bryn		
Wigan	Douglas		
Wigan	Golborne and Lowton West		
Wigan	Hindley		
Wigan	Hindley Green		
Wigan	Ince		
Wigan	Leigh East		
Wigan	Leigh South		
Wigan	Leigh West		
Wigan	Lowton East		
Wigan	Pemberton		
Wigan	Shevington with Lower Ground		
Wigan	Tyldesley		
Wigan	Wigan Central		
Wigan	Wigan West		
Wigan	Winstanley		
Wigan	Worsley Mesnes		

Manchester city centre lies on the east bank of the River Irwell, nears its confluence with the Rivers Medlock and Irk. The majority of Manchester city centre has seven services considered important. These are: managing high temperatures, managing surface water, carbon storage and sequestration, food production, managing visitor pressure, reducing the need to travel by car, and helping other species to adapt. There are parts of the ward where managing riverine flooding is also considered important. The services considered less important are: fossil fuel substitution, reducing soil erosion and managing coastal flooding. In the wards to the north of the city centre, such as Cheetham and Broughton, managing riverine flooding and fossil fuel substitution are also considered important. In parts of Manchester city centre all five priority services (managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding and food production) are considered important.; in particular along the Bridgewater canal to the south and along the River Irk in Cheetham. Any development in Manchester city centre should focus on *safeguarding* and *enhancing* the priority services, or any other services which are considered important.

Figure 35. Number of services considered important: Manchester city centre (highlighted ward)



B.4 Lancashire

The number of services and priority services considered important in Lancashire are shown in figures 36 and 37, respectively. The table which follows highlights the Lancashire wards where 8 or more services OR all 5 priority services are considered important.

Figure 36. Number of services considered important: Lancashire

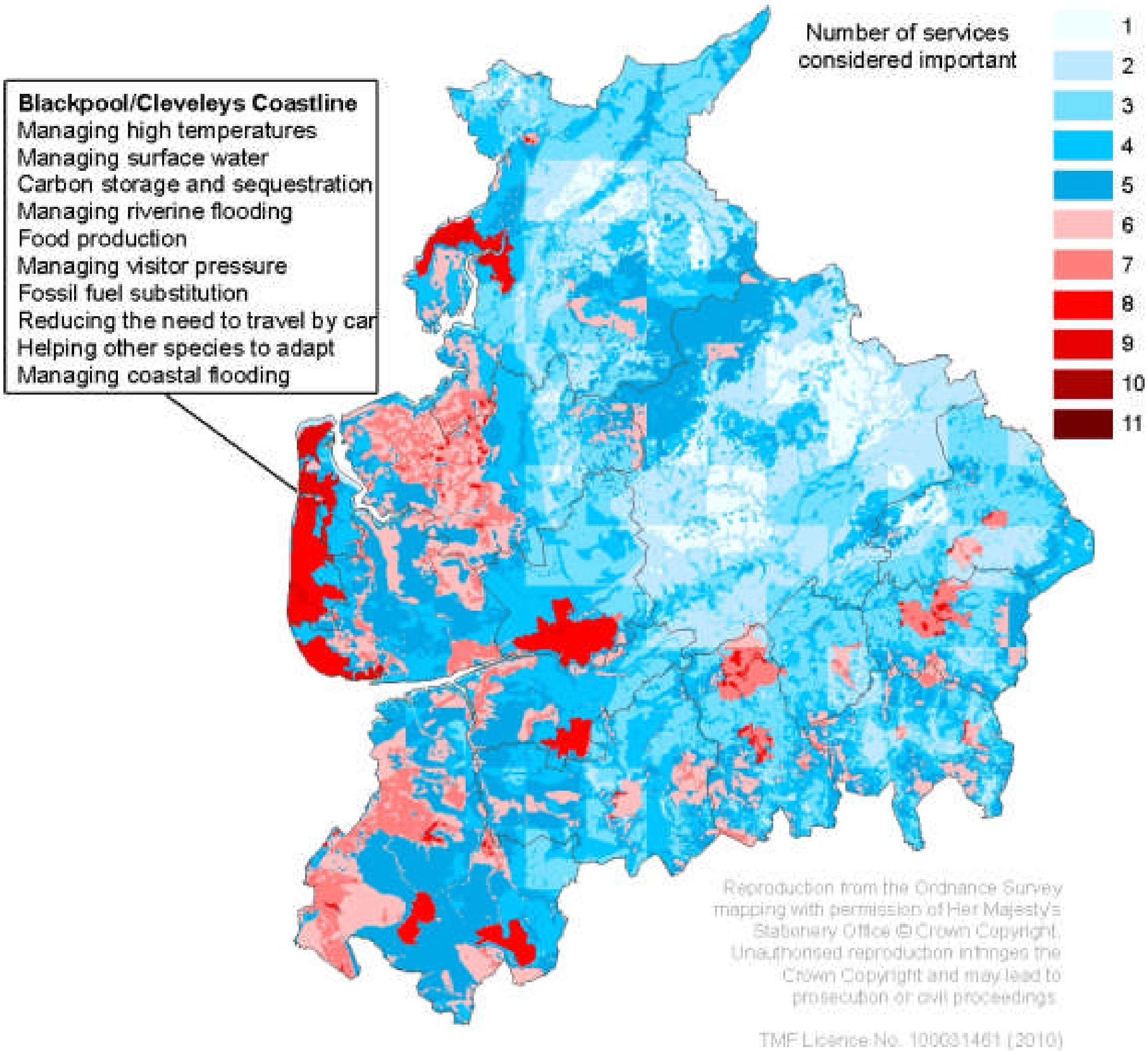
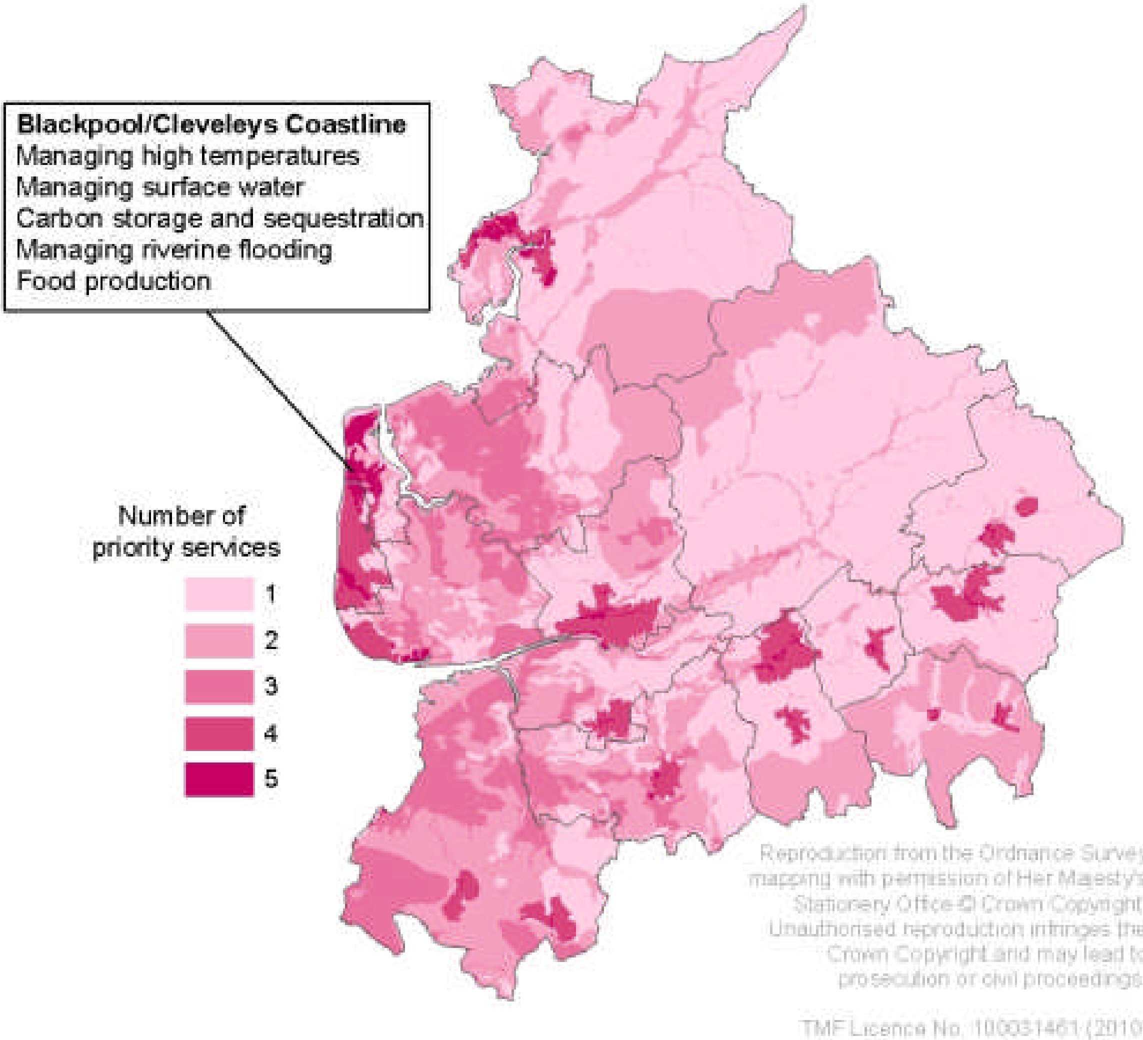


Figure 37. Number of priority services considered important: Lancashire



Lancashire wards where 8 or more services OR all 5 priority services are considered important

Local Authority	Ward	≥ 8 services	5 priority services
Blackburn with Darwen	Audley		
Blackburn with Darwen	Bastwell		
Blackburn with Darwen	Beardwood with Lammack		
Blackburn with Darwen	Corporation Park		
Blackburn with Darwen	Earcroft		
Blackburn with Darwen	Ewood		
Blackburn with Darwen	Fernhurst		
Blackburn with Darwen	Higher Croft		
Blackburn with Darwen	Little Harwood		
Blackburn with Darwen	Marsh House		
Blackburn with Darwen	Meadowhead		
Blackburn with Darwen	Mill Hill		
Blackburn with Darwen	North Turton with Tockholes		
Blackburn with Darwen	Queen’s Park		
Blackburn with Darwen	Roe Lee		
Blackburn with Darwen	Shadsworth with Whitebirk		
Blackburn with Darwen	Shear Brow		
Blackburn with Darwen	Sudell		
Blackburn with Darwen	Sunnyhurst		
Blackburn with Darwen	Wensley Fold		
Blackburn with Darwen	Whitehall		
Blackpool	Anchorshole		
Blackpool	Bispham		
Blackpool	Bloomfield		
Blackpool	Brunswick		
Blackpool	Claremont		
Blackpool	Clifton		
Blackpool	Greenlands		
Blackpool	Hawes Side		
Blackpool	Highfield		
Blackpool	Ingthorpe		
Blackpool	Layton		
Blackpool	Marton		
Blackpool	Park		
Blackpool	Norbeck		
Blackpool	Squiresgate		
Blackpool	Stanley		
Blackpool	Talbolt		
Blackpool	Tyldesley		
Blackpool	Victoria		
Blackpool	Warbeck		
Blackpool	Waterloo		
Burnley	Bank Hall		
Burnley	Brunshaw		
Burnley	Cliviger and Worsthorne		
Burnley	Coal Clough with Deerplay		
Burnley	Danehouse and Stoneyholme		
Burnley	Gannow		
Burnley	Hapton with Park		
Burnley	Lanehead		
Burnley	Queensgate		

