Baseline natural capital assessment for the Liverpool City Region

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Executive summary

The Liverpool City Region Natural Capital Working Group commissioned Natural Capital Solutions to establish a natural capital baseline for the Liverpool City Region (LCR). The assessment included an asset register of the region's natural capital, natural capital and ecosystem service maps, and the valuation, where possible, of the benefits that flow from these.

The asset register shows the habitats of the LCR to be predominantly urban (urban buildings and infrastructure (roads, pavements), and urban habitats such as amenity grassland and residential gardens), but with a reasonably diverse mosaic of other habitats including woodland and intertidal. The provision of carbon storage, sequestration, air pollution and noise regulation is relatively low and is largely dependent on the trees and woodland habitat within the LCR, the majority of which occurs outside of the urban centres. The region's woodland sequesters 32,560 tonnes of carbon every year, with an annual value of £2.22M (present value (PV) 127.6M over 50 years). The woodland and grassland also captures 213 tonnes of $PM_{2.5}$ with an annual value of £29.96M (PV 1.05Bn). The River Mersey, the Mersey Estuary and the coastal areas are also important for local climate regulation, providing an important cooling service. The provision of water flow and quality regulation in the LCR is reasonably good, with the woodland and saltmarsh habitats playing an important role. Access to nature is also reasonable, with the LCR supporting nearly 66 million visits per year at an annual value of £236 million (PV 6.02Bn). Access to greenspace in the LCR also provides an opportunity for maintaining physical health, supporting an estimated 144,586 active visits per year, at a cost saving to the NHS of 98.64M per year (PV 3.65Bn).

The demand for air pollution, local climate and noise regulation, as well as accessible nature demonstrates that the greatest demand for these services is in the urban centres, particularly in the most built-up areas where the population density is the highest. There is a spatial mismatch between supply and demand of ecosystem services in the LCR, with provision tending to be higher outside of the urban centres.

Efforts to increase ecosystem service provision should be focused on air pollution, noise and climate regulation. A strategy to increase street trees and woodlands in urban areas of each local authority could be beneficial, taking care to consider the position of the trees near to sources of pollution and to buildings and pavements for cooling. The most efficient species for the ecosystem service being targeted should be chosen. The ability of a species to sequester carbon should also be a priority, given the LCA's zero carbon target of 2040. This approach is likely to bring additional benefits, for example, increased aesthetic value and water quality, and decreased storm water runoff.

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1. Background

The Liverpool City Region Natural Capital Working Group commissioned Natural Capital Solutions to establish a natural capital baseline for the Liverpool City Region (LCR). The assessment included an asset register of the region's natural capital, natural capital and ecosystem service maps, and the valuation, where possible, of the benefits that flow from these.

The natural capital assessment was intended to build on the LCR Green Infrastructure Framework (Mersey Forest 2013) and the LCR Ecological Network (MEAS 2013) by creating a baseline which aligns with the Natural Capital Approach as set out in DEFRA's 25 Year Environment Plan and the revised planning policy guidance (23/07/19) https://www.gov.uk/guidance/natural-environment. This natural capital baseline will support the Liverpool City Region Combined Authority (LCA) and Local Authorities (LA) to engage with and manage funds created by natural capital policy mechanisms and to enhance the economic and social welling of the LCR. These policy mechanisms include an Environmental Net Gain approach (including Biodiversity net gain), DEFRA's Environmental Land Management System (public money for public goods), as well as private investment in natural capital (for examples of private investment for return see Greater Manchester Combined Authority Natural Capital Investment Plan).

The work was completed in collaboration with the chair of the LCR Natural Capital Working Group, Dr Colm Bowe from Liverpool John Moores University. This report is intended as a brief summary of the results of the assessment, as the Natural Capital Working Group will decide how best to present this evidence base in future publications. For the most part, the results are presented across the six local authority regions within the LCR. The GIS files for the maps have been supplied so that the working group can present the natural capital assets and ecosystem services separately for each local authority, should that be useful for decision-making. We have included a detailed technical appendix of the approach and methods used at the end of the report.

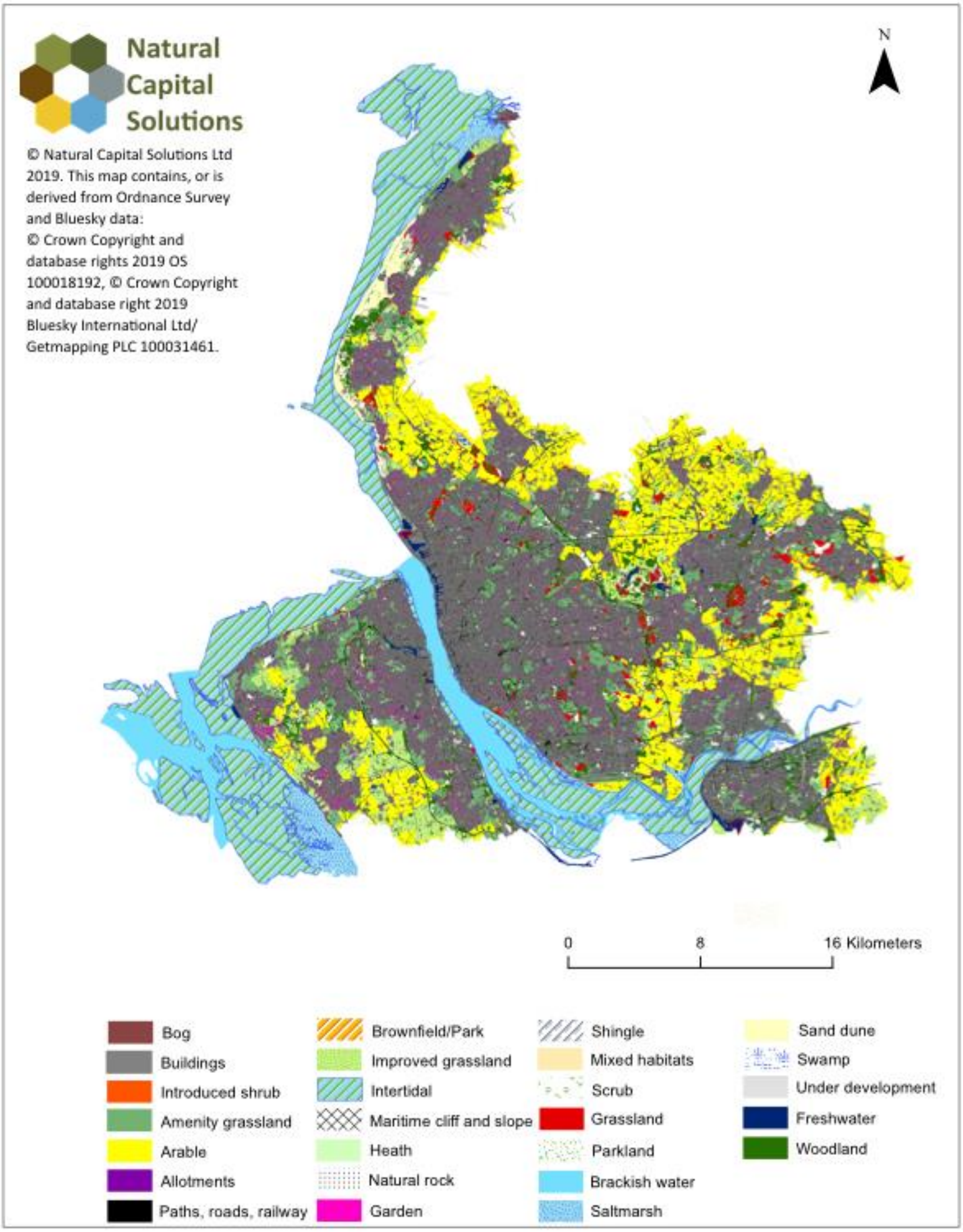
2. Natural capital basemap and asset register

The Liverpool City Region comprises six local authorities: Halton, Knowsley, Liverpool, Sefton, St Helens and Wirral, covering an area of c. 87,918 ha. The asset register (Table 2.1) and the natural capital asset map (Map 2.1) show a broad range of habitats within this area. LCR is dominated by urban buildings and infrastructure (roads, pavements), and urban habitats such as amenity grassland and residential gardens (48% in total). Arable agriculture is significant in its extent (14%) outside of the urban centre and suburbs, as is the intertidal habitat (14%) of the Mersey Estuary. There is a mosaic of small areas of other habitats in-between these comprising of grasslands, freshwater and coastal habitats. Woodland is dominated by broadleaved species, and is spread throughout the LCR (5%), with the largest continuous patch on the Sefton coast.

Table 2.1 Natural capital asset register for Liverpool City Region (LCR). The total area of LCR is 87,918 ha.

Habitat	Ha	% of total LCR area
Bog	14	0.02
Bracken	14	0.02
Arable	12,870	14.64
Allotment	160	0.18
Introduced shrub	3	0.003
Amenity grassland	10,962	12.47
Rough grassland	245	0.27
Acid grassland	24	0.03
Improved grassland	4,470	5.08
Marshy grassland	51	0.06
Neutral grassland	883	1.00
Poor semi-improved grassland	420	0.48
Heath	84	0.10
Intertidal	12,479	14.19
Maritime cliff and slope	17	0.02
Natural rock	22	0.03
Parkland	1,218	1.39
Brackish water	3,314	3.77
Saltmarsh	1,063	1.21
Sand dune	842	0.96
Scrub	521	0.59
Swamp	74	0.08
Freshwater	1,117	1.27
Broadleaved woodland	3,521	4.01
Coniferous woodland	361	0.41
Mixed woodland	688	0.78
Mixed habitats	675	0.77
Gardens	11,756	13.37
Brownfield/Park	101	0.12
Built up areas	11,148	12.67
Roads, pavements, paths, railway	8,155	9.28
Under development	440	0.50
Other	206	0.23

Map 2.1 Liverpool City Region natural capital basemap.



3. Ecosystem service mapping

The following ecosystem services were mapped:

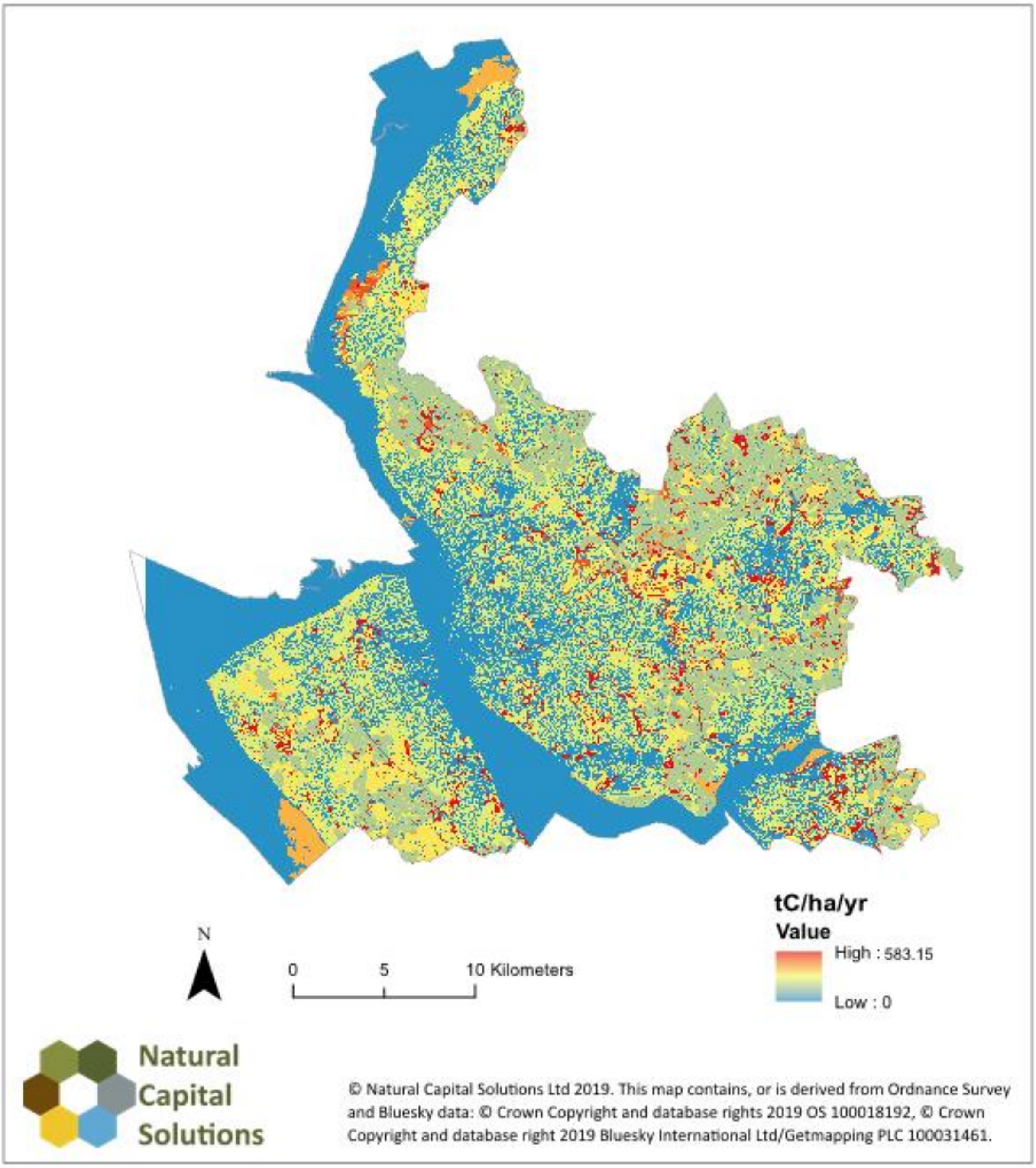
- Carbon storage capacity
- Carbon sequestration
- Air purification capacity and demand
- Local climate capacity and demand
- Noise regulation capacity and demand
- Water flow capacity
- Water quality capacity
- Accessible nature capacity and demand

The ecosystem service capacity and demand maps are presented individually for each ecosystem service, and also for all services together (mean ecosystem service capacity (excluding carbon storage) and demand). The technical appendix at the end of the report outlines the significance of each ecosystem service and how each ecosystem service was modelled and mapped.