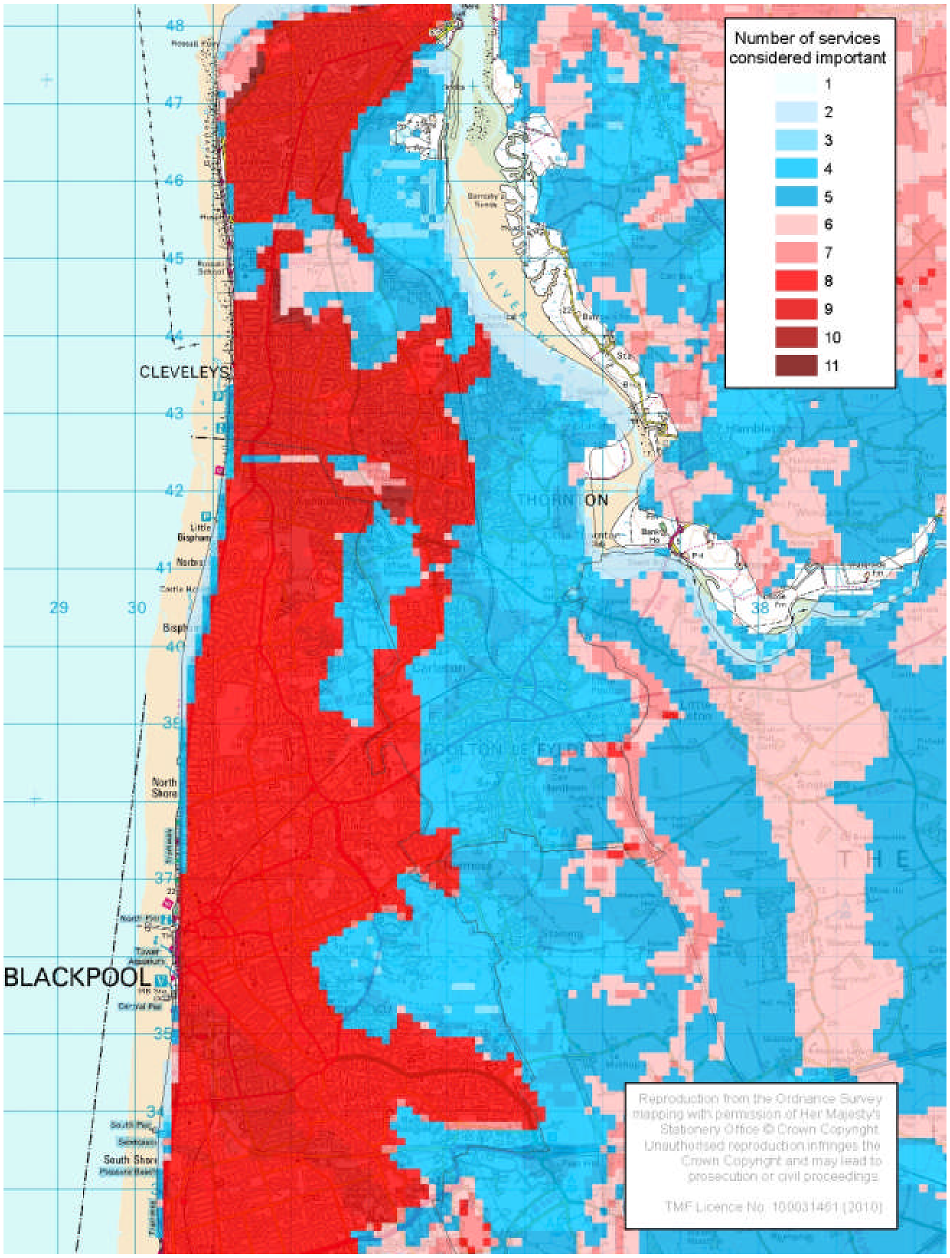
Local Authority	Ward	≥ 8 services	5 priority services
Burnley	Rosegrove with Lowerhouse		
Burnley	Rosehill with Burnley wood		
Burnley	Trinity		
Burnley	Whittlefield with Ightenhill		
Chorley	Chorley East		
Chorley	Chorley North East		
Chorley	Chorley North West		
Chorley	Chorley South East		
Chorley	Chorley South West		
Fylde	Ansdell		
Fylde	Ashton		
Fylde	Central		
Fylde	Clifton		
Fylde	Elswick and Little Eccleston		
Fylde	Fairhaven		
Fylde	Heyhouses		
Fylde	Kilnhouse		
Fylde	Medlar with Wesham		
Fylde	Newton and Treales		
Fylde	Park		
Fylde	Singleton and Greenhalgh		
Fylde	Staining and Weeton		
Fylde	St Johns		
Fylde	St Leonards		
Fylde	Warton and Westby		
Hyndburn	Barnfield		
Hyndburn	Baxenden		
Hyndburn	Central		
Hyndburn	Rishton		
Hyndburn	Spring Hill		
Lancaster	Bare		
Lancaster	Bulk		
Lancaster	Carnforth		
Lancaster	Castle		
Lancaster	Duke's		
Lancaster	Ellel		
Lancaster	Halton-with-Aughton		
Lancaster	Harbour		
Lancaster	Heysham Central		
Lancaster	Heysham North		
Lancaster	Heysham South		
Lancaster	John O'Gaunt		
Lancaster	Lower Lune Valley		
Lancaster	Poulton		
Lancaster	Scotforth East		
Lancaster	Scotforth West		
Lancaster	Slyne-with-Hest		
Lancaster	Skerton East		
Lancaster	Skerton West		
Lancaster	Torrisholme		
Lancaster	Warton		
Lancaster	Westgate		
Pendle	Barrowford		

Local Authority	Ward	≥ 8 services	5 priority services
Pendle	Bradley		
Pendle	Briersfield		
Pendle	Boulsworth		
Pendle	Clover Hill		
Pendle	Old Laund Booth		
Pendle	Southfield		
Pendle	Vivary Bridge		
Pendle	Waterside		
Pendle	Whitefield		
Preston	Ashton		
Preston	Brookfield		
Preston	Cadley		
Preston	College		
Preston	Deepdale		
Preston	Fishwick		
Preston	Garrison		
Preston	Greyfriars		
Preston	Larches		
Preston	Lea		
Preston	Moor Park		
Preston	Ingol		
Preston	Preston Rural East		
Preston	Preston Rural North		
Preston	Ribbleton		
Preston	Riversway		
Preston	Sharoe Green		
Preston	St George's		
Preston	St Mathew's		
Preston	Town Centre		
Preston	Tulketh		
Preston	University		
Rossendale	Cribden		
Rossendale	Facit and Shawforth		
Rossendale	Greensclough		
Rossendale	Hareholme		
Rossendale	Irwell		
Rossendale	Longholme		
South Ribble	Earnshaw Bridge		
South Ribble	Farington East		
South Ribble	Farington West		
South Ribble	Golden Hill		
South Ribble	Leyland Central		
South Ribble	Leyland St. Amrose		
South Ribble	Leyland St. Mary's		
South Ribble	Lowerhouse		
South Ribble	Moss Side		
South Ribble	Seven Stars		
West Lancashire	Ashurst		
West Lancashire	Aughton and Downholland		
West Lancashire	Aughton Park		
West Lancashire	Bickerstaffe		
West Lancashire	Birch Green		
West Lancashire	Burscough East		

Local Authority	Ward	≥ 8 services	5 priority services
West Lancashire	Derby		
West Lancashire	Digmoor		
West Lancashire	Halsall		
West Lancashire	Knowsley		
West Lancashire	Moorside		
West Lancashire	Newburgh		
West Lancashire	North Meols		
West Lancashire	Scarisbrick		
West Lancashire	Scott		
West Lancashire	Skelmersdale North		
West Lancashire	Skelmersdale South		
West Lancashire	Tarnhouse		
West Lancashire	Up Holland		
Wyre	Bourne		
Wyre	Breck		
Wyre	Carleton		
Wyre	Cleveleys Park		
Wyre	Garstang		
Wyre	Great Eccleston		
Wyre	Hambleton & Stalmine-with-Stayn		
Wyre	Hardhorn		
Wyre	High Cross		
Wyre	Jubilee		
Wyre	Mount		
Wyre	Norcross		
Wyre	Park		
Wyre	Pharos		
Wyre	Pilling		
Wyre	Rossall		
Wyre	Staina		
Wyre	Tithebarn		
Wyre	Victoria		
Wyre	Warren		
Wyre	Wyresdale		

Blackpool is one of the most visited tourist sites in the Northwest. The number of green infrastructure services considered important varies along the coastline; with a higher number in the north around Cleveleys in the wards of Warren and Rossall (figure 38), than close to Blackpool town centre in the wards of Bloomfield, Talbolt and Waterloo. In the more southerly wards of Jubilee and Bispham managing riverine flooding, reducing soil erosion and managing coastal flooding are considered less important. At points along the coastline all five priority services (managing high temperatures, managing surface water, carbon storage and sequestration, managing riverine flooding and food production) are considered important; particularly in the wards of Warren, Rossall, Park, Mount, Jubilee and Cleveleys Park. Any development and investment in the Blackpool/Cleveleys coastline should focus on *safeguarding* and *enhancing* the priority services, or any other services which are considered important.

Figure 38. Number of services considered important: Blackpool/Cleveleys coastline



B.5 Merseyside

The number of services and priority services considered important in Merseyside are shown in figures 39 and 40, respectively. The table which follows highlights the Merseyside wards where 8 or more services OR all 5 priority services are considered important.

Figure 39. Number of services considered important: Merseyside

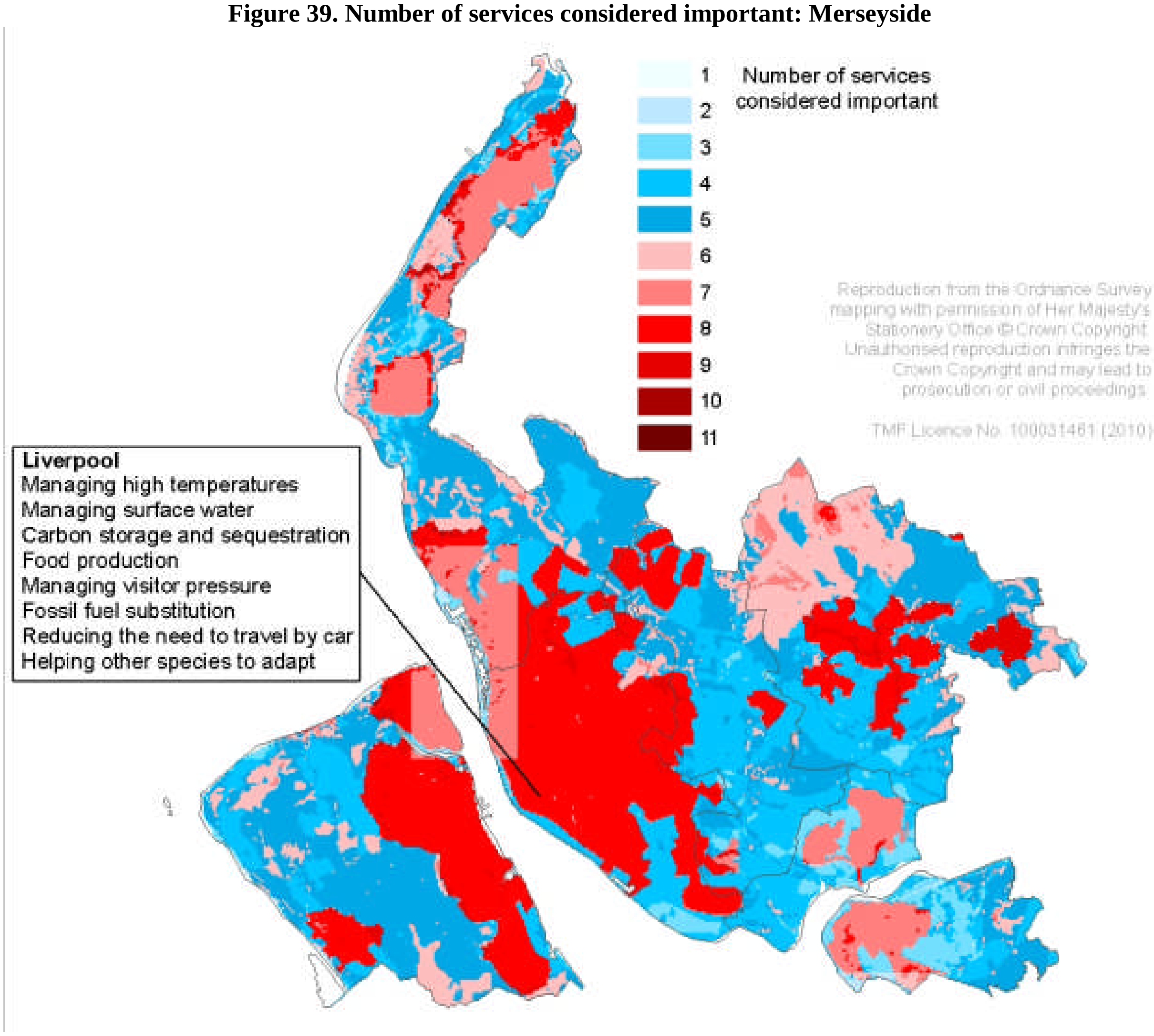
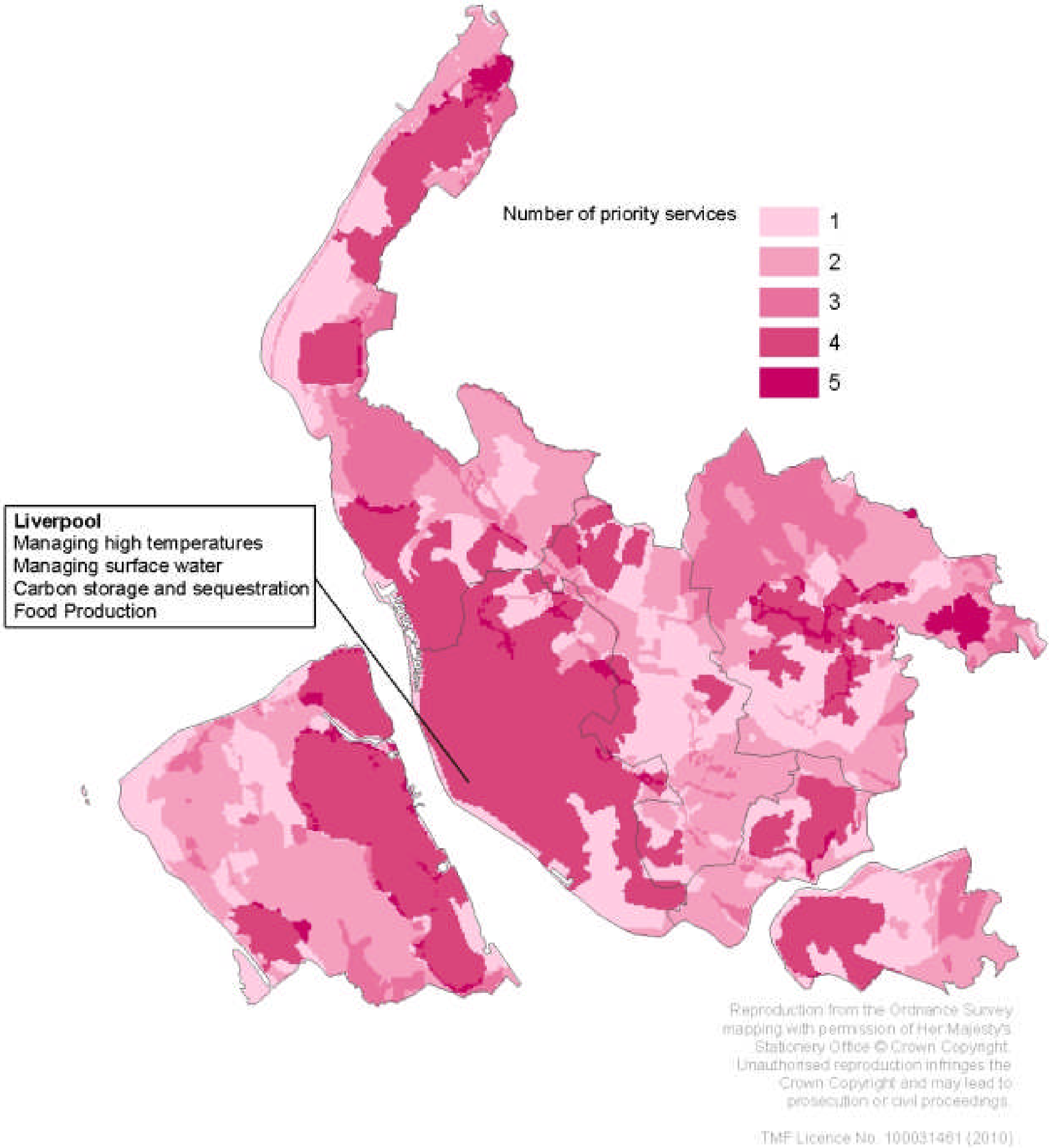


Figure 40. Number of priority services considered important: Merseyside



Merseyside wards where 8 or more services OR all 5 priority services are considered important

Local Authority	Ward	≥ 8 services	5 priority services
Halton	Appleton		
Halton	Beechwood		
Halton	Castlefields		
Halton	Daresbury		
Halton	Ditton		
Halton	Grange		
Halton	Halton Brook		
Halton	Halton Lea		
Halton	Halton View		
Halton	Heath		
Halton	Mersey		
Halton	Norton South		
Halton	Riverside		
Knowsley	Cherryfield		
Knowsley	Halewood North		
Knowsley	Halewood South		
Knowsley	Halewood West		
Knowsley	Kirby Central		
Knowsley	Longview		
Knowsley	Northwood		
Knowsley	Page Moss		
Knowsley	Park		
Knowsley	Prescot East		
Knowsley	Prescot West		
Knowsley	Roby		
Knowsley	Shevington		
Knowsley	Stockbridge		
Knowsley	St Bartholomews		
Knowsley	Swanside		
Knowsley	Whiston North		
Knowsley	Whitefield		
Liverpool	Anfield		
Liverpool	Allerton and Hunts Cross		
Liverpool	Belle Vale		
Liverpool	Central		
Liverpool	Childwall		
Liverpool	Church		
Liverpool	Clubmoor		
Liverpool	County		
Liverpool	Cressington		
Liverpool	Croxteth		
Liverpool	Everton		
Liverpool	Fazakerley		
Liverpool	Greenbank		
Liverpool	Kensington and Fairfield		
Liverpool	Kirkdale		
Liverpool	Knotty Ash		
Liverpool	Mossley Hill		
Liverpool	Norris Green		
Liverpool	Old Swan		
Liverpool	Picton		

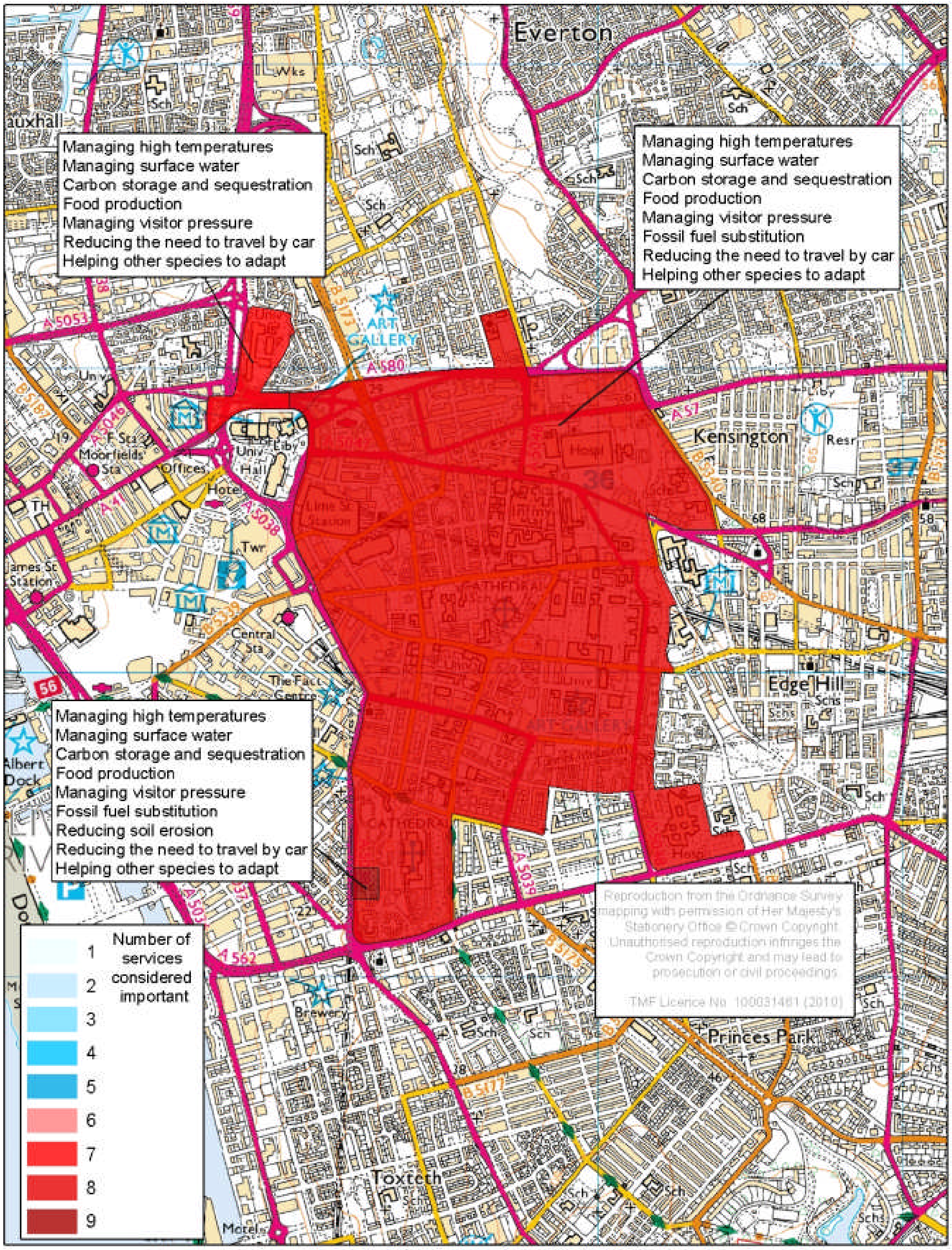
Local Authority	Ward	≥ 8 services	5 priority services
Liverpool	Princes Park		
Liverpool	Riverside		
Liverpool	Speke-Garston		
Liverpool	St Michael’s		
Liverpool	Tuebrook and Stoneycroft		
Liverpool	Warbeck		
Liverpool	Wavertree		
Liverpool	West Derby		
Liverpool	Woolton		
Liverpool	Yew Tree		
Sefton	Ainsdale		
Sefton	Birkdale		
Sefton	Blundellsands		
Sefton	Cambridge		
Sefton	Church		
Sefton	Derby		
Sefton	Duke’s		
Sefton	Ford		
Sefton	Harington		
Sefton	Kew		
Sefton	Linacre		
Sefton	Litherland		
Sefton	Manor		
Sefton	Meols		
Sefton	Molyneux		
Sefton	Netherton and Orrell		
Sefton	Norwood		
Sefton	Park		
Sefton	Ravemeols		
Sefton	St Oswald		
Sefton	Victoria		
St Helens	Billinge and Seneley Green		
St Helens	Blackbrook		
St Helens	Bold		
St Helens	Earlestown		
St Helens	Eccleston		
St Helens	Haydock		
St Helens	Moss Bank		
St Helens	Newton		
St Helens	Parr		
St Helens	Rainford		
St Helens	Sutton		
St Helens	Thatto Heath		
St Helens	Town Centre		
St Helens	West Park		
St Helens	Windle		
Wirral	Bebington		
Wirral	Bidston and St James		
Wirral	Birkenhead and Tranmere		
Wirral	Bromborough		
Wirral	Clatterbridge		
Wirral	Claughton		
Wirral	Eastham		