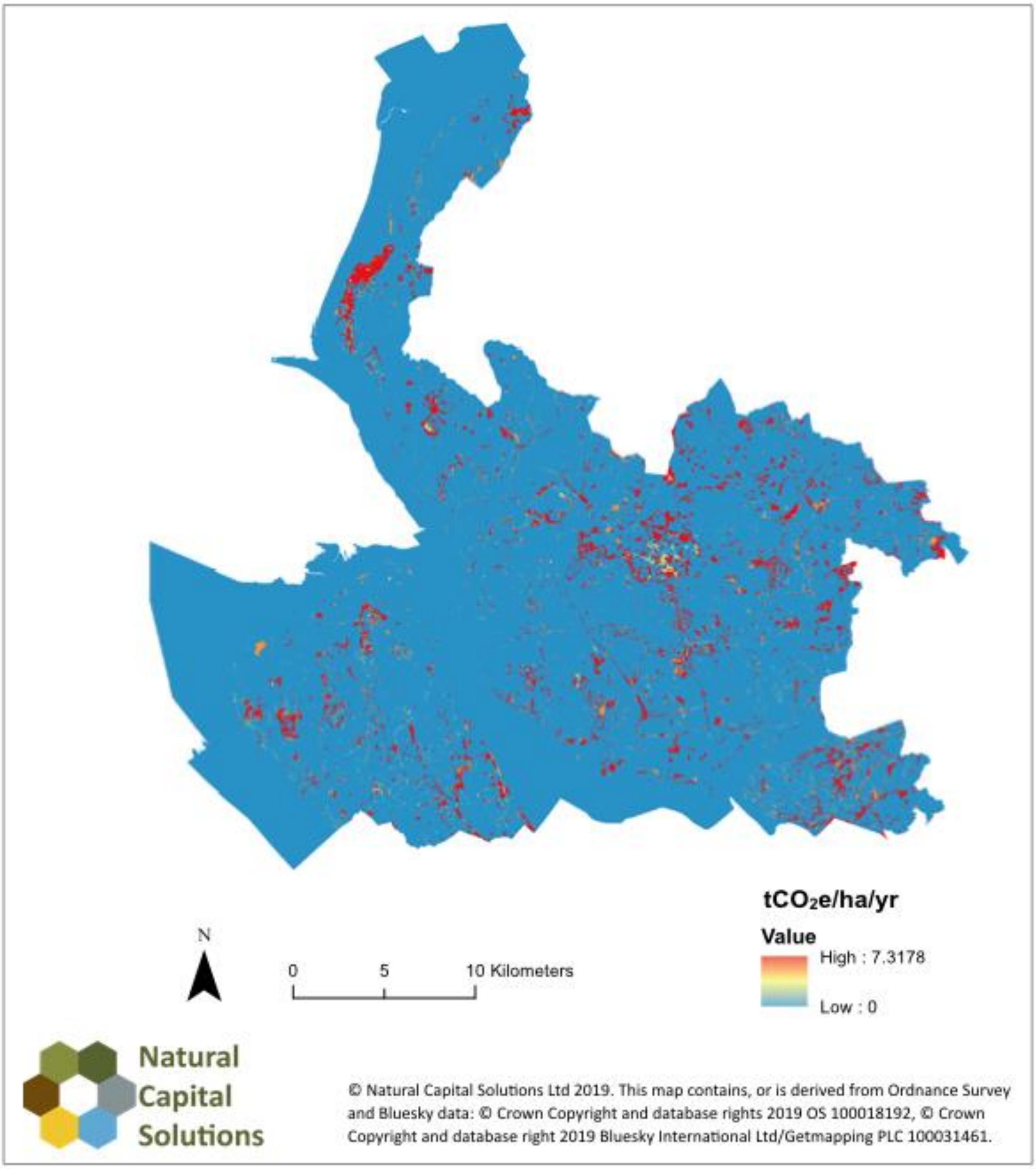
Carbon storage capacity indicates the amount of carbon stored naturally in soil and vegetation (the stock of carbon). The importance of managing land as a carbon store has been recognised by the UK Government, and land use has a major role to play in national carbon accounting. Changing land use from one type to another can lead to significant changes in carbon storage, as can restoration of degraded habitats. The capacity scores (out of 100) for carbon storage and carbon sequestration in the LCR are quite low (10.5 and 5.24 respectively). Carbon storage considers the carbon stored in vegetation and the top 30cm of the soil. The sealed surfaces and arable land covers in the LCR provide the least capacity to store carbon (blue areas on Map 3.1). The woodland areas in LCR are providing the highest capacity to store carbon, demonstrated by the orange and red areas on Map 3.1). However, there is also an area of saltmarsh in the Mersey Estuary in the south-west that is also important for carbon storage.

Carbon sequestration is the uptake of carbon by plants as they grow. While carbon storage (Section 4.2) measures the stock of carbon in the natural environment, carbon sequestration measures its annual flow. Woodland is known to be particularly effective at carbon sequestration, as are peatlands. Little is known about how carbon sequestration occurs in other habitats or through soil respiration, and plants that are harvested annually (e.g. arable crops, improved grassland) will be approximately carbon neutral over the course of a year as the sequestered carbon is immediately harvested. Therefore, estimates are solely based on carbon sequestration in woodland habitats. The carbon sequestration rate map (Map 3.2) shows the sequestration capacity of the woodland in the area. The majority of the woodland is broadleaved which is shown in red, indicating the highest rate of sequestration, and the orange areas are coniferous or mixed woodland, including scrub and parkland.

Map 3.1 Carbon storage.



Map 3.2 Carbon sequestration rate.



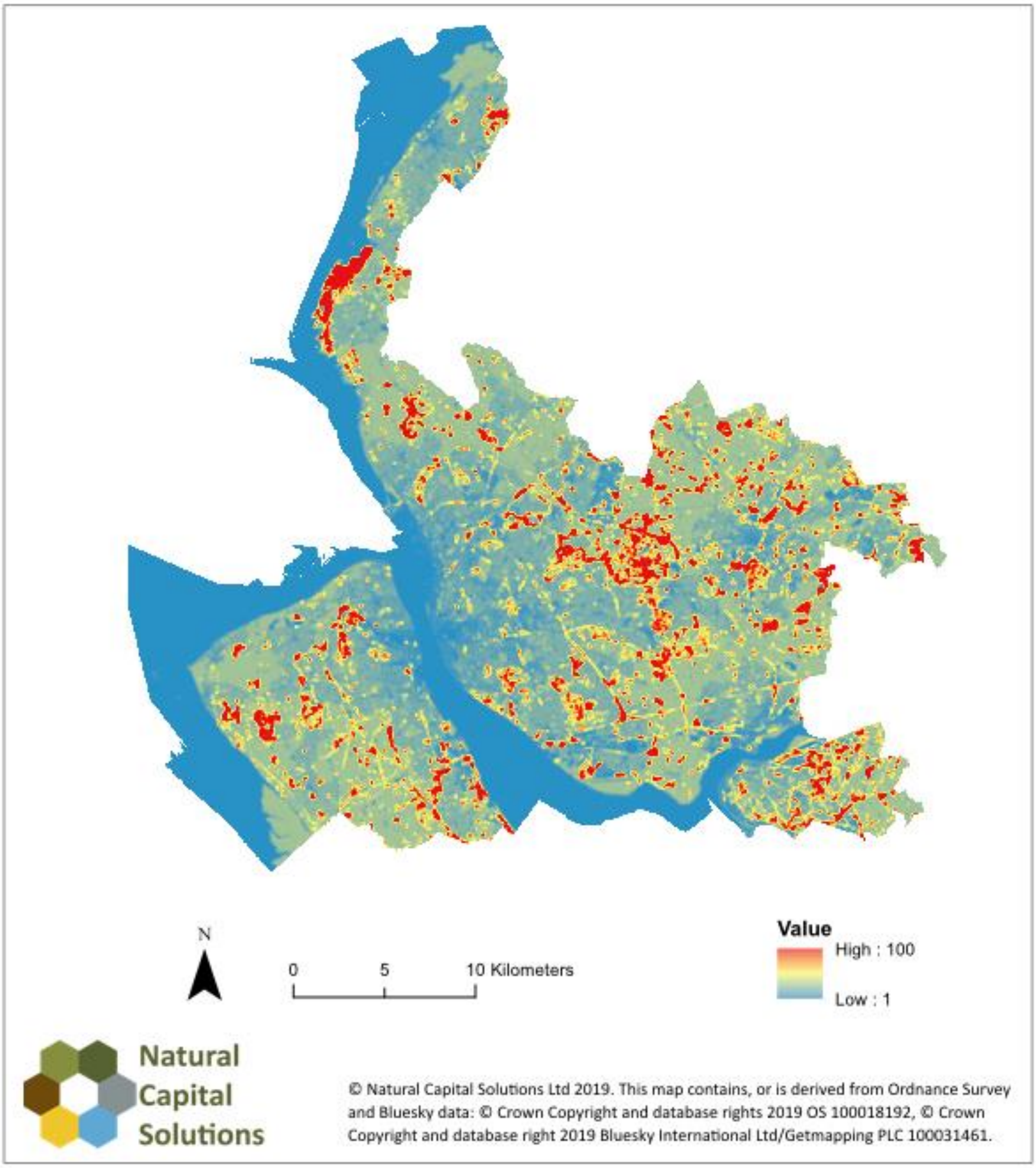
Vegetation can be effective at mitigating the effects of air pollution, primarily by intercepting particulates, especially $PM_{2.5}$ (particulate matter 2.5 micrometres or less in diameter), but also by absorbing ozone, SO_2 and NO_x. Trees are much more effective than grass or low-lying vegetation, although effectiveness varies greatly depending on the species. The ability of the woodland and grassland habitats of the baseline to absorb two of these key pollutants, $PM_{2.5}$ and sulphur dioxide SO_2, was quantified.

As the capacity of the natural environment to intercept and absorb the pollutants $PM_{2.5}$ and SO_2 (Map 3.3) is largely dependent on trees, the score for this service is also reasonably low (10.7). The red areas on this map tend to be located where the woodland occurs, although grassland and other habitats are also able to mitigate the effects of air pollution, they do so at a much reduced rate (yellow areas on map). The blue areas, the lowest scores, are man-made sealed surfaces and water. The areas that are best at regulating pollution do not coincide with the areas of highest demand for this service (Map 3.4). The areas of highest demand for this service tend to be the urban centres, as these have both higher air pollution levels and a higher population that will benefit from improved air quality. The main road networks are also clearly visible as a major source of pollution, particularly where they pass through built up urban areas. The divergence between supply and demand is particularly noticeable in the Liverpool local authority. The overall demand score is 18.49.