Local Authority	Ward	≥ 8 services	5 priority services
Wirral	Heswall		
Wirral	Leasowe and Moreton East		
Wirral	Liscard		
Wirral	Moreton West and Saughall Massie		
Wirral	New Brighton		
Wirral	Oxton		
Wirral	Pensby and Thingwall		
Wirral	Prenton		
Wirral	Rock Ferry		
Wirral	Seacombe		
Wirral	Upton		
Wirral	Wallasey		

Liverpool is a port located on the river Mersey; it is an area of significant regeneration within the Northwest. In the wards of Princes Park, Riverside, Everton, Kensington and Fairfield, Greenbank, St Michael's, Mossley Hill, Wavertree, Old Swan, Childwall, Church Knotty Ash and Cressington, eight green infrastructure services are considered important (managing high temperatures, managing surface water, carbon storage and sequestration, food production, managing visitor pressure, fossil fuel substitution, reducing the need to travel by car and helping other species adapt); managing riverine flooding, reducing soil erosion and managing coastal flooding are considered less important. Any development and investment in Liverpool should focus on *safeguarding* and *enhancing* the priority services, or any other services which are considered important.

Liverpool Knowledge Quarter is identified as a strategic employment site within the Regional Economic Strategy and is subject to significant change and restructuring. The area includes three universities, two cathedrals, the region's largest teaching hospital, the School of Tropical Medicine, Royal Liverpool Philharmonic Hall and a thriving mix of theatres, restaurants and bars. The majority of the site lies within the Central ward of Liverpool, the extreme northern and southern parts of the site lie within Everton to the North and Riverside/ Princes Park to the South. All of these wards have ≥ 8 services present and none have all 5 priority services, because managing riverine flooding is not considered a priority in Liverpool city centre. Existing and proposed green infrastructure in the area has previously been mapped through the Natural Economy Northwest project and is a case study for the forthcoming Green Infrastructure Valuation Toolbox being developed by a consortium of UK partners. Figure 41 shows, at a broad level, the climate change services provided by green infrastructure which are considered important to *safeguard* and *enhance* through the restructuring of the area. This could help to inform plans for the area.

Figure 41. Number of services considered important: Liverpool Knowledge Quarter



Appendix C. Reasoning behind service compatibility scores

The boxes below explore the compatibility of the climate change services provided by green infrastructure.

1. Carbon storage & sequestration – storing carbon in soils and vegetation

<u>1-2 Carbon storage & sequestration vs. Fossil fuel substitution (+)</u>

- Will depend on existing carbon density of the soil and vegetation on the site where biofuels may be grown.
- Will depend on nature of biofuels.
- Whilst biofuels are growing they will sequester some carbon. This will be released into the atmosphere when burnt, so will only be sequestered in the short term. But a new crop of biofuels can be grown in its place which will sequester the same amount of carbon. Therefore, some carbon is stored in the longer term.
- Woodlands could have continuous cover with any management work and thinnings used for fuel, in this way a longer term carbon store could still be maintained. It may provide less wood fuel and could cost more for the management works than if the stand was felled.
- Management works on trees (not in woodland) could also similarly be used for wood fuel.

<u>1-3 Carbon storage & sequestration vs. Material substitution (++)</u>

- Will depend on existing carbon density of soil that trees or other vegetation (to be used as a substitute for other materials) may be grown on and on existing vegetation.
- Will depend on nature of the trees or other vegetation grown.
- Whilst trees and other vegetation are growing, they will sequester some carbon. This will not be released into the atmosphere when they are harvested, but will continue to be stored in the products that they become. In addition, a new crop of trees or other vegetation can be grown in its place which will sequester more carbon (and will then form products which again will store this carbon, etc). Therefore, carbon continues to be sequestered and stored in the long term.
- Woodlands could have continuous cover with individual trees (or smaller stands) removed on rotation to be used as a substitute for other materials. In this way a longer term carbon store could still be maintained. It may provide less material and could cost more for the management works than if the stand was felled.
- Management works on trees (not in woodland) could also potentially be used for material.

<u>1-4 Carbon storage & sequestration vs. Food production (o)</u>

- Will depend on existing carbon density of soil that food is grown on and on existing vegetation.
- Will depend on nature of the food production.
- Intensive agriculture could lead to carbon emissions (e.g. if it degrades the soil).
- Sensitive management (and organic practices) could increase the carbon store (e.g. by fertilising with compost, organic matter, and using mulches).
- May be opportunities (e.g. on field margins) to sequester and store carbon (e.g. through planting of trees and woodland).
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and will sequester and store some carbon.

<u>1-5 Carbon storage & sequestration vs. Reducing the need to travel by car (++)</u>

- Providing green travel routes and local recreation areas should generally be compatible with carbon sequestration and storage.
- Carbon sequestration and storage could be increased by planting trees as part of the green travel routes and local recreation areas.

- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

1-6 Carbon storage & sequestration vs. Managing high temperatures (++)
- Managing high temperatures should generally be compatible with carbon sequestration and storage.
- Carbon sequestration and storage could be increased by planting trees as part of the management of high temperatures; this would also provide localised shading for people and buildings.

1-7 Carbon storage & sequestration vs. Managing water supply (+)
- Will depend on the nature of the vegetation. Vegetated surface will generally help to manage the water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers.
- All vegetation sequesters and stores carbon, but woodlands are the most effective. The roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).
- Will depend on the nature of the soils. For example, peaty soils are high in carbon and also hold a lot of water, maintaining base flows. Management of eroding peat soils will maintain the carbon store and will also improve water quality (less treatment to remove colour).

1-8 Carbon storage & sequestration vs. Managing riverine flooding (++)
- Vegetated surface will generally help to manage flooding by reducing the volume and timing of peak flows.
- All vegetation sequesters and stores carbon, but woodlands are the most effective. Woodlands are also potentially effective in managing riverine flooding as their canopy intercepts and temporarily stores water, their roots can increase infiltration into the ground (rather than it being converted to runoff), and they have a high surface roughness that slows down the progression of water (e.g. in floodplains). However, branches and debris in channels could increase flooding.
- For managing riverine flooding, it may be most desirable to build in water storage areas into vegetated areas, but this should be compatible with carbon storage and sequestration.
- Soils with high carbon content will generally have the ability to store more water, which may mean less flooding.

1-9 Carbon storage & sequestration vs. Managing coastal flooding (++)
- These services should generally be compatible.
- All vegetation sequesters and stores carbon, coastal sand dune systems included. In the coastal zone, dunes act as a natural flood defence.
- Soils with high carbon content will generally have the ability to store more water, which may mean less flooding.

1-10 Carbon storage & sequestration vs. Managing surface water (+)
- These services should generally be compatible.
- Vegetated surfaces will generally help to manage surface water by reducing the volume and timing of peak flows to drains.
- All vegetation sequesters and stores carbon, but woodlands are the most effective. Woodlands are also potentially effective in managing flooding as their canopy intercepts and temporarily stores water, their roots can increase infiltration into the ground (rather than it being converted to

runoff), and they have a high surface roughness that slows down the progression of water (e.g. in floodplains). However, branches and debris blocking drains could increase flooding.

- For managing surface water, it may be most desirable to build in water storage areas into vegetated areas, but this should be compatible with carbon storage and sequestration.
- Soils with high carbon content will generally have the ability to store more water, which may help reduce pressure on drains.

<u>1-11 Carbon storage & sequestration vs. Reducing soil erosion (++)</u>

- These services should generally be compatible.
- Vegetated surface will generally help to reduce soil erosion.
- All vegetation sequesters and stores carbon, but woodlands are the most effective. Woodlands are also effective in reducing soil erosion.
- In particular, where soils with high carbon content are eroding, re-vegetating these surfaces and taking other action to reduce the erosion will help to maintain the carbon store.

<u>1-12 Carbon storage & sequestration vs. Helping other species to adapt (++)</u>

- These services should generally be compatible.
- Increased vegetation for carbon storage and sequestration can also provide habitats, food sources, and spaces for species to move through.
- All vegetation sequesters and stores carbon, but woodlands are the most effective. Woodlands can also provide habitats, food sources, and spaces for species to move through. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Urban trees and woodlands can also provide habitats, food sources, and spaces for species to move through.
- Peatlands and mosslands store a large amount of carbon and are important habitats for other species. Re-vegetating areas such as these will provide both services.

<u>1-13 Carbon storage & sequestration vs. Managing visitor pressure (o)</u>

- The compatibility of these is dependent on management.
- Upland areas and lowland mosslands, where soils have high carbon content may be vulnerable to increasing pressure from visitors and associated erosion. This could reduce the carbon store. This will need careful management. This could be providing well signposted access routes and encouraging people to stay on these, designating certain areas of a site for limited access, encouraging people to use other sites which may be more resilient to visitor pressure (e.g. forests).
- Forests and woodland are the most effective vegetated stores of carbon; they are also high capacity recreational landscapes and could be used to divert visitors from more sensitive landscapes.

2. Fossil fuel substitution – replacing fossil fuels with sustainably managed biofuels

<u>2-3 Fossil fuel substitution vs. Material substitution (o)</u>

- One crop could provide vegetation for both material substitution and fossil fuel substitution; wood or vegetation not suitable for material substitution could be used for fossil fuel substitution.
- It is likely that residues from crops grown for material substitution could be used as biofuels; however, there is unlikely to be residue from crops grown as biofuels to be used for material substitution.

<u>2-4 Fossil fuel substitution vs. Food production (--)</u>

- It is unlikely that these two services are compatible.
- Trees and woodland at field margins could potentially be harvested for woodfuel.

- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and can also potentially be managed for woodfuel as well.

2-5 Fossil fuel substitution vs. Reducing the need to travel by car (o)

- Green infrastructure can provide local recreation areas and green walking and cycling routes which could reduce the need to travel by car. Depending on the vegetation planted and how it is managed, these areas could also be used for biofuels.
- Trees and woodland could be part of local recreation areas and on green travel routes; management works on these could be used for woodfuel.
- In order to maintain the attractiveness of local recreation areas and green travel routes so that people want to use them, it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less woodfuel and could cost more for the management works than if the stand was felled.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

2-6 Fossil fuel substitution vs. Managing high temperatures (o)

- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and, depending on the vegetation planted and how it is managed, could also be used for woodfuel.
- Trees and woodland in urban areas provide shading and evaporative cooling; management works on these could be used for woodfuel.
- In order to manage high temperatures it may mean felling smaller stands on rotation or selected trees rather than the whole stand, so that some cooling remains. It may provide less woodfuel and could cost more for the management works than if the stand was felled.

2-7 Fossil fuel substitution vs. Managing water supply (-)

- Vegetated surface will generally help to manage the water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers.
- Woodlands could be harvested for biofuels.
- The roots of trees can increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply. This may be especially true of conifer plantations.
- Water bodies can be incorporated into biofuel growing areas, which could potentially be used for irrigation.
- Trees and woodlands within urban areas (including street trees) can increase water infiltration into the soil; management works on these could be used for woodfuel.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

2-8 Fossil fuel substitution vs. Managing riverine flooding (o)

- Vegetated surfaces will generally help to manage riverine flooding by reducing the volume and timing of peak flows.
- Woodlands in floodplains and along stream and river sides could help manage flooding; these could also potentially be harvested for biofuels. Branches and debris in channels could increase flooding.
- Permanent water storage may not be an option if the crop is to be harvested, or would only be an option in selected parts of the site. If the site is to be used for temporary water storage, the vegetation will need to be able to withstand flooding, and the quality of the crop not be affected by flooding.

- In order to manage flooding it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less biofuels and could cost more for the management works than if the stand was felled
- If planted in rows parallel to water flows, this could increase flooding

2-9 Fossil fuel substitution vs. Managing coastal flooding (o)
- Vegetated surfaces will generally help to manage coastal flooding by reducing the volume and timing of tidal surges.
- Locating biofuels crops in coastal areas may not be practical for easy harvesting.
- Permanent water storage may not be an option if the crop is to be harvested, or would only be an option in selected parts of the site. If the site is to be used for temporary water storage, the vegetation will need to be able to withstand flooding, and the quality of the crop not be affected by flooding.
- In order to manage flooding it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less biofuels and could cost more for the management works than if the stand was felled.

2-10 Fossil fuel substitution vs. Managing surface water (o)
- Vegetated surfaces will generally help to manage surface water by reducing the volume and timing of peak flows.
- Trees and woodlands within urban areas (including street trees) can intercept rainwater; management works on these could be used for wood fuel. Branches and debris blocking drains could increase flooding.
- Permanent water storage may not be an option if the crop is to be harvested, or would only be an option in selected parts of the site. If the site is to be used for temporary water storage, the vegetation will need to be able to withstand flooding, and the quality of the crop not be affected by flooding.
- In order to manage surface water it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less biofuels and could cost more for the management works than if the stand was felled.
- If planted in rows parallel to water flows, this could increase flooding.

2-11 Fossil fuel substitution vs. Reducing soil erosion (o)
- Vegetation can help to stabilise soil that is vulnerable to erosion, and, depending on what is being grown, could also be harvested for biofuels.
- Trees and woodlands could be harvested for biofuels. This could mean felling of smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.
- Harvesting could disturb the soil and increase erosion.
- If planted in rows parallel to water and wind flows, soil erosion could be increased.

2-12 Fossil fuel substitution vs. Helping other species to adapt (o)
- Depends on existing land cover. For example, if biofuels are grown on high quality habitat then this will not help other species to adapt.
- Depends on the nature of the biofuel crop and management practices.
- Harvesting of biofuel crops could be disruptive for some species.
- Felling woodlands for fuel could mean less dead wood, which is beneficial for wildlife.
- In woodlands there is a huge amount of wood that could be extracted sustainably (under managed woodlands).
- If woodlands are being managed for biofuel production, the felling regime could be altered so that it is less disruptive to other species. This could mean felling smaller stands on rotation or selected trees rather than the whole stand. Rotation cropping may mean that diseases and pests do not

build up within woodlands. Open spaces in woodlands will be beneficial for wildlife. It may provide less biofuels and could cost more for the management works than if the stand was felled.
- Selected areas of the woodland could be harvested, whilst other areas are left specifically for wildlife.
- Traditional coppice would have biodiversity benefits.
- Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Urban trees and woodland could provide habitats, food sources, and spaces for species to move through; management works on these could be used for wood products

2-13 Fossil fuel substitution vs. Managing visitor pressure (o)
- Woodlands could be managed as a high capacity recreational resource, with any management work and thinnings used for fuel.
- If woodlands are being managed for biofuel production, the felling regime could be altered so that they can provide an attractive visitor resource. This could mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less biofuels and could cost more for the management works than if the stand was felled.
- Management works on urban trees and woodland, which increases the attractiveness of these areas as a visitor resource, could be used for wood fuel.
- Other biofuel crops could potentially have some limited access around fields.

3. Material substitution – replacing materials such as concrete and steel (which involve high fossil fuel consumption in their production) with sustainably managed wood (and other natural materials)

3-4 Material substitution vs. Food production (--)
- It is unlikely that these two services are compatible.
- Trees and woodland at field margins could potentially be harvested for wood.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and can potentially be managed for wood as well.

3-5 Material substitution vs. Reducing the need to travel by car (o)
- Green infrastructure can provide local recreation areas and green walking and cycling routes which could reduce the need to travel by car. Depending on the vegetation planted and how it is managed, these areas could also be used for material substitution.
- Trees and woodland could be part of local recreation areas and on green travel routes; management works on these could be used for wood products.
- In order to maintain the attractiveness of local recreation areas and green travel routes so that people want to use them, it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

3-6 Material substitution vs. Managing high temperatures (o)
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and, depending on the vegetation planted and how it is managed, could also be used for material substitution.
- Trees and woodland in urban areas provide shading and evaporative cooling; management works on these could be used for wood products.
- In order to manage high temperatures it may mean felling smaller stands on rotation or selected trees rather than the whole stand, so that some cooling remains. It may provide less material and could cost more for the management works than if the stand was felled.

3-7 Material substitution vs. Managing water supply (-)

- Vegetated surface will generally help to manage the water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers.
- Woodlands could be harvested for material substitution.
- The roots of trees can increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply. This may be especially true of conifer plantations.
- Water bodies can be incorporated into areas producing timber, which could potentially be used for irrigation.
- Trees and woodlands within urban areas (including street trees) can increase water infiltration into the soil; management works on these could be used for wood products.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

3-8 Material substitution vs. Managing riverine flooding (o)

- Vegetated surfaces will generally help to manage riverine flooding by reducing the volume and timing of peak flows.
- Woodlands in floodplains and along stream and river sides could help manage flooding; these could also potentially be harvested for timber. Branches and debris in channels could increase flooding.
- Permanent water storage may not be an option if the crop is to be harvested, or would only be an option in selected parts of the site. If the site is to be used for temporary water storage, the vegetation will need to be able to withstand flooding, and the quality of the crop not be affected by flooding.
- In order to manage flooding it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.
- If planted in rows parallel to water flows, this could increase flooding.

3-9 Material substitution vs. Managing coastal flooding (o)

- Vegetated surfaces will generally help to manage coastal flooding by reducing the volume and timing of tidal surges.
- Locating crops for wood in coastal areas may not be practical for easy harvesting.
- Permanent water storage may not be an option if the crop is to be harvested, or would only be an option in selected parts of the site. If the site is to be used for temporary water storage, the vegetation will need to be able to withstand flooding, and the quality of the crop not be affected by flooding.
- In order to manage flooding it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.

3-10 Material substitution vs. Managing surface water (o)

- Vegetated surfaces will generally help to manage surface water by reducing the volume and timing of peak flows.
- Trees and woodlands within urban areas (including street trees) can intercept rainwater; management works on these could be used for wood products. Branches and debris blocking drains could increase flooding.
- Permanent water storage may not be an option if the crop is to be harvested, or would only be an option in selected parts of the site. If the site is to be used for temporary water storage, the

vegetation will need to be able to withstand flooding, and the quality of the crop not be affected by flooding.
- In order to manage surface water it may mean felling smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.
- If planted in rows parallel to water flows, this could increase flooding.

<u>3-11 Material substitution vs. Reducing soil erosion (o)</u>
- Vegetation can help to stabilise soil that is vulnerable to erosion, and, depending on what is being grown, could also be harvested for its material.
- Trees and woodlands could be harvested for material. This could mean felling of smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.
- Harvesting could disturb the soil and increase erosion.
- If planted in rows parallel to water and wind flows, soil erosion could be increased.

<u>3-12 Material substitution vs. Helping other species to adapt (o)</u>
- Compatibility will depend primarily on the nature of the vegetation being grown (for material substitution) and on harvesting regimes.
- Certain harvesting regimes could be disruptive for other species.
- Woodlands provide habitats, food sources, and spaces for species to move through; these woodlands could also be managed for timber to replace other materials.
- Felling woodlands for timber could mean less dead wood, which is beneficial for wildlife.
- In woodlands there is a huge amount of wood that could be extracted sustainably.
- If woodlands are being managed for timber production, the felling regime could be altered so that it is less disruptive to other species. This could mean felling smaller stands on rotation or selected trees rather than the whole stand. Rotation cropping may mean that diseases and pests do not build up within woodlands. Open spaces in woodlands will be beneficial for wildlife. It may provide less timber and could cost more for the management works than if the stand was felled.
- Selected areas of the woodland could be harvested, whilst other areas are left specifically for wildlife.
- Traditional coppice would have biodiversity benefits.
- Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Trees and woodlands within urban areas (including street trees) can provide habitats, food sources, and spaces for species to move through; management works on these could be used for wood products.

<u>3-13 Material substitution vs. Managing visitor pressure (o)</u>
- Compatibility will depend primarily on the nature of the vegetation being grown (for material substitution) and on harvesting regimes.
- Woodlands are a high capacity recreational resource; these woodlands could also be managed for timber to replace other materials. This could mean felling of smaller stands on rotation or selected trees rather than the whole stand. It may provide less material and could cost more for the management works than if the stand was felled.
- Trees and woodlands within urban areas (including street trees) make these areas more attractive to visitors; management works on these could be used for wood products.

4. Food production – reducing food miles and altering agricultural practices (such as organic farming) to reduce carbon emissions

<u>4-5 Food production vs. Reducing the need to travel by car (+)</u>

- Green infrastructure can provide local recreation areas and green walking and cycling routes which could reduce the need to travel by car. These areas could also be used for community food production.
- Community farms, orchards and allotments could provide local recreation areas, potentially reducing the need for people to travel.
- Other farms could also diversify from food production to attract visitors (e.g. having tea rooms and selling local produce, maize mazes).
- Planting along road corridors and green travel routes could provide a food source for other species, including bees and insects, as well as food for people.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and can also make local recreation areas and green travel routes more attractive.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

4-6 Food production vs. Managing high temperatures (+)

- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures. The vegetation planted could also provide a food source for both people and other species.
- Although in urban areas, where managing high temperatures will be especially important, there is limited space for large scale food production, there are still opportunities for urban agriculture and food production.
- Community farms, orchards and allotments can be incorporated into urban areas.
- Other green areas could be used for food production and the vegetation planted in these areas could include species that produce food (for both humans and other species). Private gardens, local recreation areas, general amenity spaces and green roofs provide opportunities for more food growing, and edible fruit and nut trees could be planted more often, including as street trees.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and can help manage high temperatures.
- Trees and woodlands can also provide shade for agricultural stock.

4-7 Food production vs. Managing water supply (-)

- Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate the ground, improving its quality and maintaining base flows in rivers.
- Organic farming is particularly useful for managing the water supply as potentially harmful pesticides and chemicals are not used.
- Water bodies can be incorporated into agricultural areas which could potentially be used for irrigation.
- Intensive agriculture could degrade the soil, leading to poor water management.
- Agriculture generally needs a water supply.
- Trampling by stock could compact soils and reduce the infiltration capacity, thereby reducing water entering ground water.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).
- Permanent vegetation grown in field margins could help to trap and remove sediment, improving water quality.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and can increase water infiltration in compacted soils. Woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.