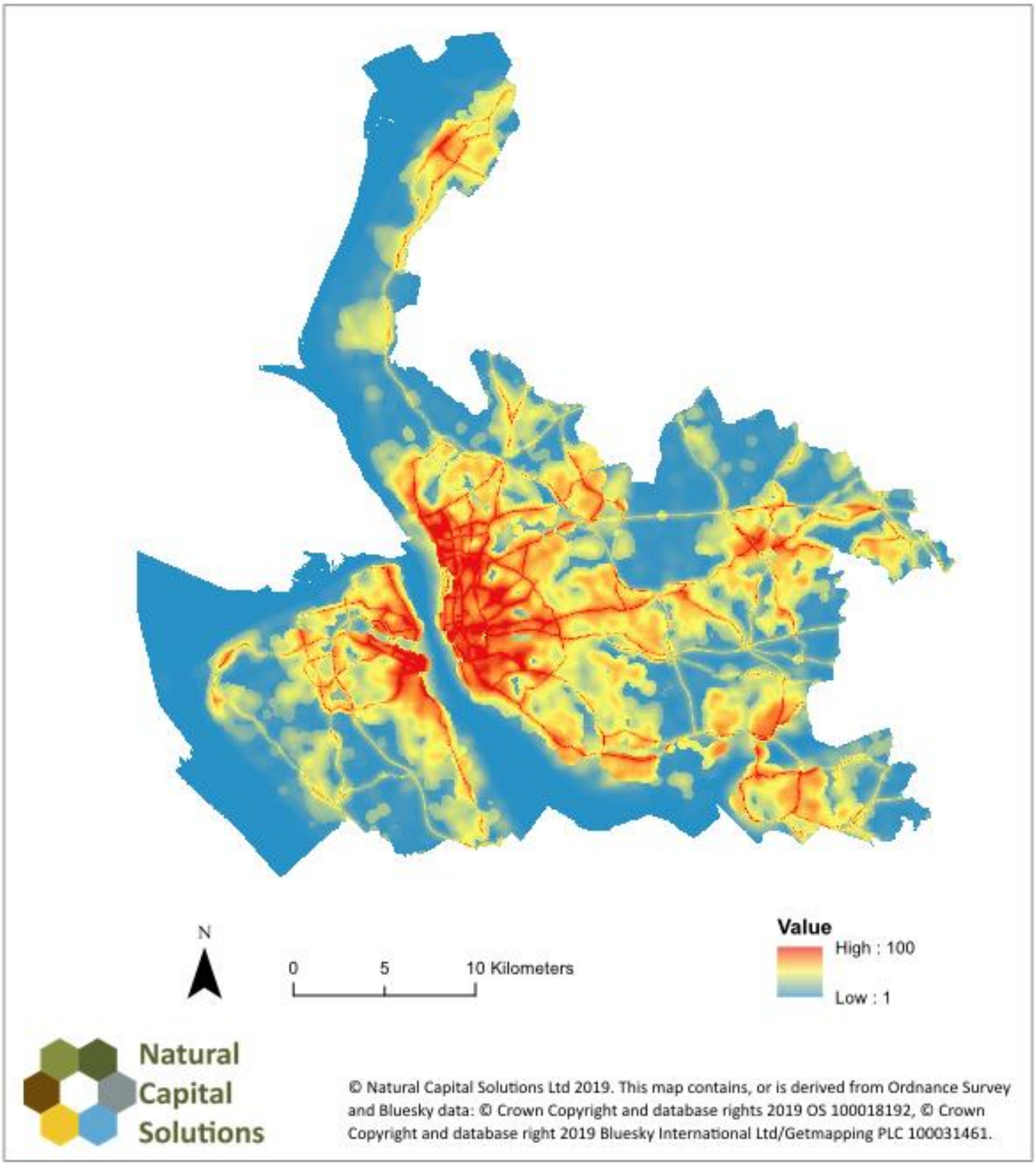
Land use can have a significant effect on local temperatures. Urban areas tend to be warmer than surrounding rural land due to a process known as the “urban heat island effect”. This is caused by urban hard surfaces absorbing more heat, which is then released back into the environment, coupled with energy released by human activity such as lighting, heating, vehicles and industry. Climate change impacts are predicted to make the overheating of urban areas and urban buildings a major environmental, health and economic issue over the coming years. Natural vegetation, especially trees / woodland and rivers, are able to have a moderating effect on local climate. Local climate regulation capacity estimates the capacity of natural habitats to cool the local environment and cause a reduction in urban heat maxima.

The local climate regulation capacity model is based around woodland / scrub and water features, which are the most effective habitats at regulating local climate. Hence Map 3.5 highlights these habitats in red as the highest scoring. These are the River Mersey, the estuary and coastal habitats, and the patches of woodland, mainly in between the urban centres. The average climate regulation capacity score for LCR is 24.87. The demand map for this service (Map 3.6) shows that the highest demand for the service is in the densest most built up parts of urban centres, with patterns of demand influenced by urban layout and the presence of parks, the river, and other greenspaces. The average demand score for this service is 36.21.

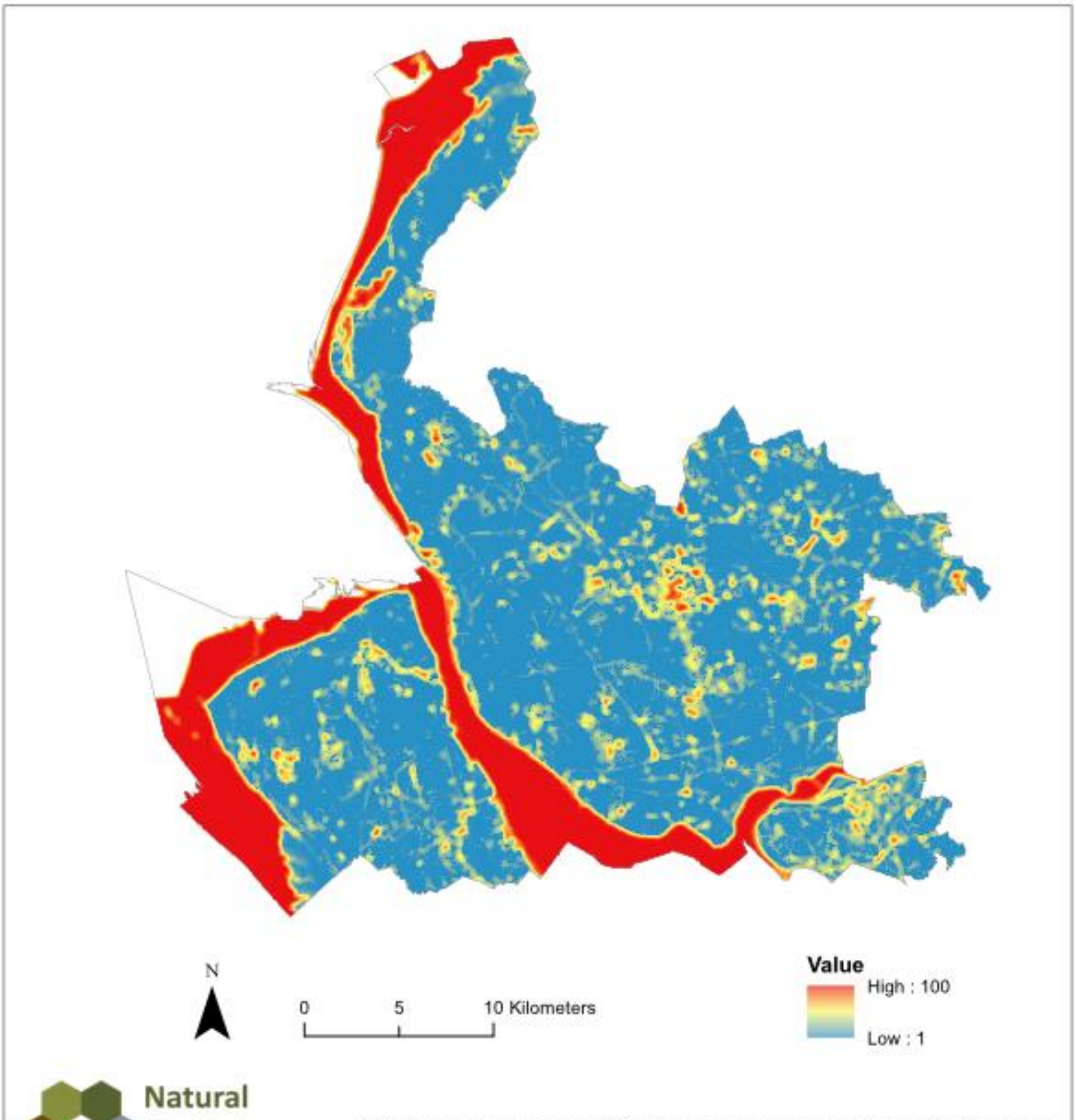
Map 3.3 Air purification capacity.



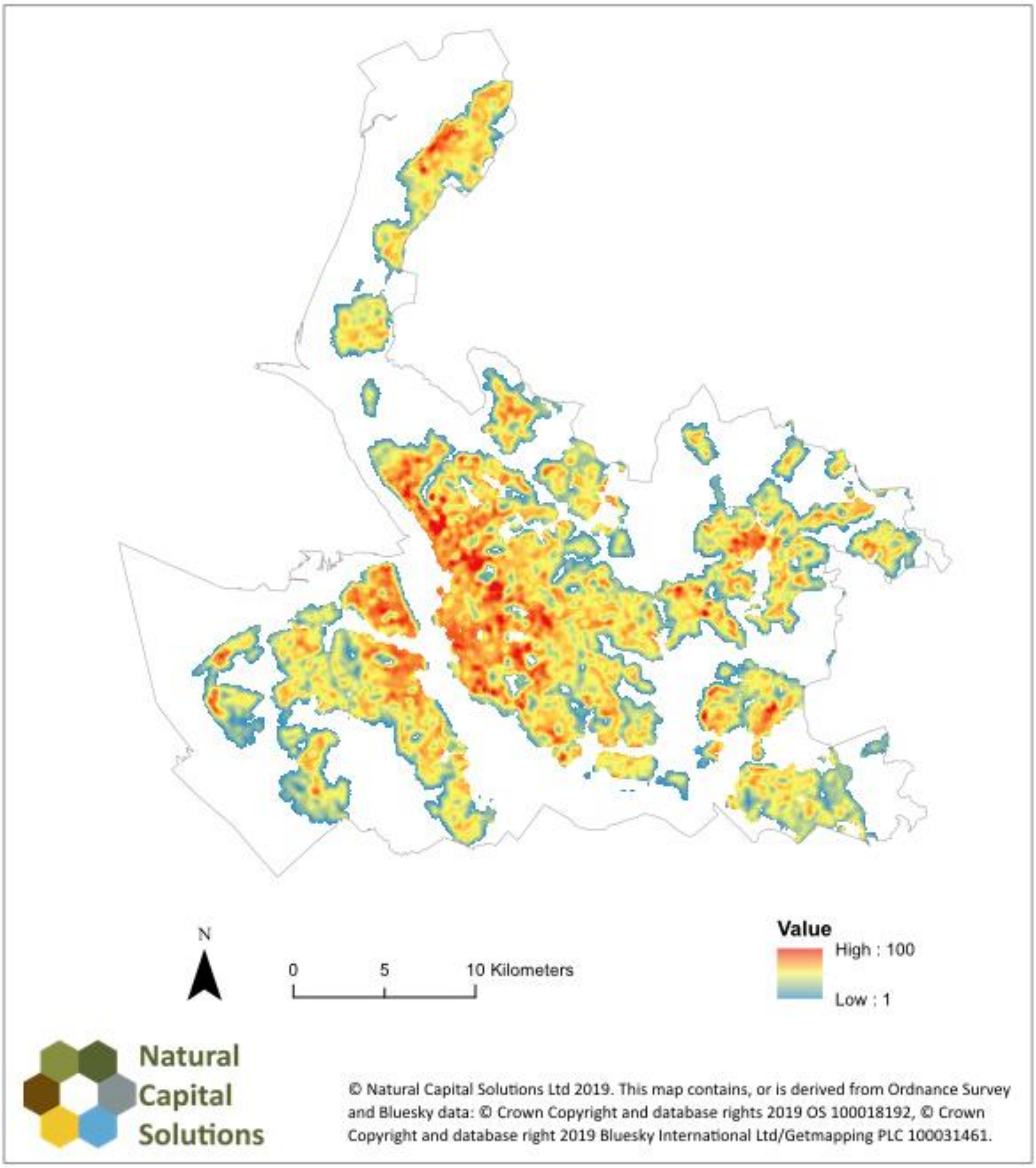
Map 3.4 Air purification demand.



Map 3.5 Local climate regulation capacity.



Map 3.6 Local climate regulation demand.



Noise regulation capacity is the capacity of the land to diffuse and absorb noise pollution. Noise can impact on health, well-being, productivity and the natural environment and the World Health Organisation (WHO) have identified environmental noise as the second largest environmental health risk in Western Europe (after air pollution). Major roads, railways, airports and industrial areas can be sources of considerable noise, but use of vegetation can screen and reduce the effects on surrounding neighbourhoods. Complex vegetation cover such as woodland, trees and scrub is considered to be most effective, although any vegetation cover is more effective than artificial sealed surfaces, and the effectiveness of vegetation increases with width.

Woodland is by far the most effective habitat at absorbing noise. However, the effects are modest, with reductions of 2- 4 dB typically recorded across dense tree belts. Similar to air purification, the woodland areas in LCR (Map 3.7) are the most effective areas at absorbing noise pollution. The average capacity score for noise regulation in LCR is 8.42. However, the greatest demand for regulating noise is in the urban centres close to major roads, where there are few if any trees (Map 3.8). These areas have large populations with poor health scores, that would benefit from noise abatement from main roads. Liverpool city clearly provides the greatest demand for this service, with the towns of St Helens, Widnes, Runcorn and Southport also demonstrating a high demand. The average demand score for LCR is 23.89.

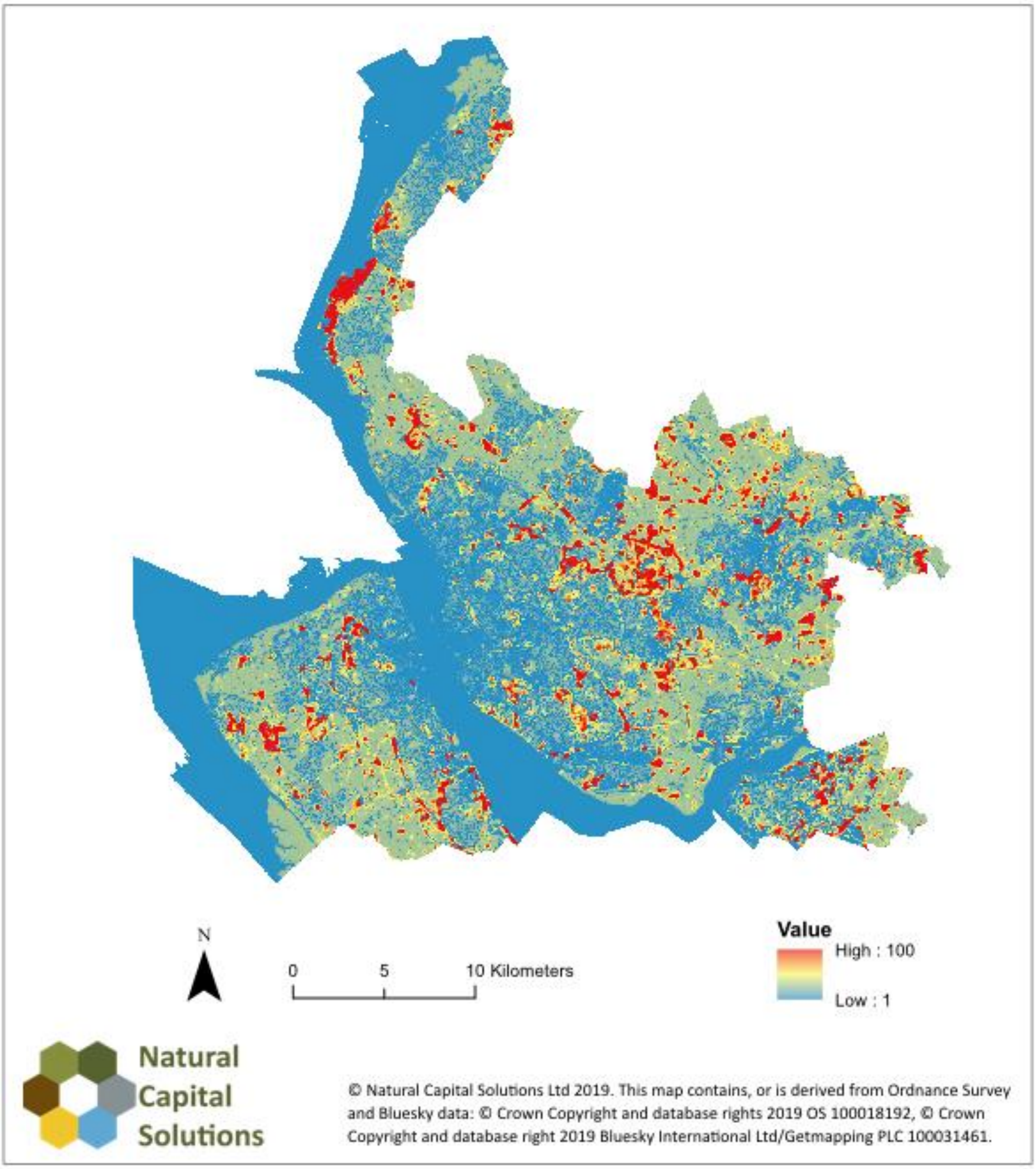
Water flow regulation is the capacity of the land to slow water runoff and thereby potentially reduce flood risk downstream. Following a number of recent flooding events in the UK and the expectation that these will become more frequent over the coming years due to climate change, there is growing interest in working with natural process to reduce downstream flood risk. These projects aim to “slow the flow” and retain water in the upper catchments for as long as possible. Maps of water flow regulation can be used to assess relative risk and help identify areas where land use can be changed.

The best locations for slowing water runoff are areas of woodland on flat land and permeable soils. The worst areas (blue on the map) are those with impermeable surfaces. The greatest level of the water flow capacity service in LCR are woodlands and saltmarsh habitats (Map 3.9). The areas of arable and improved grassland in the rural areas of the LCR are reasonably good at slowing the flow of water. The worst areas are the urban centres, although green spaces such as parks and gardens within these are able to provide some level of service. The average capacity score for the region is 68.28.

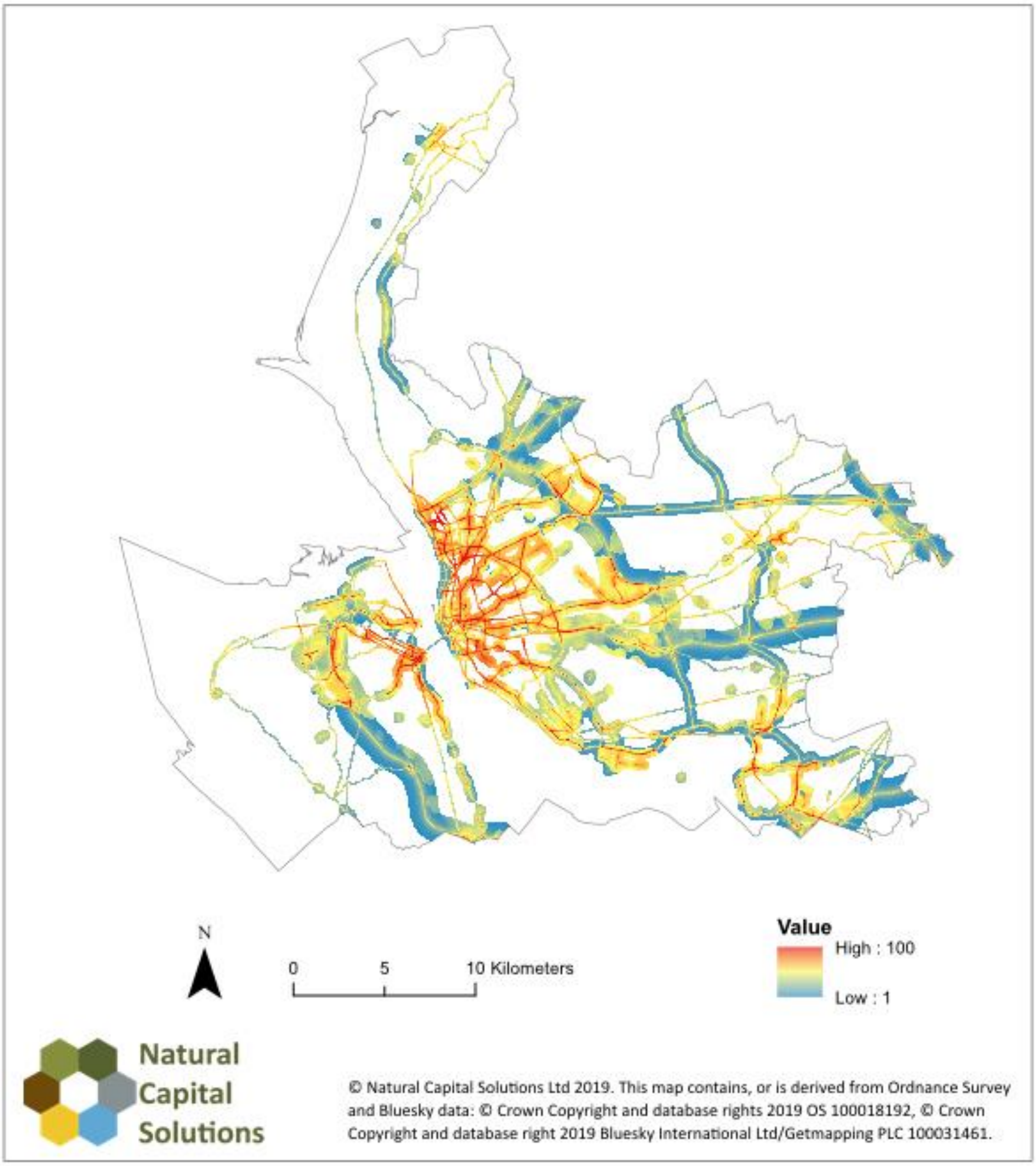
Water quality regulation maps the risk of surface runoff water becoming contaminated with high pollutant and sediment loads before entering a watercourse, with a higher water quality capacity indicating that water is likely to be less contaminated. Note that the focus is on sedimentation risk from agricultural diffuse pollution, hence built-up areas are not well accounted for in the existing model.

Water quality capacity maps the risk of surface runoff water becoming contaminated with high pollutant sediment loads before entering a watercourse. The focus is on sedimentation from agricultural diffuse pollution, so the arable fields on the outskirts of the city and towns in LCR show the lowest provision of this service (Map 3.10). The areas of highest provision are the salt marsh and coastal habitats in the Wirral and Sefton. The average score for this service in the LCR is 42.18.

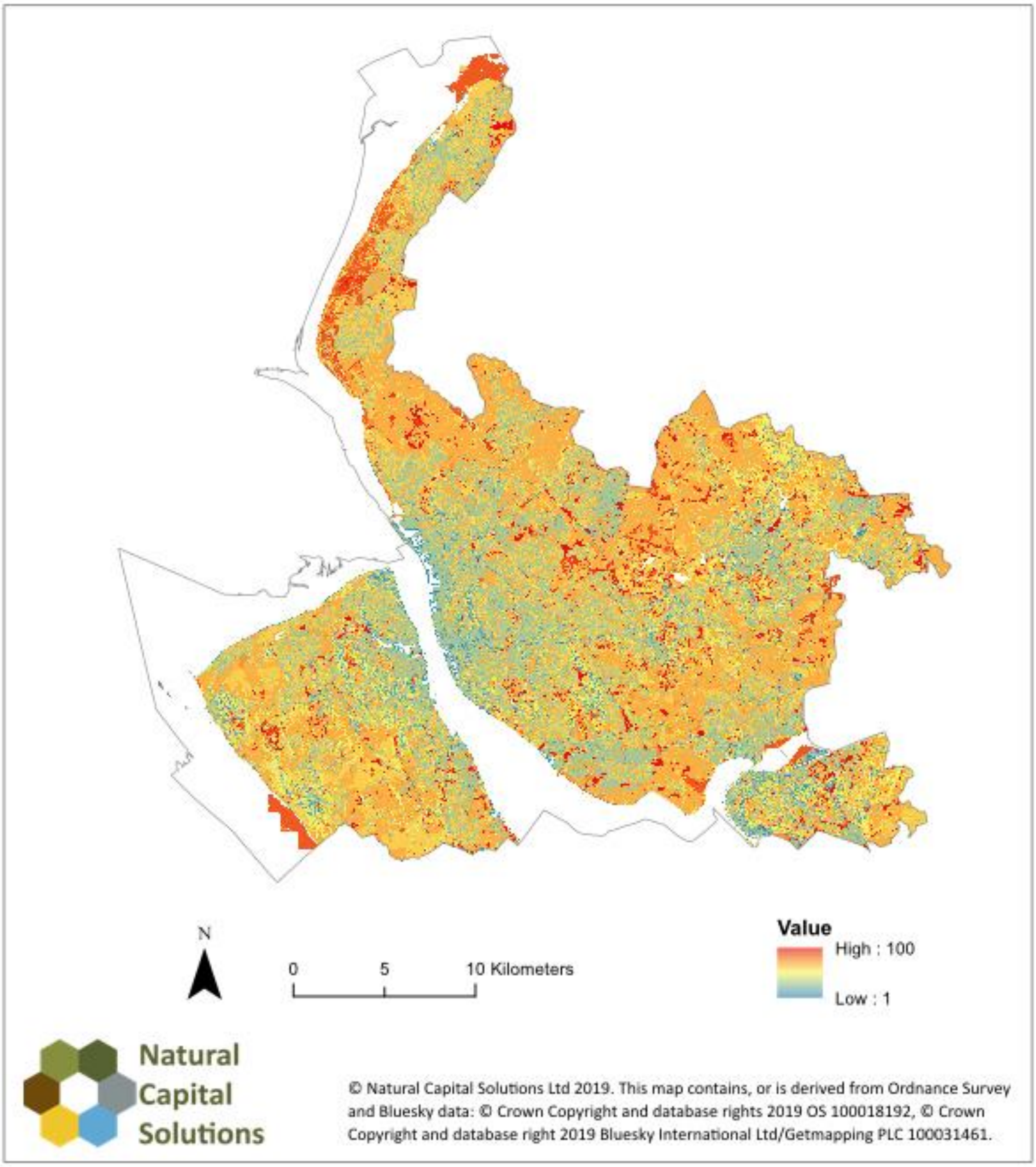
Map 3.7 Noise regulation capacity.