4-8 Food production vs. Managing riverine flooding (-)

- Vegetated surfaces will generally help to manage riverine flooding by reducing the volume and timing of peak flows. Vegetation grown as crops will also do this, although its effectiveness will depend upon the stage of the growing season.
- Permanent vegetation grown in field margins can assist in managing riverine floods.
- Crops grown in rows could channel runoff and increase flood risk, unless planting at right angles to flow paths.
- Agriculture (urban or rural) can incorporate water bodies to permanently or temporarily store water.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and are also effective at intercepting water. Branches and debris in channels could increase flooding.

4-9 Food production vs. Managing coastal flooding (-)

- Vegetated surfaces will generally help to manage coastal flooding by reducing the volume and timing of tidal surges. Vegetation grown as crops will also do this, although its effectiveness will depend upon the stage of the growing season.
- Permanent vegetation grown in field margins can assist in managing coastal floods.
- Crops grown in rows could channel runoff and increase flood risk, unless planting at right angles to flow paths.
- Coastal habitats can incorporate water bodies to permanently or temporarily store water.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and are also effective at intercepting water. Branches and debris in channels could increase flooding.

4-10 Food production vs. Managing surface water (-)

- Vegetated surfaces will generally help to manage surface water by reducing the volume and timing of peak flows. Vegetation grown as crops will also do this, although its effectiveness will depend upon the stage of the growing season.
- Permanent vegetation grown in field margins can assist in managing surface water.
- Crops grown in rows could channel runoff, unless planting at right angles to flow paths.
- Urban and other agriculture can incorporate ponds and areas to store surface water.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and are also effective at intercepting water. Branches and debris blocking drains could increase flooding.

4-11 Food production vs. Reducing soil erosion (-)

- Farming practices could lead to increased soil erosion.
- Upland trampling by stock could lead to erosion of vulnerable landscapes.
- Organic farming is especially effective in reducing soil erosion; this is largely because of reduced crop rotation, fewer tillage operations and the use of green fertilisers.
- Windbreaks, such as hedges or strips planted with coarse grass at field margins can reduce soil erosion from wind.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and help to stabilise the soil.

4-12 Food production vs. Helping other species to adapt (o)

- Monocultures or large expanses of one crop are not useful for helping other species to adapt.
- Organic farming is particularly useful for other species as potentially harmful pesticides and chemicals are not used.
- Agri-environment schemes encourage the management of field margins/ or set aside of whole fields for biodiversity, particularly for the provision of food for birds.

- Crops grown for human consumption can also provide a food source for other species (e.g. pollen and nectar for bees and other insects).
- Food production in urban areas (e.g. in community farms, orchards and allotments) can also provide food source for other species (e.g. pollen and nectar for bees and other insects).
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and also provide habitats, food sources, and spaces for species to move through.
- Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Orchards grow fruit and provide food sources (e.g. nectar and pollen) for other species.

4-13 Food production vs. Managing visitor pressure (o)

- Community farms could provide an alternative visitor destination, reducing pressure on more vulnerable landscapes.
- Other farms could also diversify from food production to attract visitors (e.g. having tea rooms and selling local produce, maize mazes).
- Upland trampling by stock and by visitors could lead to erosion of vulnerable landscapes, careful management will be needed.
- Trees and woodlands can provide berries, fruit, nuts, fungi, and game (e.g. venison) for human consumption and less vulnerable to visitor pressure. In urban areas they can increase the attractiveness for visitors.

5. Reducing need to travel by car – providing local recreation areas and green travel routes to encourage walking and cycling

5-6 Reducing the need to travel by car vs. Managing high temperatures (++)

- These services should generally be compatible.
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and green areas could also provide local recreation and green travel routes, thereby reducing the need to travel by car.
- Tree lined green travel routes in urban areas will provide shading for people walking and cycling.
- Local green recreation areas reduce temperatures and reduce the need to travel further for recreational purposes. Trees and woodland provide the best shade and make recreational areas more attractive.
- Water courses provide evaporative cooling and can provide green travel routes and recreation.
- Green travel routes can also provide paths for air flows into urban areas.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-7 Reducing the need to travel by car vs. Managing water supply (+)

- These services should generally be compatible.
- Green infrastructure can provide local recreation areas and green walking and cycling routes. Green areas can also help to manage water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers.
- The roots of trees can increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).
- Water bodies and courses supply water and can be used as walking and cycling routes and for recreation.
- Vegetation along a green travel route can help to clean the water coming off the road.

- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-8 Reducing the need to travel by car vs. Managing riverine flooding (++)

- These services should generally be compatible.
- Green infrastructure can provide local recreation areas and green walking and cycling routes. Green areas can also manage flooding, by reducing the volume and timing of peak river flows.
- Local recreation grounds and green travel routes alongside rivers that can double up as floodplain in times of need can assist both of these services
- Trees and woodland can be part of attractive local recreation areas and are also very beneficial in terms of intercepting water. Branches and debris in channels could increase flooding.
- Water courses store and convey water and can be used as walking and cycling routes and for recreation.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-9 Reducing the need to travel by car vs. Managing coastal flooding (+)

- These services should generally be compatible.
- Green infrastructure can provide local recreation areas and green walking and cycling routes. Green areas can also manage flooding, by reducing the volume and timing of tidal surges.
- Local recreation grounds and green travel routes at the coast that can double up as floodplain in times of need can assist both of these services.
- Trees and woodland can be part of attractive local coastal recreation areas and are also very beneficial in terms of intercepting water.
- Sand dunes and coastal systems can be fragile if subjected to high amounts of visitor pressure, the use of coastal areas as local recreation grounds will require careful management.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-10 Reducing the need to travel by car vs. Managing surface water (+)

- These services should generally be compatible.
- Green infrastructure can provide local recreation areas and green walking and cycling routes. Green areas can also manage surface water, especially when designed to intercept, store and infiltrate water to reduce the timing and volume of peak flows.
- Trees and woodland can be part of attractive local recreation areas and are also very beneficial in terms of intercepting water. Branches and debris blocking drains could increase flooding.
- Water bodies also can be part of attractive local recreation areas and provide storage areas for water. Local recreation areas can also incorporate sustainable urban drainage systems.
- Water courses store and convey water and can be used as walking and cycling routes and for recreation.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-11Reducing the need to travel by car vs. Reducing soil erosion (-)

- Recreation and walking and cylcing could increase erosion from vulnerable soils (e.g. through trampling). This will need careful management. This could be by providing well signposted access routes and encouraging people to stay on these, maintenance of footpaths, restricting access to the most vulnerable areas, encouraging people to use sites which are more resilient to erosion (e.g. forests).
- Planting vegetation, such as trees and woodlands, on soils most vulnerable to erosion may help to stabilise these so that they can continue to provide local recreation and green travel routes.

- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-12 Reducing the need to travel by car vs. Helping other species to adapt (+)
- There may be some conflict here, but it is not impossible to manage.
- Local recreation areas in towns and cities can provide habitats, food sources, and spaces for species to move through. However, not all green infrastructure types will have the same value for wildlife. For example, areas of mown grass used for sport will have less value than 'wilder' areas with a variety of plants, shrubs and trees. Local recreation areas can be managed sensitively for wildlife to incorporate more of these features onto a site.
- Transport corridors with green verges can aid species migration, especially when they are aligned north-south and managed sensitively for wildlife. East-west transport corridors could act as barriers to species movement although careful design could reduce this effect (e.g. the orientation of bridges crossing motorways should be altered to minimise the amount of shade they cast and thereby allow butterflies to pass underneath them).
- Vegetation on walking and cycling routes can provide habitats, food sources, and spaces for species to move through. Strategic wildlife movement corridors could be aligned with these routes.
- Recreation and habitat management may sometimes need careful management, especially where habitats are more sensitive to disturbance. However, combining the two, especially close to where people live, provides a valuable educational tool.
- Trees and woodlands can provide habitats, food sources, and spaces for species to move through and can also make local recreation areas and green travel routes more attractive. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

5-13 Reducing the need to travel by car vs. Managing visitor pressure (++)
- These services should generally be compatible.
- Providing local recreation areas will assist both of these services.
- Vulnerable landscapes may often be accessed by car; the provision of local recreation spaces may divert some of the pressure from these vulnerable areas (as people feel less of a need to 'escape to the country' and reduce car travel).
- Green travel routes could also help relieve pressure on vulnerable landscapes as an alternative recreation ground. They can also connect people to high capacity landscapes. High capacity landscapes should also be accessible by public transport.
- Providing good quality green travel routes and local recreation areas will not necessarily stop people travelling by car.

6. Managing high temperatures – particularly in urban areas, where evaporative cooling and shading provided by green infrastructure can ensure that towns and cities continue to be attractive and comfortable places to live, work, visit and invest

6-7 Managing high temperatures vs. Managing water supply (++)
- These services should generally be compatible.
- Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate the ground, improving its quality and maintaining base flows in rivers.
- Trees provide shade and evaporative cooling, and their roots can also break up compacted soils and increase water infiltration.
- The roots of trees can increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply. However, urban woodlands

(which are most beneficial for managing high temperatures as this is where people are) are unlikely to be on this large scale.

- Vegetation in urban areas can assist in managing high temperatures and also help to clean the water coming off the roads, footpaths and buildings. Sustainable urban drainage systems and green roofs can be designed to improve water quality.
- Water bodies and courses can supply water and also help to manage high temperatures through evaporative cooling. Stored water can be re-used for irrigating vegetation, thereby ensuring that it provides evaporative cooling to manage high temperatures during droughts.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

6-8 Managing high temperatures vs. Managing riverine flooding (++)

- These services should generally be compatible.
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and can also manage riverine flooding, especially when designed to intercept, store and infiltrate water.
- Trees and woodland provide the best shade and are also very beneficial in terms of intercepting water. Branches and debris in channels could increase flooding.
- Planting trees as part of floodplain woodland would also assist in the management of high temperatures, particularly when the floodplain is part of an urban area.
- Urban recreation grounds next to rivers can be used to store water in times of need; these areas will also help cool urban areas.

6-9 Managing high temperatures vs. Managing coastal flooding (+)

- These services should generally be compatible.
- Coastal areas do not suffer from high temperatures to the same extent as urban areas, but vegetation present in these areas will help cool them.
- Large shade trees which are the best at providing shade and managing high temperatures may not be suitable in a coastal habitat.
- Trees and woodland provide the best shade and are also beneficial for intercepting water.

6-10 Managing high temperatures vs. Managing surface water (++)

- These services should generally be compatible.
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and can also manage surface water, especially when designed to intercept, store and infiltrate water.
- Trees and woodland provide the best shade and are also very beneficial in terms of intercepting water. Branches and debris blocking drains could increase flooding.
- Trees are needed in denser urban areas, where there is little opportunity to increase green cover by other means.
- Large canopied mature trees provide the most shade and will also capture the most water.
- Water bodies, courses and features help to manage high temperatures through evaporative cooling.
- Green roofs can help manage high temperatures and reduce the rate and volume of surface water runoff. They are most needed in denser urban areas, where there is little opportunity to increase green cover by other means.

6-11 Managing high temperatures vs. Reducing soil erosion (++)

- These services should generally be compatible.
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and can also reduce soil erosion.

- Trees and woodlands provide shade and help to stabilise soil.