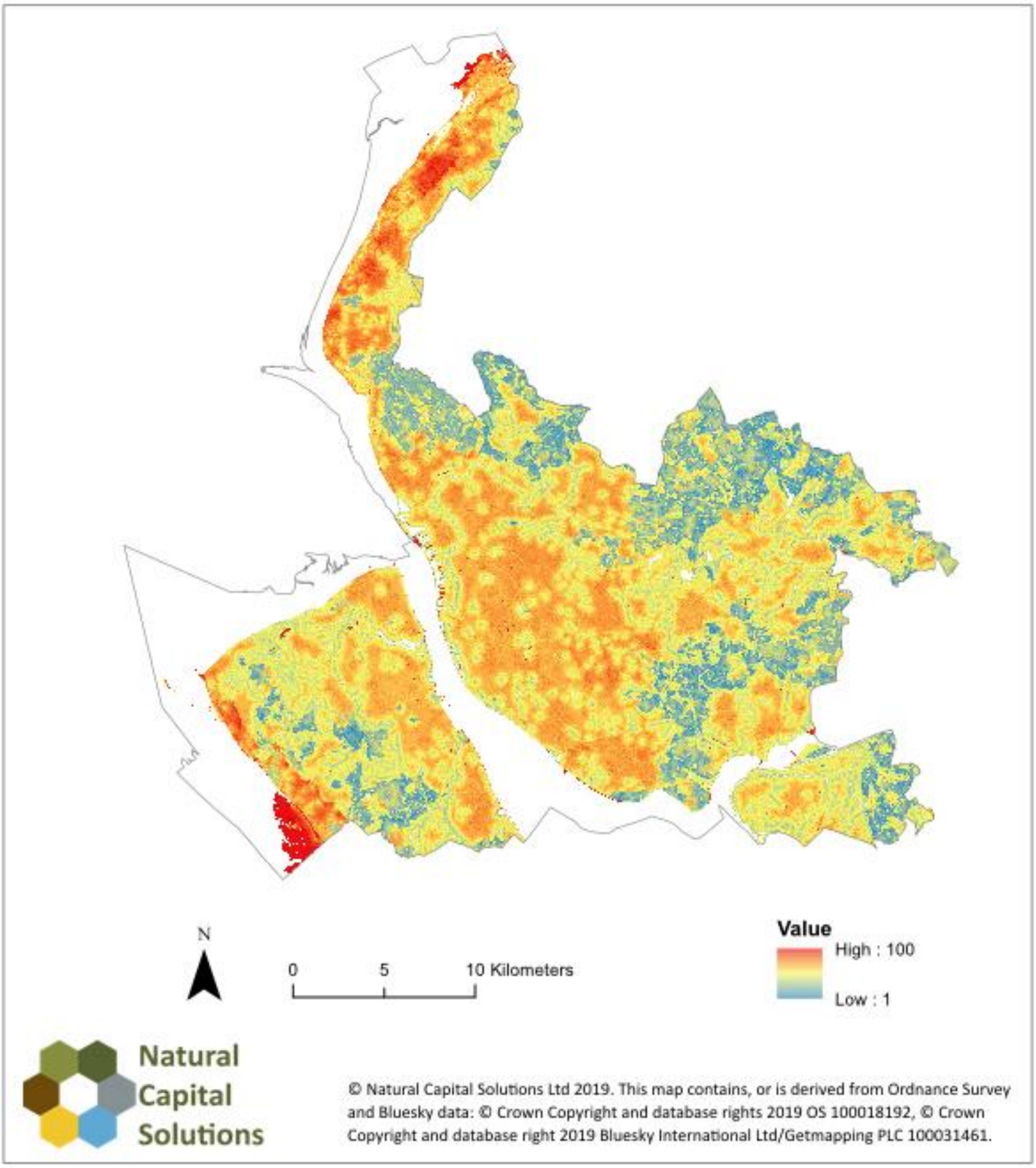
Map 3.8 Noise regulation demand.



Map 3.9 Water flow capacity.



Map 3.10 Water quality capacity.



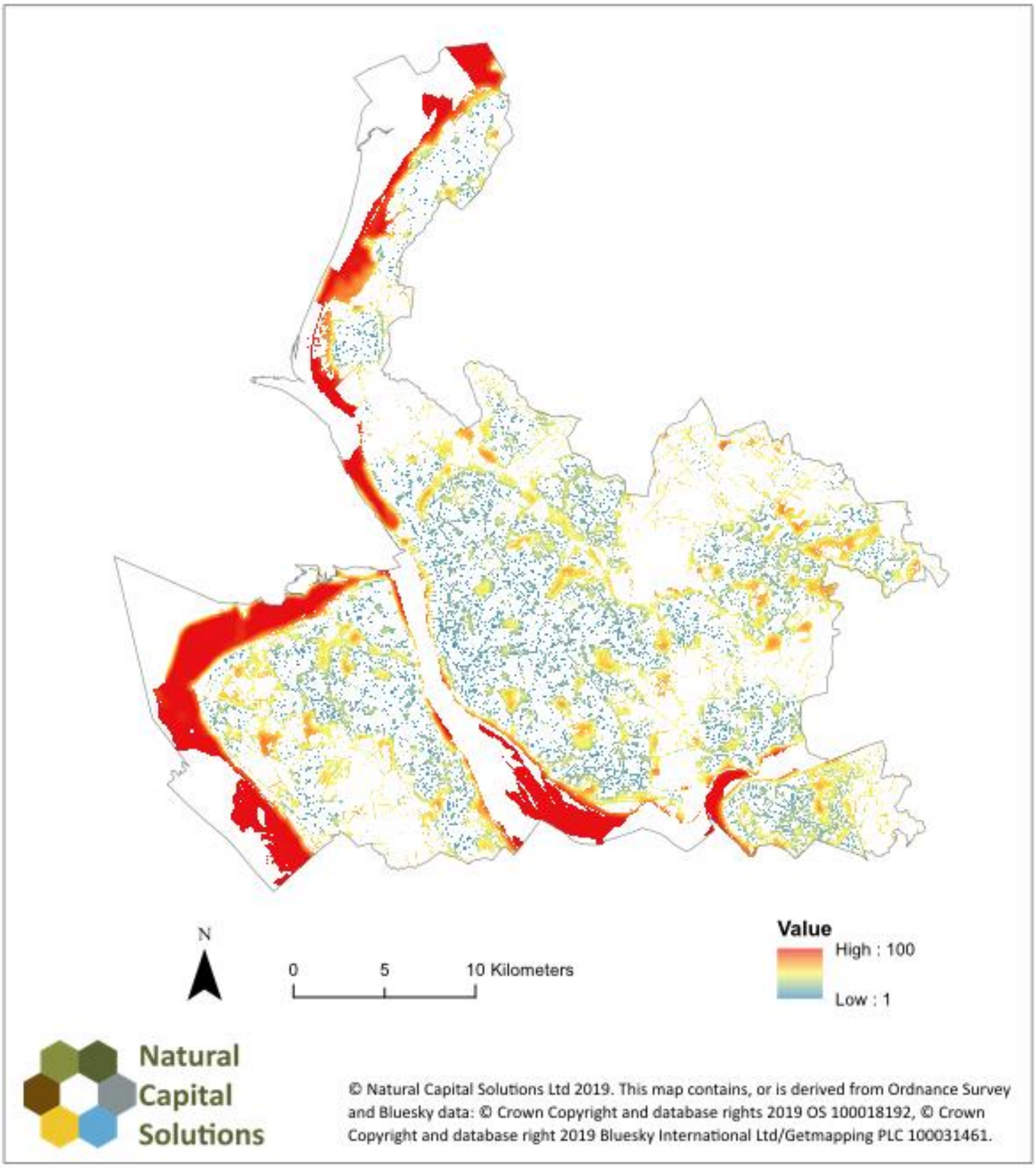
Access to greenspace is being increasingly recognised for the multiple benefits that it can provide to people. Research has also shown that there is a link between well-being and perceptions of biodiversity and naturalness. Natural England have published guidelines that promote the enhancement of access, naturalness and connectivity of greenspaces. The two key components of accessible nature capacity are therefore public access and perceived naturalness. Both of these components are captured in the model, which maps the availability of natural areas and scores them by their perceived level of "naturalness".

The accessible nature capacity of LCR is shown in Map 3.11. The highest provision (in red) tends to be either the coastal areas, or along the urban River Mersey, where there is good access, and high perceived naturalness. Other areas that have a reasonable capacity are publicly accessible parks, woodlands and local wildlife sites, that will score quite well for perceived naturalness. These occur both in and around the urban centres. The lowest scores are found in the urban centres where there is less access to nature and less natural surroundings. Overall the average score across LCR for this service is 59.49. The demand for accessible nature is around where people live, hence Map 3.12 shows the highest demand in the urban centres of the LCR. The average demand score for accessible nature is 57.01.

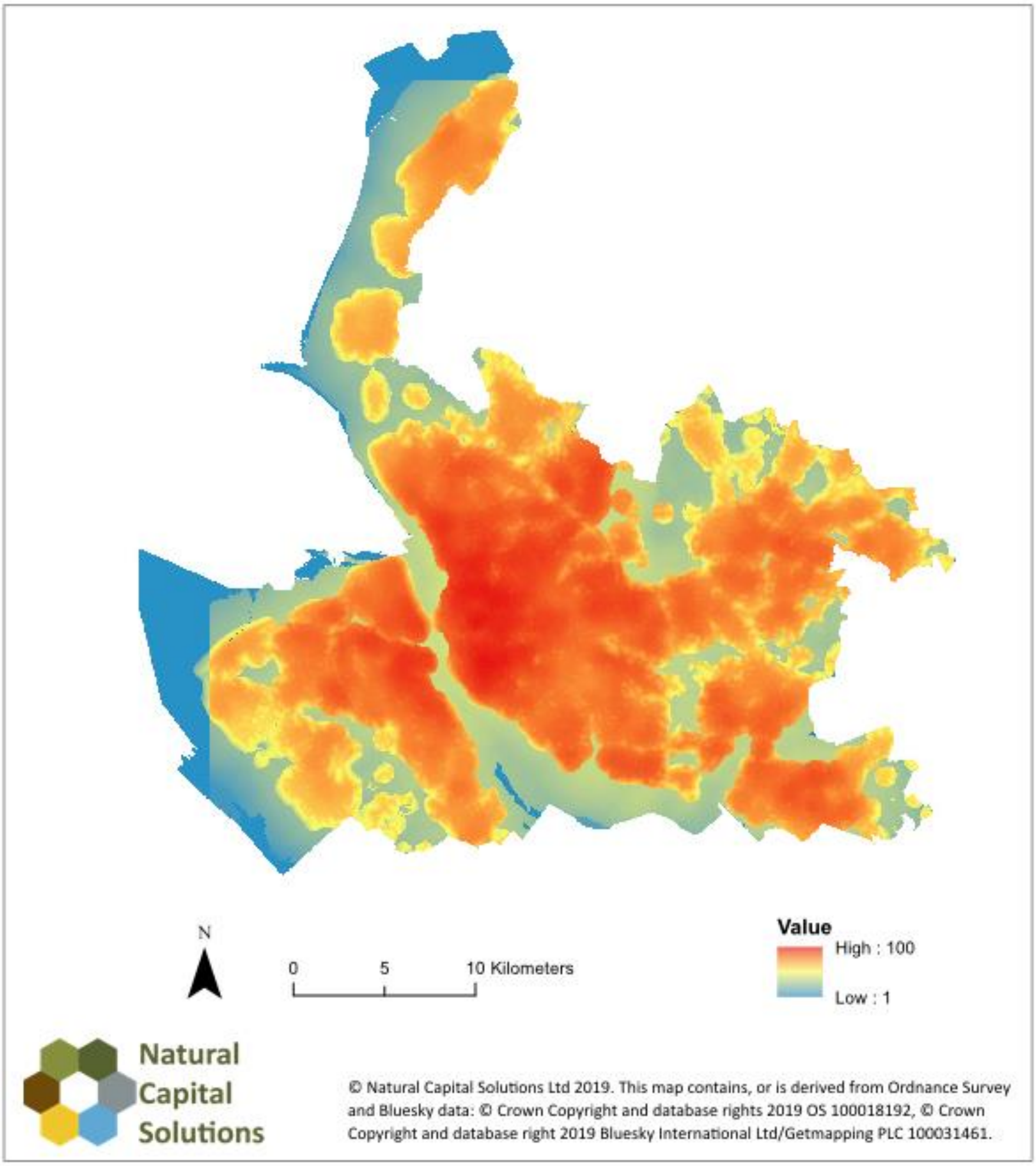
The mean capacity map (Map 3.13) combines all of the individual capacity maps, excluding carbon storage, as this is a natural capital stock rather than a flow. This map highlights that the highest provision of services comes from outside the urban centres, and is dependent on woodland, salt marsh and other intertidal and coastal habitats.

The mean demand map (Map 3.14) combines all of the individual demand maps. This emphasises the high demand in the urban centres of the LCR for the air purification, local climate, noise regulation and access to nature services.

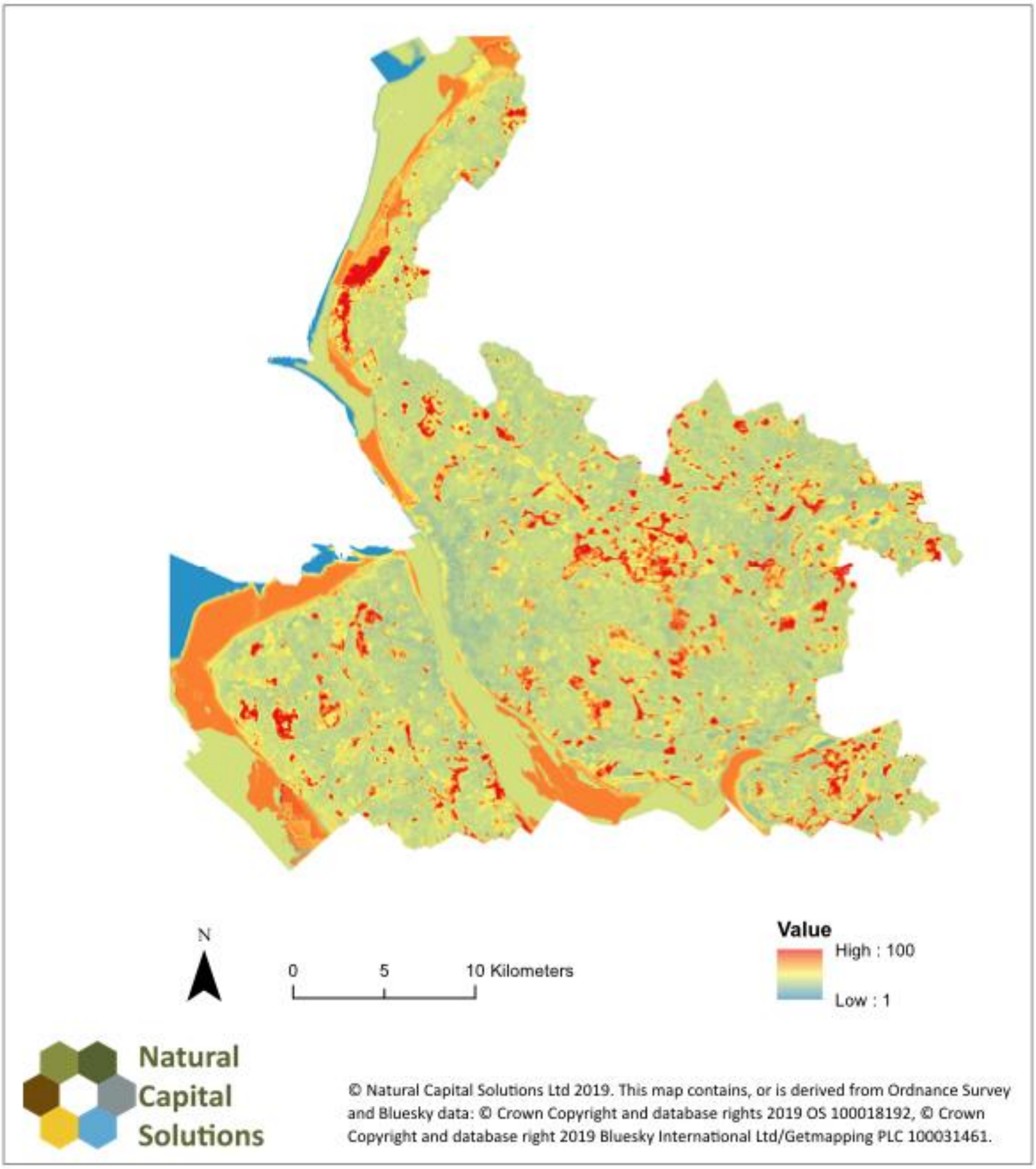
Map 3.11 Accessible nature capacity.



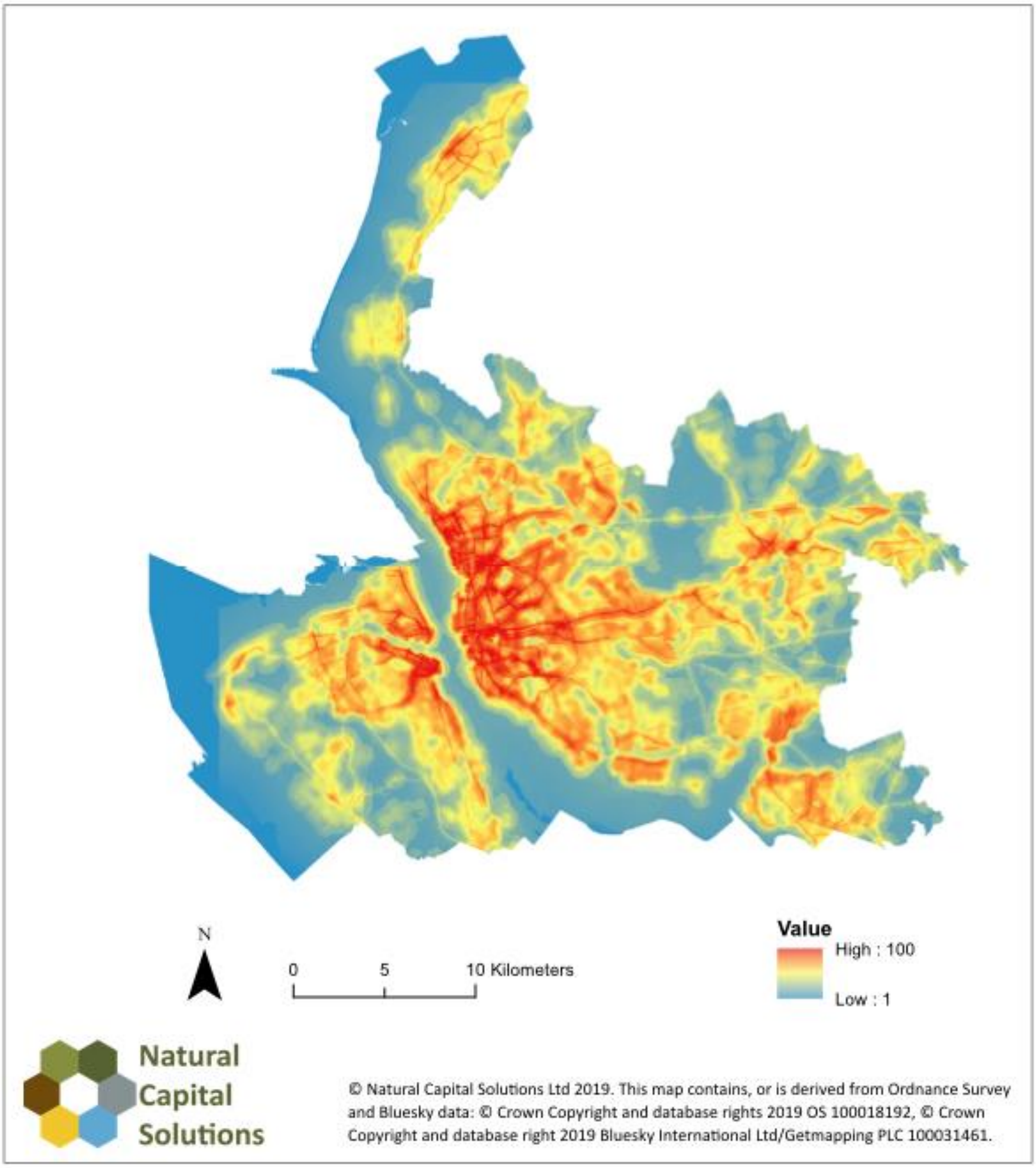
Map 3.12 Accessible nature demand.



Map 3.13 Mean capacity.



Map 3.14 Mean demand.



Box 1: Using the Liverpool City Region natural capital baseline for environmental net gain assessment

The LCR natural capital baseline can be used to assess potential changes in the provision of ecosystem services due to changes in the landscape (environmental net gain or loss). These landscape changes may be due to the habitat restoration, creation of new green infrastructure or housing or commercial developments and any associated mitigation.

The Ecoserv approach (Fig. 1) was used to modify the basemap based on real-world development plans, and the effects of these developments on ecosystem service capacity and demand assessed. These changes were assessed over a number of scales, for example from site scale, ward, local authority scale all the way up to city region scale. Site scale assessments may be particularly relevant to developers looking to maximise net gain on their land and inform their development design. Assessment at larger scale may be of use to local authorities aiming to achieve net gain locally and to inform local plans, all the way up to city region scale – useful for strategic planning across larger areas.

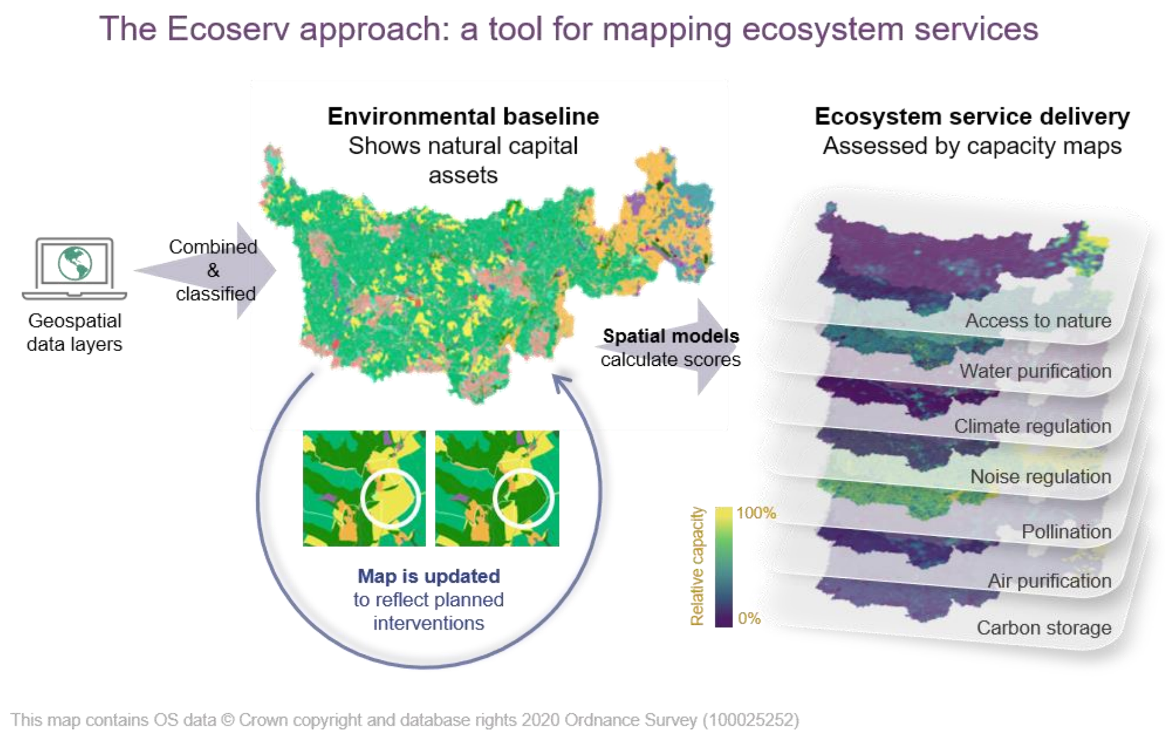


Figure 1 – The Ecoserv approach workflow and application methodology

This approach has now been trialled across the Liverpool City Region on a number of interventions, ranging from small scale nature-based solutions to large scale housing developments. One such example is the Heath Park development in Runcorn, where EcoservR was used to model the effects of an innovative new design plan as part of the winning entry for the RIBA "Vision of the Future" competition (Fig. 2). Ecosystem service provision was calculated under both the current site layout and the new design.

Environmental net gain was achieved in all seven ecosystem services tested (Table B1), showing significant environmental benefits for both the site itself and the wider Runcorn area (a 15 km^2 area).

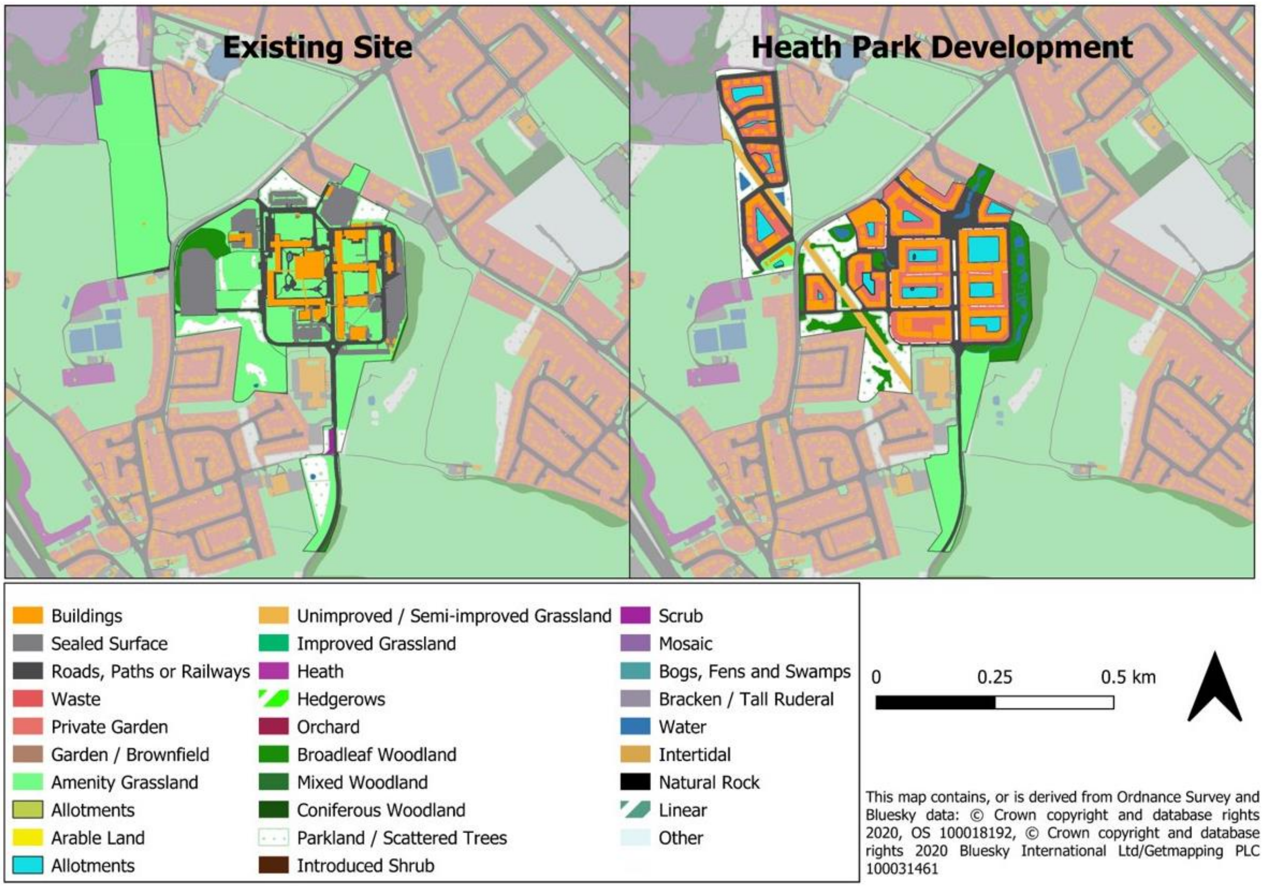


Figure 2 - Site layout both pre- and post- the Heath Park development, demonstrating changes to the LCR basemap

This natural capital backed project proposal won the RIBA "A Vision of the Future" design competition, and demonstrates how the Liverpool City Region baseline can be used to inform development plans and to provide an evidence base for environmentally conscious design proposals.