6-12 Managing high temperatures vs. Helping other species to adapt (+)

- These services should generally be compatible.
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and can also provide habitats, food sources, and spaces for species to move through.
- Not all green infrastructure types will have the same value for wildlife.
- Trees and woodland provide the best shade. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Trees are needed in denser urban areas, where there is little opportunity to increase green cover by other means. Increasing tree cover in urban areas with a high proportion of built surfaces should be beneficial to wildlife.
- Street trees can also be used to link habitats.
- Large canopied mature trees provide the most shade and are also beneficial to wildlife.
- Water bodies, courses and features help to manage high temperatures through evaporative cooling and can also be beneficial for wildlife
- Green roofs can help manage high temperatures and are beneficial to wildlife (especially if the substrate type and depth is varied over the roof). They are most needed in denser urban areas, where there is little opportunity to increase green cover by other means.

6-13 Managing high temperatures vs. Managing visitor pressure (++)

- These services should generally be compatible.
- Green infrastructure provides evaporative cooling and shading, and can allow air to flow into urban areas. This helps to manage high temperatures and will ensure that they continue to be comfortable places to visit in summer, thereby ensuring their viability as a visitor attraction.
- Urban areas have a high capacity in terms of the visitors that they can accommodate, so could divert some pressure from more vulnerable landscapes.
- Woodlands provide a resilient visitor attraction and also help to manage high temperatures,
- Water bodies, courses and features help to manage high temperatures through evaporative cooling and are also visitor attractions.
- Some sites may be more vulnerable to increased visitor pressure. These should be carefully managed.

7. Managing water supply – green infrastructure can provide places to store water for re-use, allows water to infiltrate into the ground sustaining aquifers and river flows, and can catch sediment and remove pollutants from the water, thereby ensuring that water supply and quality is maintained

7-8 Managing water supply vs. Managing riverine flooding (++)

- Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate the ground, improving its quality and maintaining base flows in rivers. These functions could also help in managing flooding.
- Water bodies and courses help to both manage flooding and supply.
- Increasing water storage and retention areas will help to manage riverine flooding and can also be used as a water supply (e.g. grey water recycling systems for irrigation of green infrastructure).
- Woodlands on stream and river banks and in floodplains can help to manage flooding and may reduce sediment entering the water supply. Branches and debris in channels could increase flooding.
- Woodlands will help manage flooding and the roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.

- In upland areas, peatlands act to retain water and thereby manage flooding. Retaining waters also ensures a water supply.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

7-9 Managing water supply vs. Managing coastal flooding (+)

- Water bodies and courses in the coastal environment help to both manage flooding and supply.
- Increasing water storage and retention areas will help to manage coastal flooding and can also be used as a water supply (e.g. grey water recycling systems for irrigation of green infrastructure).
- Woodlands will help manage flooding and the roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply. Also woodlands may not be suitable to plant in the coastal zone.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

7-10 Managing water supply vs. Managing surface water (+)

- Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate the ground, improving its quality and maintaining base flows in rivers. These functions will also assist with managing surface water.
- Water bodies and courses help to both manage surface water and supply.
- Increasing water storage and retention areas will help to manage surface water and can also be used as a water supply (e.g. grey water recycling systems for irrigation of green infrastructure).
- Woodlands will help manage surface water and the roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply. However, smaller scale tree planting in urban areas would be unlikely to have this impact. Branches and debris blocking drains could increase flooding.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

7-11 Managing water supply vs. Reducing soil erosion (+)

- Reducing erosion will mean less sediment in and hence better quality of water supplies.
- Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers. Vegetated areas will also stabilise the soil, reducing erosion.
- Trees and woodlands planted alongside streams and rivers and on bare ground can stabilise the soil, reducing erosion and thereby helping to control sediment entering the water (hence maintaining its quality). The roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

7-12 Managing water supply vs. Helping other species to adapt (o)

- Water bodies ensure a water supply and also provide habitats (and water) for species. Man-made reservoirs may have less biodiversity value.

- Will depend on the nature of the vegetation. Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers. Vegetated areas will also provide habitats, food sources, and spaces for species to move through.
- Woodlands will help some species to adapt and the roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

7-13 Managing water supply vs. Managing visitor pressure (o)

- Water bodies (including reservoirs) ensure a water supply and are also key attractions for visitors.
- Will depend on the nature of the vegetation. Vegetated surfaces will generally help to manage the water supply, allowing water to infiltrate into the ground, improving its quality and maintaining base flows in rivers. Vegetated areas could also be attractive to visitors.
- Woodlands provide a resilient visitor attraction and the roots of trees can also increase water infiltration into the ground (rather than it being converted to runoff). However, woodlands could reduce water yields due to their own use of the water; so on a large scale could be incompatible with managing a water supply.
- Increased visitor pressure in vulnerable upland peatland areas could potentially increase erosion and thereby reduce their capacity to retain water (and hence manage the water supply). Increased visitor pressure would need to be carefully managed.
- There may be some instances (e.g. where ground is contaminated) where it is undesirable for water to infiltrate into the ground (as this may wash out contaminants to aquifers or water courses and bodies).

8. Managing riverine flooding – green infrastructure can provide water storage and retention areas, reducing and slowing down peak flows, and thereby helping to alleviate river flooding

8-9 Managing riverine flooding vs. Managing coastal flooding (++)

- These services should be compatible.
- Green infrastructure used to manage river flooding should also help to manage coastal water flooding, should it occur on the same site.

8-10 Managing riverine flooding vs. Managing surface water (++)

- These services should be compatible.
- Green infrastructure used to manage river flooding should also help to manage surface water flooding, should it occur on the same site.
- Branches and debris in channels and blocking drains could increase flooding.
- All green infrastructure will slow the flow of water in the landscape.

8-11 Managing riverine flooding vs. Reducing soil erosion (+)

- These services should generally be compatible.
- Woodlands on stream and river banks and in floodplains can help to manage flooding and reduce soil erosion by stabilising banks. Branches and debris in channels could increase flooding.
- In upland areas, peatlands act to retain water and thereby manage flooding. Ensuring that they have adequate vegetation cover also reduces their erosion.
- If the area was under intense pressure from flooding, this may worsen the issue of soil erosion.

8-12 Managing riverine flooding vs. Helping other species to adapt (+)

- These services should generally be compatible.

- Some species (including tree species) may not be well adapted to periods of flood.
- Many habitats can help to manage river flooding, including wetlands and wet woodlands. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Floodplain woodland restoration could be very good for biodiversity as this is a rare habitat. Branches and debris in channels could increase flooding, but may be beneficial for wildlife.

8-13 Managing riverine flooding vs. Managing visitor pressure (++)

- These services should generally be compatible.
- Wetlands, water storage and retention areas could also be managed for recreation purposes, thereby creating attractive landscapes for people to visit which may help to divert visitor pressure from other more sensitive landscapes. Boardwalk features can allow people to still access wet sites.
- Recreational areas alongside rivers can also act as temporary water storage areas.
- Floodplain forests can retain and slow down water to manage peak flows, and also provide a resilient visitor attraction. Branches and debris in channels could increase flooding.

9. Managing coastal flooding – green infrastructure can provide water storage and retention areas, reducing and slowing down tidal surges, and thereby helping to alleviate coastal flooding

9-10 Managing coastal flooding vs. Managing surface water (++)

- These services should generally be compatible.
- Green infrastructure used to manage coastal flooding should also help to manage surface water flooding, should it occur on the same site.
- All green infrastructure will slow the flow of water in the landscape.

9-11 Managing coastal flooding vs. Reducing soil erosion (+)

- These services should generally be compatible.
- In coastal areas, establishment of vegetation may stabilise eroding dune systems and reduce long shore drift. The dune system acts as a natural flood defence.
- If the area was under intense pressure from flooding, this may worsen the issue of soil erosion.
- Wetland habitats reduce the velocity of waves, and help prevent flooding inland of the site, thus also protecting the soils of these coastal areas.

9-12 Managing coastal flooding vs. Helping other species to adapt (+)

- These services should generally be compatible.
- Some species (including tree species) may not be well adapted to periods of flood in their habitat.
- Many habitats can help to manage coastal flooding, including dune systems, wetlands, wet woodlands. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Managed realignment and creation of new green infrastructure habitats may destroy other habitats currently protected by manmade sea defences.

9-13 Managing coastal flooding vs. Managing visitor pressure (++)

- These services should generally be compatible.
- Dune systems, wetlands, water storage and retention areas which help to manage coastal flooding could be managed for recreation purposes, thereby creating attractive landscapes for people to visit which may help to divert visitor pressure from other more sensitive landscapes. Boardwalk features can allow people to still access wet sites.

10. Managing surface water – urban green infrastructure can help to manage surface water and sewer flooding by reducing the rate and volume of water runoff; it intercepts water, allows it to infiltrate into the ground, and provides permanent or temporary storage areas

10-11 Managing surface water vs. Reducing soil erosion (++)

- These services should generally be compatible.
- Using sustainable urban drainage systems (SUDS) schemes in urban areas can help reduce run off and the vegetation can also help reduce soil erosion through strategic planting to stabilise soils.
- Branches and debris blocking drains could increase flooding.
- If an area is under intense pressure from surface water flooding, this may worsen the issue of soil erosion.

10-12 Managing surface water vs. Helping other species to adapt (++)

- These services should generally be compatible.
- Altering the way we manage water in the urban landscape, through increased use and functionality of green infrastructure and SUDS will provide new habitats in an often harsh urban environment.
- Trees and woodlands can help to manage surface water. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Branches and debris blocking drains could increase flooding.
- In urban areas, green roofs are particularly useful for providing these two services.

10-13 Managing surface water vs. Managing visitor pressure (++)

- These services should generally be compatible.
- Surface water storage and retention areas could also be managed for recreation purposes, thereby creating attractive landscapes for people to visit which may help to divert visitor pressure from other more sensitive landscapes.
- Recreational areas can also act as temporary water storage areas
- Woodlands intercept water, break up the soil allowing greater infiltration, and slow down the progression of water across the surface, and also provide a resilient visitor attraction. Branches and debris blocking drains could increase flooding.

11. Reducing soil erosion – using vegetation to stabilise soils that many be vulnerable to increasing erosion

11-12 Reducing soil erosion vs. Helping other species to adapt (++)

- These services should generally be compatible.
- Vegetation (including trees and woodland) can stabilise soils and provide a habitat for species. Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.
- Leaving some patches of eroding soil may be beneficial for certain species (e.g. for mining bees).
- Preventing sediment transport could also protect other sensitive habitats downstream.

11-13 Reducing soil erosion vs. Managing visitor pressure (-)

- Attracting large amounts of visitors to a site could increase erosion from vulnerable soils (e.g. through trampling). This will need careful management. This could be by providing well signposted access routes and encouraging people to stay on these, maintenance of footpaths, restricting access to the most vulnerable areas, encouraging people to use other sites which may be more resilient to erosion from visitor pressure (e.g. forests).
- Planting vegetation, such as trees and woodlands, on soils most vulnerable to erosion may help to stabilise these so that they can continue to attract visitors.

12. Helping other species to adapt – providing a more vegetated and permeable landscape through which species can move northwards to new 'climate spaces'

12-13 Helping other species to adapt vs. Managing visitor pressure (-)

- Combining visitors and habitat management may sometimes need careful management, especially where habitats are more sensitive to disturbance. However, combining the two provides a valuable educational tool. Wildlife sites which help other species to adapt and are accessible to people can provide information to raise awareness and inform people about the protection of vulnerable areas.
- Biodiversity can attract funding to enhance local visitor attractions, encouraging people not to travel as far for high quality recreational resources. Biodiverse sites are popular with the public and therefore attract funding for improvement (e.g. construction of a visitor centre). If locally biodiverse sites are made more attractive then the need to travel far for a high quality recreational resource is reduced.
- People like to recreate in natural areas which are biodiverse.
- Attracting large amounts of visitors to a site could lead to pressure on the site and its wildlife. This will need careful management. This could be by providing well signposted access routes and encouraging people to stay on these, designating certain areas of a site for wildlife only (or access in guided groups), encouraging people to use other sites which may be more resilient to visitor pressure and could still accommodate wildlife (e.g. forests).
- Mixed tree species should be used in woodlands that are the most beneficial for wildlife. Monocultures will be of the least value. Planting woodlands on other high quality habitat will not help other species to adapt.