Table 1 - Percentage change in capacity of various ecosystem services due to the Heath Park development, at both a site scale and wider Runcorn scale (approximately 15 km² area).

	Percentage Change (%)	
Ecosystem Service (Capacity)	Heath Park	Wider Runcorn (15 km² area)
Accessible nature experience	3.31	0.46
Air purification	26.95	0.89
Carbon storage	13.63	0.31
Local climate regulation	132.26	2.78
Noise regulation	22.23	1.22
Pollination	2.20	0.05
Water purification	0.66	0.02

4. Ecosystem service valuations

It was possible to value the provision of carbon sequestration, timber production, air pollution regulation, recreation and physical health services. All services are presented as a physical flow, annual flow and a present value calculated over 50 years. The HM Treasury discount rate of 3.5% is used in all cases but physical health, where a discount rate of 1.5% is suggested. The pollution regulation service also applies a 2% uplift to reflect assumptions of willingness to pay for health will rise in line with economic growth (Defra 2019).

The annual physical flow of carbon sequestration is 32,560 tonnes of CO_2e per year, which has a monetary flow value of £2.22M. (Table 4.1) The present value of this over a 50 year period is £127.55M. This was calculated using the estimated central non-traded carbon values (DBEIS 2019) for each of the 50 years starting in 2019.

Table 4.1 Carbon sequestration.

Woodland type	Annual physical flow ($t/Co_2e/yr$)	Annual monetary flow (central value £2019)	Present value (£ PV)
Broadleaved	23,200	1.58M	
Coniferous	2,640	180,000	
Mixed	4,780	327,000	
Parkland	1,610	110,000	
Scrub	327	22,300	
Total	**32,560**	**2.22M**	**127.6M**

The timber production value was also calculated (Table 4.2). The 36,200 cubic metres of timber has an annual flow value of £2M and a present value of £51.1M. This is based on the average price for softwood in 2019 taken from the Forestry Commission Coniferous Standing Sales Price Index (Forestry Commission 2019), and the 2015 price for broadleaved timber adjusted for inflation to reflect 2019 prices (ABC 2015).

Table 4.2 Timber production.

Timber type	Annual physical flow (m^3)	Annual monetary flow (£2019)	Present value (£ PV)
Hardwood	28,200	1.83M	
Softwood	7,980	171,000	
Total	**36,200**	**2.00M**	**51.1M**

The value of the air pollution regulation service was based on the physical flow of the service based on woodland and grass habitats. These habitats in the LCR capture 213 tonnes per year of $PM_{2.5}$, which has an annual value of 29.96M, and a present value of £1.05Bn (Table 4.3). There is now strong evidence to show that fine particles such as these increase human mortality and morbidity from cardiovascular and respiratory diseases. As a result the damage costs avoided are high. The physical and monetary flows from the regulation of SO_2 are much lower than $PM_{2.5}$ (Table 4.3). Woodland and grass take up 17 tonnes per year, with an annual value of £110,500 and a present value of £3.83M.

Table 4.3 Air pollution regulation.

Habitat	Annual physical flow (tonnes/yr)	Annual monetary flow (£2019)	Present value (£ PV)
$PM_{2.5}$ Broadleaved	103		
Coniferous	66.5		
Grass	44.9		
Total	**213**	**29.96M**	**1.05Bn**
SO_2 Broadleaved	6.65		
Coniferous	4.40		
Grass	5.95		
Total	**17**	**110,502**	**3.83M**

The importance of access to greenspace in urban environments is increasingly recognised, as outlined for accessible nature in the previous section. Visits to natural areas have been shown to enhance physical and mental health and well-being, increase social cohesion and contribute greatly to the local economy. This service is related to that of accessible nature, as both are based around accessible greenspaces, but recreation is concerned with estimating the annual number of visits, whereas accessible nature is concerned with the naturalness of the sites.

Information on recreational visits and their value was taken from the University of Exeter's Outdoor Recreation Valuation Tool (ORVal) version 2. The results are broken down by each local authority within the LCR (Table 4.4). Recreation is an important service to the region, with Liverpool, Sefton and Wirral receiving the most annual visits among the local authorities. The total number of visits per year to LCR is 65,864,000, with an annual monetary flow of £236.04M and a present value of £6.02Bn.

Table 4.4 Recreation.

Local Authority	Annual physical flow Visits/yr	Annual monetary flow (£2019)	Present value (£ PV)
Liverpool City	18,382,000	5,743,000	
Halton	5,613,000	18,774,000	
Knowsley	4,468,000	13,254,000	
Sefton	15,101,000	64,661,000	
St Helens	6,346,000	20,123,000	
Wirral	15,954,000	61,791,000	
Liverpool City Region total	**65,864,000**	**236.04M**	**6.02Bn**

The opportunities for physical exercise that the natural environment provides has been shown to reduce diseases related to lack of exercise (for example, heart disease, stroke, diabetes and certain types of cancers). However, there is still a limited understanding of how spatial location, access and different types of natural capital and its quality will affect the number of visitors to greenspaces.

The physical health service was based on the visits to the LCR estimated by the ORVal tool. These were converted into number of visitors using Natural England Monitor of Engagement with the Natural Environment (MENE) survey data. The proportion of the visitors that are likely to meet physical activity guidelines were taken from White et al. (2016). These were then translated into Quality Adjusted Life Years (QALYs) scores, with 30 minutes of moderate to intense physical activity (if taken 52 weeks a year) being equal to 0.0107 of a QALY. The number of active visits to greenspaces in LCR is estimated at 144,586 per year, which is equivalent to 4932 QALYs per year (Table 4.5). This has an annual value of £98.64M and a present value of 3.65Bn.

Table 4.5 Physical health.

Annual physical flow Active visits*/yr	QALYs/yr	Annual monetary flow (£2019)	Present value (£ PV)
144,586	4932	98.64M	3.65Bn

* Individuals who met national physical activity guidelines.

Data gaps assumptions and limitations

Work is progressing rapidly on the calculation of physical and monetary flows of ecosystem services from natural capital assets, but it remains a developing area. A number of ecosystem services remain difficult to quantify and value. Some are highly location specific, for example water flow and impact on downstream flood risk. This can be quantified and valued by running detailed hydrological and flood risk modelling, but it is difficult to generalise. Others, such as water quality can be modelled, but are very difficult to value, while there are additional cultural services, such as aesthetic experiences, cultural heritage, spiritual experience and sense of place that are difficult to even quantify. It should, therefore, be borne in mind that the valuations presented in this section place values on several key benefits, but these are necessarily incomplete.

For the services that have been included here, a range of assumptions have been made, and these are outlined when describing the methodology (see Section B of the Technical Appendix). In addition, a summary of the main uncertainties is provided for each service in Table 4.6 (below), along with a RAG rating highlighting the overall confidence in each estimate. For most ecosystem services these assumptions are minimal, as established production functions exist, linking natural capital to ecosystem service production, and levels of production to monetary value. For some services, despite fast developing research in relevant areas, broad assumptions have to be made because these links are not clear. This is particularly the case for physical health, and this estimate should, therefore, be used with care.

Table 4.6: Summary of uncertainties in the calculation of physical flows and monetary values of each natural capital benefit, and an overall assessment of confidence, using a red, amber, green (RAG) rating.

Natural capital benefits	Assessment of uncertainties	RAG rating
Air purification	A lot of uncertainty over change in absorption as trees grow. Also based on averages for broadleaved and coniferous trees and grassland. Valuation follows ONS guidance.	
Carbon sequestration	Well studied, standardised carbon lookup tables available. Valuation uses UK Government carbon price.	
Timber production	Well studied over many years as part of forestry management. Valuation uses market prices.	
Recreation	Uncertainty over the number of visits that would be made to greenspaces. Some uncertainty over the value of these visits.	
Physical health	The most uncertain of the services measured. High uncertainty over both the number of visitors who would make active visits to the greenspaces and the monetary value of these benefits.	

5. Conclusions

The natural capital assets of the Liverpool City Region are a reasonably diverse mosaic of habitats, but are dominated by urban land covers. Despite this the assets provide a wide range of benefits to society. The assets store and sequester carbon, absorb and intercept air pollutants, provide regulation of noise and the local climate, help to regulate water flow and quality. They also provide important cultural services through access to recreational opportunities that can enhance physical health. A diverse number of habitats in the LCR play a role in providing these services to a varying degree, but of particular importance are the woodland and the intertidal salt marsh habitats. Due to the large urban component within the LCR there is a high demand for ecosystem services within the more densely populated and built up areas. The analyses have revealed a spatial mismatch between provision of the benefits and this demand. The provision of most of the services is highest in the urban fringes and in the rural areas of the region, and tends to be the lowest in the urban centres.

6. Recommendations

The most gains in terms of ecosystem service benefits can be made in air pollution regulation, noise regulation and local climate regulation. In terms of air pollution and noise regulation, planting (or maintaining) trees and woodland close to main roads and other pollution and noise sources in built-up areas would be highly beneficial, with considerable benefits to society possible. All of these services can be very localised, hence it is also important to consider the specific location of trees within each local authority to gain the maximum benefit from the services.

Trees are very effective at mitigating the effects of air pollution. However, there are major differences in the ability of different species to intercept pollution. The location of trees relative to pollution sources also determines how effective they are at removing pollutants, with trees close to sources being the most effective. Urban woodland is particularly effective as it has high capacity to absorb pollution and is also situated in locations likely to have high demand for the service. Street trees would be a beneficial addition as they can be very important at absorbing air pollution adjacent to busy urban roads at a local level. It is important that the right types of trees are planted in the right places, and databases are available that indicate the effectiveness of different species at absorbing air pollution. Other factors should also be taken into account when planting street trees such as carbon sequestration ability, resilience to urban conditions and climate change, and growth form. In terms of noise regulation, whilst only modest reductions in noise can be achieved, there is some evidence to suggest that the presence of vegetation blocking views of a noise source such as a road can enhance the perception of noise reduction. Densely planted and complex vegetation cover such as trees mixed with scrub is considered to be most effective, although any vegetation cover is more effective than artificial sealed surfaces. Increasing street trees, scrub and other vegetation in urban areas can also lower surface and air temperatures by providing shade and through evapotranspiration, therefore off-setting the heat island effect. If planted in strategic locations around buildings and on the street to shade pavements.

Planting urban trees and complex vegetation to increase these three services will also provide additional benefits. It will provide increased carbon sequestration, which is particularly pertinent in the context of the LCR having declared a climate emergency and can contribute to the LCA's zero carbon target of 2040. It will decrease storm water runoff and increase water quality. It can also increase the aesthetic value of urban spaces, and green views have been shown to increase certain aspects of human health and well-being.

Extending the planting of trees in urban areas, it is also important to ensure access to greenspace. The natural capital assessment shows that the provision of this service is reasonable in LCR, however, the demand for this service is high. LCR is a destination for recreation and there are numerous parks, river and coastal walks in the region. However, numerous research has shown that people travel most frequently to greenspaces very close to their homes and Natural England recommend that everyone should have access to at least some greenspace within 300m (5 minutes walk), and larger sites within 2 km. Furthermore, national surveys have shown that the median distance that people will travel to visit even high quality greenspace is only 3.2 km. Whilst it is important to have accessible greenspace, well-being benefits will be greater if the sites are more natural and richer in biodiversity. This should be considered particularly when assessing new residential developments, and when considering potential land uses and values in the spatial plan.

7. Future work

There are two further ecosystem services that could be mapped. The physical and monetary flow of recreation in the LCR was estimated, but could not be mapped as part of this project. This is possible by taking the accessible sites in the LCR from the ORVal tool, and highlighting them in the natural capital basemap, and coding them in relation to visitor rate. The physical and monetary flows of agriculture production could also be estimated, but were not seen as a priority for this project. This production can also be mapped.

(i) Habitat / landscape opportunity mapping

Habitat opportunity mapping can be used to identify possible locations where new habitat can be created that will be able to deliver particular benefits, whilst taking certain constraints (such as current land use or proximity to gas lines or Scheduled Monuments) into account. It can be used to assess opportunities for biodiversity, with a focus on key habitats that are thought to be of importance in the LCR, and / or areas that can deliver particular ecosystem services. Combined, the opportunity maps can show areas that deliver biodiversity and multiple ecosystem services. For example, it is possible to map opportunities for ameliorating air pollution, increasing carbon sequestration, enhancing recreation in the natural environment, enhancing the reduction in surface water runoff, and increasing water quality. The maps can be used to highlight key locations and to guide decision making in relation to investing in green infrastructure for biodiversity and natural capital net gain, for creating carbon and biodiversity offsetting, and for identifying nature recovery networks.

(ii) Scenario analyses

This project focused on the production of a baseline for LCR, highlighting its natural capital assets, including the type and extent of these assets, and the level of ecosystem service provision and demand, as well as the value of key services. This can now be used as a baseline from which to compare the impacts of future targets and policies (e.g. future planning and development projects, industrial strategy, carbon sequestration targets, environmental net gain) on the natural capital assets and ecosystem service provision and demand. Future work should include scenario analyses where a new natural capital basemap of future interventions (e.g. increasing urban trees or the masterplan of a development) can be created and compared to the baseline to understand the change in ecosystem services provision, demand and their value. This allows targets and policies to be tested before the interventions are implemented, to understand likely outcomes predicted based on the most up to date science.