13. Managing visitor pressure – providing a recreation and visitor resource for a more outdoors lifestyle, and helping to divert pressure from landscapes which are sensitive to climate change

Appendix D. Reasoning behind service prioritisation scores

The reasoning behind the scores in table 9 are given below. Scores are out of 3 (where 3 is highest and 1 is lowest), the final summed score is out of 12 (where 12 is the highest).

Carbon storage and sequestration = 11
Need for mitigation/adaptation: probability = 3
Climate change is now inevitable yet its severity depends upon emissions reductions. If the world continues emitting greenhouse gases like carbon dioxide at today's levels then average global temperatures could rise by up to 6°C by the end of this century[9].

Need for mitigation/adaptation: magnitude = 3
As for 'need for mitigation/adaptation: probability'.

Potential for green infrastructure as a solution: effectiveness = 3
Green infrastructure is a highly effective carbon store and also sequesters (or removes) carbon from the atmosphere. It must be borne in mind that carbon stored in green infrastructure has the potential to act as a source in the future.

Potential for green infrastructure as a solution: practicality = 2
Using green infrastructure to store and sequester carbon has moderate potential in terms of practicalities. The main issue is that of space, the UK does not have enough land to store all the carbon it emits.

Fossil fuel substitution = 9
Need for mitigation/adaptation: probability = 3
As for carbon storage and sequestration.

Need for mitigation/adaptation: magnitude = 3
As for carbon storage and sequestration.

Potential for green infrastructure as a solution: effectiveness = 2
Green infrastructure can provide a renewable energy source and make some contribution to reducing greenhouse gas emissions. Its overall contribution to meeting energy demand is fairly low. There are potentially other renewable energy sources which will make more of a contribution.

Potential for green infrastructure as a solution: practicality = 1
Green infrastructure cannot wholly substitute fossil fuels due to issues with the amount land needed. A further barrier could be public perception. A survey of public opinions to forestry found that 53% of respondents agree or strongly agree that 'cutting down forests and woodland makes climate change worse, even if they are replanted'[112].

Material substitution = 9
Need for mitigation/adaptation: probability = 3
As for carbon storage and sequestration.

Need for mitigation/adaptation: magnitude = 3
As for carbon storage and sequestration.

[112] Forestry Commission (2009). Public Opinion of Forestry. www.forestry.gov.uk/pdf/POFUK2009final.pdf/$FILE/POFUK2009final.pdf

Potential for green infrastructure as a solution: effectiveness = 2
Wood based products can replace other construction materials with higher embedded energy and continue to act as a carbon store.

Potential for green infrastructure as a solution: practicality = 1
There is probably not enough land in the UK to grow timber to fully replace other materials. With wood products there are few timber processing plants in the Northwest and a lack of established production chains. It is possible to establish these chains.

Food production = 10
Need for mitigation/adaptation: probability = 3
As for carbon storage and sequestration.

Need for mitigation/adaptation: magnitude = 3
As for carbon storage and sequestration.

Potential for green infrastructure as a solution: effectiveness = 2
The potential for carbon reductions to be achieved through changes in the way food is produced is moderate. Organic agriculture and reducing food miles have potential. Increasing local food produce will not necessarily reduce supermarket imports of foreign foods.

Potential for green infrastructure as a solution: practicality = 2
Under utilised spaces in towns and cities can easily be modified to produce food, but there are barriers to local food production in the form of lack of available land where people are concentrated.

Reducing the need to travel by car = 9
Need for mitigation/adaptation: probability = 3
As for carbon storage and sequestration.

Need for mitigation/adaptation: magnitude = 3
As for carbon storage and sequestration.

Potential for green infrastructure as a solution: effectiveness = 1
Providing green travel routes and local recreation areas will not necessarily alter people's habits with regards to travel.

Potential for green infrastructure as a solution: practicality = 2
The provision of green travel routes is relatively straightforward and can be incorporated into new developments at relatively low costs. Retrofitting green travel routes is more difficult than incorporating into new developments. The quality of existing local recreation areas can be enhanced to attract visitors to them. It may be difficult to create significant new recreation areas in urban areas due to land demands.

Managing high temperatures = 11
Need for mitigation/adaptation: probability = 2
Climate change modelling suggests that temperatures experienced during the European summer heatwave of 2003 could be considered normal by the 2040s and cool by the end of the century[113].

Need for mitigation/adaptation: magnitude = 3
The European summer heatwave of 2003 claimed an estimated 52,000 lives across Europe[114] and more than 2000 in England and Wales[115]. A heatwave in 2006 resulted in 60 excess deaths in the Northwest.

[113] Stott *et al* (2004). Human contribution to the European heatwave of 2003. Nature. 432 (7017), 610-614.
[114] www.earth-policy.org/Updates/2006/Update56.htm

Potential for green infrastructure as a solution: effectiveness = 3
Green infrastructure provides evaporative cooling and shading that makes it a highly effective tool for managing high temperatures[61].

Potential for green infrastructure as a solution: practicality = 3
Green infrastructure offers a practical solution, especially as it provides other benefits in urban areas. Green infrastructure provision can be incorporated into new developments through planning policies and conditions. It can be retrofitted into older developments. There are some public perception issues which may have to be overcome.

Managing water supply = 7
Need for mitigation/adaptation: probability = 2
Climate change scenarios indicate that 'short' droughts, lasting one or two seasons, will increase significantly by the 2050s and be common-place by the 2080s[116].

Need for mitigation/adaptation: magnitude = 2
A lack of water supply could have serious impacts for society, in terms of human consumption, food production, supply for other species and irrigation of green infrastructure.

Potential for green infrastructure as a solution: effectiveness = 1
Green infrastructure can help to regulate water quantity and quality. Reducing pollutant input to water courses could be much more effective in terms of increasing quality. Delivering the quantity needed will rely on hard engineering. Some green infrastructure types could reduce water yield.

Potential for green infrastructure as a solution: practicality = 2
Green infrastructure could be moderately practical in helping to manage water supply.

Managing riverine flooding = 10
Need for mitigation/adaptation: probability = 3
The risk of flooding from rivers and the sea could at least double by the 2080s, and may increase by up to 20 times.

Need for mitigation/adaptation: magnitude = 3
Over this period, the number of people at a high risk of flooding could rise from 1.5 million to 2.3-3.5 million, and costs rise from £1 billion a year to £1.5-£21 billion[117]. The Environment Agency estimates that the 2007 floods cost the UK economy £3.2 billion.

Potential for green infrastructure as a solution: effectiveness = 2
Green infrastructure has a high potential to help us adapt the risk of increased riverine flooding. Green infrastructure options such as floodplain woodland can help retain water in the landscape so it does not impact upon properties or flood urban areas. It should be noted that flooding is a natural process, not all flood water can be contained by green infrastructure solutions alone.

Potential for green infrastructure as a solution: practicality = 2
The cost of green infrastructure solutions is relatively low; however the allowing flooding to happen may be controversial and requires space. This space could be multifunctional and used of other purposes. Green infrastructure approaches need to be employed at all points in a catchment or along a river; this will require collaborative working which is a potential barrier.

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[115] Kovats *et al* (2006). Mortality in southern England during the 2003 heat wave by place of death. National Statistics. www.statistics.gov.uk/articles/hsq/1419.pdf
[116] Wade *et al* (2006). Climate Change Impacts and Adaptation-Cross Regional Research Programme. Project C-Water. www.ukcip.org.uk/images/stories/Pub_pdfs/ProjectC_Water.pdf
[117] Foresight (2004). Future Flooding Report. www.foresight.gov.uk/Flood%20and%20Coastal%20Defence/Executive_Summary.pdf

Managing coastal flooding = 6
Need for mitigation/adaptation: probability = 1
Coastal flooding is expected to increase in a changing climate.

Need for mitigation/adaptation: magnitude = 2
People live on the coast in the Northwest and the area is a large visitor attraction for the region. Coastal flooding has similar impacts to riverine flooding.

Potential for green infrastructure as a solution: effectiveness = 2
Green infrastructure can help to manage coastal flooding. Sand dunes, wetlands and marshes can act as natural flood defence measures by slowing the speed of waves and preventing water reaching vulnerable areas on shore. However in some cases there will be no green infrastructure option suitable for flood defence and hard engineering solutions will be needed.

Potential for green infrastructure as a solution: practicality = 1
Green infrastructure solutions may be cheaper than engineered solutions. Green infrastructure solutions to coastal flooding can be aesthetically appealing. There may be public opinion issues if hard defences are removed and managed realignment is pursued.

Managing surface water = 12
Need for mitigation/adaptation: probability = 3
Towns and cities are likely to experience increased sewer flooding as rainfall increases under a changing climate.

Need for mitigation/adaptation: magnitude = 3
Most people live in towns and cities in the UK. This will have severe negative impacts on health, infrastructure, and the economy.

Potential for green infrastructure as a solution: effectiveness = 3
Green infrastructure, as part of a SUDS system, could be highly effective in managing surface water.

Potential for green infrastructure as a solution: practicality = 3
Green infrastructure solutions to aid in managing surface water can be relatively cheap and do not necessarily take up much land. They can be implemented within urban areas and have other benefits. It is possible to retrofit solutions.

Reducing soil erosion = 7
Need for mitigation/adaptation: probability = 1
Increased rainfall with climate change could increase in soil erosion.

Need for mitigation/adaptation: magnitude = 1
This could have a negative effect through loss of habitats and reduced water quality. Soil erosion in agricultural areas will lead to a less productive landscape.

Potential for green infrastructure as a solution: effectiveness = 3
Using green infrastructure is a highly effective way to stabilise soils. The roots of vegetation will help bind soil together and reduce erosion.

Potential for green infrastructure as a solution: practicality = 2
Green infrastructure is a cost effective way to prevent soil erosion. The employment of certain green infrastructure solutions may not be suitable as they could conflict with landscape character.

Helping other species to adapt = 8
Need for mitigation/adaptation: probability = 1

Species are already expanding into to new climate spaces. This trend will continue and increase as the climate changes.

Need for mitigation/adaptation: magnitude = 1
Some species will benefit from an increased range, whilst others may face difficulties and become locally or globally extinct. Ultimately, a diversity of species underpins our existence.

Potential for green infrastructure as a solution: effectiveness = 2
Other species rely on green infrastructure which provides habitats and corridors for movement. There will be some loss of species (e.g. from niche habitats and uplands). It may also be necessary to consider other ways of moving species to new climate spaces.

Potential for green infrastructure as a solution: practicality = 2
For green infrastructure to provide the service of helping other species adapt it has to be connected. This may be difficult to achieve in some areas and for some habitats.

Managing visitor pressure = 7
Need for mitigation/adaptation: probability = 1
Climate change could increase the vulnerability of landscapes.

Need for mitigation/adaptation: magnitude = 1
The most vulnerable landscapes often hold the highest visitor appeal.

Potential for green infrastructure as a solution: effectiveness = 2
Green infrastructure resources could be created to divert some visitor pressure from the most vulnerable landscapes. However, there may still be a demand for recreation and tourism in these areas. This will need to be carefully managed.

Potential for green infrastructure as a solution: practicality = 3
Green infrastructure solutions could be highly practical.