(iii) Assessing habitat quality across the LCR

This assessment provides a baseline for natural capital net gain, but not for the assessment of biodiversity net gain. This requires data on the condition of habitats within the LCR. This can be gained through on the ground habitat survey, but this would be a big undertaking over such a large area. Natural Capital Solutions are currently developing a way of assessing the condition of habitat from a range of spatial data that is available, and incorporating it into the natural capital basemap. This would then allow an assessment of biodiversity net gain, using a tool such as Natural England's Biodiversity Metric 2.0, not just at individual small sites, but across the whole of the LCR. The effect that proposed developments and policies can have on biodiversity can then also be assessed alongside the effect on ecosystem services.

(iv) Natural capital investment plan

The natural capital baseline established for LCR, the scenario and opportunity mapping are key to the development of a natural capital investment plan for the region. The policy priorities for the region should direct the scenarios and opportunities that are explored, this can then establish where investments should be targeted for the greatest gains in biodiversity and ecosystem service benefits. A number of investment options can then be established. Options should include areas of habitat that can be packaged as biodiversity and carbon off-setting opportunities.

(v) Net gain policy

Natural Capital Solutions have experience of developing local authority net gain policy, particularly in relation to achieving biodiversity net gain, but also integrating natural capital net gain into local planning policy. We can advise on how to develop a policy that works within individual local authorities, but that integrates across the LCR, by incorporating the evidence from biodiversity and natural capital assessments, scenario analyses, opportunity mapping, and the priorities in the investment plan.

Technical Appendix

Section A

Modelling and mapping ecosystem services

A1. Creating a habitat basemap

Before the physical flow or value of ecosystem services can be calculated and mapped, it was necessary to obtain an accurate assessment of the natural capital assets currently present in the Liverpool City Region (LCR). The most important component of this was to create a habitat basemap for the area.

The habitat basemap was created using EcoServ GIS, a toolkit developed by the Wildlife Trusts, with a number of bespoke modifications. This approach uses OS MasterMap polygons as the underlying mapping unit, and then uses a series of different data sets to classify each polygon to a detailed habitat type and to associate a range of additional data with each polygon. The data that was used to classify habitats in the basemap is shown below.

- OS Mastermap topography layer
- OS VectorMap District data
- OS Mastermap Greenspace
- CORINE European land cover data
- Priority habitats and phase 1 habitat survey data
- National Vegetation Classification
- Public Rights of Way data
- LCR Green Infrastructure Typology layer
- LCR Core Biodiversity Areas
- Digital Terrain Model

Polygons were classified into Phase 1 habitat types and were also classified into broader habitat groups. Multiple modifications were made to the EcoServ programme code to enable improved classification of habitats. Furthermore, upon initial completion the basemap was carefully checked and manual alterations were made in a number of places where misclassifications had occurred. Note, however, that the final map was not ground truthed for accuracy, hence some misclassifications are inevitable. The basemap was produced to cover the whole of the Liverpool City Region area, plus an additional buffer zone of 1 km to ensure that all maps were accurate right to the edge of the main study area.

A2. Ecosystem service models

Once a detailed habitat basemap was created for the baseline, it was then possible to quantify and map the benefits that these habitats (natural capital) provide to people. The following benefits (ecosystem services) have been assessed for this project:

- Carbon storage capacity
- Carbon sequestration
- Air purification capacity and demand
- Local climate capacity and demand
- Noise regulation capacity and demand
- Water flow capacity
- Water quality capacity
- Accessible nature capacity and demand

A variety of methods were used, and these are described for each individual ecosystem service in the sections below. In all cases the models were applied at a 10m by 10m resolution to provide fine scale mapping across the area. The models are based on the detailed habitat information determined in the basemaps, together with a variety of other external data sets (e.g. digital terrain model, UK census data 2011, open space data, and many other data sets and models mentioned in the methods for each ecosystem service). Note, however, that many of the models are indicative (showing that certain areas have higher capacity or demand than other areas) and are not process-based mathematical models (e.g. hydrological models). In all cases the capacity and demand for ecosystem services is mapped relative to the values present within the study area, on a scale from 0-100.

A2.1 Carbon storage

Carbon storage capacity indicates the amount of carbon stored naturally in soil and vegetation. Carbon storage and sequestration is seen as increasingly important as we move towards a low-carbon future. The importance of managing land as a carbon store has been recognised by the UK government, and land use has a major role to play in national carbon accounting. Changing land use from one type to another can lead to major changes in carbon storage, as can restoration of degraded habitats.

The EcoServ GIS carbon storage model was used. This model estimates the amount of carbon stored in the vegetation and top 30cm of soil. It applies average values for each habitat type taken from a review of a large number of previous studies in the scientific literature. As such it does not take into account habitat condition or management, which can cause variation in amounts of carbon stored. It is calculated for each 10m by 10m cell across the study area. Scores are scaled on a 0 to 100 scale, relative to values present within the mapped area.

A2.2 Carbon sequestration

Carbon sequestration from woodland areas were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2018a,b). Coniferous woodland sequestration rates were averaged over an 80-year period and deciduous woodland sequestration rates were averaged over a 100-year period, as this is the length of a typical forestry cycle for deciduous woodland. Information on species composition was taken from the Forestry Commission 'Tree species in the NW' (Forestry Commission 2002). The annual sequestration rate for each woodland type were then multiplied by the area of each and added together to give the total annual sequestration estimate for woodland at the site. Parkland areas were included assuming a sequestration capacity of 20% of woodland, and dense continuous scrub was assumed to be 50%. Maps of the sequestration rate scaled from 0 to 100 were produced.

A2.3 Air purification capacity

Local climate regulation capacity was mapped using a modified version of the EcoServ model. The model assigns a score to each habitat type representing the relative capacity of each habitat to ameliorate air pollution. The cumulative score in a 20m and 100m radius around each 10m by 10m pixel was then calculated and combined. The benefits of pollution reduction by trees and greenspace may continue for a distance beyond the greenspace boundary itself, with evidence that green area density within 100m can have a significant effect on air quality. Therefore, the model extends the effects of greenspace over the adjacent area, with the maximum distance of benefits set at 100m. Note that the model does not take into account seasonal differences or differences in effect due to prevailing wind direction.

A2.4 Air quality regulation demand

Air quality regulation demand estimates societal and environmental need for ecosystems that can absorb and ameliorate air pollution. Demand is assumed to be highest in areas where there are likely to be high air pollution levels and where there are lots of people who could benefit from the air quality regulation service. The model combines two indicators of air pollution sources (log distance to roads, and % cover of sealed surfaces) and two indicators of societal need for air quality regulation (population density, and Index of Multiple Deprivation health score). The scores for each indicator were normalised and combined with equal weighting. The final score was then projected on a 0 to 100 scale, relative to values present within the study area.

A2.5 Local climate regulation provision

Land use can have a significant effect on local temperatures. Urban areas tend to be warmer than surrounding rural land due to a process known as the "urban heat island effect". This is caused by urban hard surfaces absorbing more heat, which is then released back into the environment, coupled with energy released by human activity such as lighting, heating, vehicles and industry. Climate change impacts are predicted to make the overheating of urban areas and urban buildings a major environmental, health and economic issue over the coming years. Natural vegetation, especially trees / woodland and rivers, are able to have a moderating effect on local climate, making nearby areas cooler in summer and warmer in winter. Local climate regulation capacity estimates the capacity of an ecosystem to cool the local environment and cause a reduction in urban heat maxima.

EcoServ was used to model local climate regulation capacity. The model calculates the proportion of the landscape that is covered by woodland / scrub and water features within a 200m radius around each 10m by 10m cell across the study area. However, temperature regulating effects of woodland and water will also occur in nearby adjacent areas, with the distance of the effect dependent on the patch size of the natural area. To incorporate this effect, a buffer was applied around each woodland / water patch, with wider buffers modelled around larger natural sites.

Note that this model only includes woodland / scrub and water features which provide the most significant effects. All greenspace is beneficial compared to artificial sealed surfaces, so a future iteration of the model could include all natural surfaces.

The final capacity score was calculated for each 10m by 10m cell across the study area, and was scaled from 0 to 100, relative to values present within the mapped area. High values (red) indicate areas that have the highest capacity to regulate temperatures, keeping them cool in the summer and warmer in the winter.

A2.6 Local climate regulation demand

Local climate regulation demand estimates societal and environmental need for ecosystems that can regulate local temperatures and reduce the effects of the urban heat island. Local climate regulation demand combines one indicator showing the location of areas suffering from the urban heat island effect (the proportion of sealed surfaces), with two indicators showing societal need for local climate abatement (population density, and proportion of the population in the highest risk age categories – defined as under 10 and over 65). Scores are on a 1 to 100 scale, relative to values present within the study area.

A2.7 Noise regulation capacity

Noise regulation capacity is the capacity of the land to diffuse and absorb noise pollution. Noise can impact on health, wellbeing, productivity and the natural environment and the

World Health Organisation (WHO) have identified environmental noise as the second largest environmental health risk in Western Europe (after air pollution). It is estimated that the annual social cost of urban road noise in England is £7 to £10 billion (Defra 2013). Major roads, railways, airports and industrial areas can be sources of considerable noise, but use of vegetation can screen and reduce the effects on surrounding neighbourhoods. Complex vegetation cover such as woodland, trees and scrub is considered to be most effective, although any vegetation cover is more effective than artificial sealed surfaces, and the effectiveness of vegetation increases with width.

The EcoServ noise regulation model was used, with some modifications. First, the capacity of the natural environment is mapped by assigning a noise regulation score to vegetation types based on height, density, permeability and year round cover. Next, the noise absorption score in 30m and 100m radii around each point was modelled and the scores combined, which results in wider belts of vegetation receiving a higher score. The score was calculated for each 10 m by 10m cell across the study area, and is scaled from 0 to 100, relative to values present within the mapped area.

A2.8 Noise regulation demand

Noise regulation demand estimates societal and environmental need for ecosystems that can absorb and reduce anthropogenic noise. The model combines one indicator that maps noise sources (inverse log distance to different road classes and railways) and two indicators of societal demand for noise abatement (population density, and Index of Multiple Deprivation health scores). Scores are on a 1 to 100 scale, relative to values present within the study area.

A2.9 Water flow capacity

Water flow capacity is the capacity of the land to slow water runoff and thereby potentially reduce flood risk downstream. Following a number of recent flooding events in the UK and the expectation that these will become more frequent over the coming years due to climate change, there is growing interest in working with natural process to reduce downstream flood risk. These projects aim to “slow the flow” and retain water in the upper catchments for as long as possible. Maps of water flow capacity can be used to assess relative risk and help identify areas where land use can be changed.

A bespoke model was developed, building on an existing EcoServ model and incorporating many of the features used in the Environment Agency’s catchment runoff models used to identify areas suitable for natural flood management. Runoff was assessed based on the following two factors and mapped for each 10m by 10m cell across the study area:

- **Roughness score** – Manning’s Roughness Coefficient provides a score for each land use type based on how much the land use will slow overland flow.

• **Slope score** – based on a detailed digital terrain model, slope was re-classified into a number of classes based on the British Land Capability Classification and others.

Each indicator was normalised from 0-1, then added together and projected on a 0 to 100 scale, as for the other ecosystem services. Note that this is an indicative map, showing areas that have generally high or low capacity and is not a hydrological model.

A2.10 Water quality capacity

Water quality capacity maps the risk of surface runoff water becoming contaminated with high pollutant and sediment loads before entering a watercourse, with a higher water quality capacity indicating that water is likely to be less contaminated. Note that although urban diffuse pollution is partially captured in the model at catchment scale, the focus is on sedimentation risk from agricultural diffuse pollution, hence built-up areas are not particularly well accounted for in the existing model.

A modified version of an EcoServ model was developed, which combines a coarse and fine-scale assessment of pollutant risk. At a coarse scale, catchment land use characteristics were used to determine the overall level of risk. The percentage cover of sealed surfaces and arable farmland in each sub-catchment was calculated and the values were re-classified into a number of risk classes. There is a strong link between the percentage cover of these land uses and pollution levels, with water quality particularly sensitive to the percentage of sealed surfaces in the catchment.

At a fine scale, a modification of the Universal Soil Loss Equation (USLE) was used to determine the rate of soil loss for each cell. This is based on the following three factors:

- **Distance to watercourse** – using a least cost distance analysis, taking topography into account.

- **Slope length** – using a flow accumulation grid and equations from the scientific literature. Longer slopes lead to greater amounts of runoff.

- **Land use erosion risk** – certain land uses have a higher susceptibility to erosion and standard risk factors were applied from the literature. Bare soil is particularly prone to erosion.

Each of the three fine scale indicators and the catchment-scale indicator were normalised from 0-1, then added together and projected on a 0 to 100 scale. As previously, this is an indicative map, showing areas that have generally high or low capacity and is not a process-based model. High values (red) indicate areas that have the greatest capacity to deliver high water quality.

A2.11 Accessible nature capacity

Access to greenspace is being increasingly recognised for the multiple benefits that it can provide to people. In particular there is strong evidence linking access to greenspace to a variety of health and wellbeing measures. Research has also shown that there is a link between wellbeing and perceptions of biodiversity and naturalness. Natural England and others have published guidelines that promote the enhancement of access, naturalness and connectivity of greenspaces. The two key components of accessible nature capacity are therefore public access and perceived naturalness. Both of these components are captured in the model, which maps the availability of natural areas and scores them by their perceived level of "naturalness".

An EcoServ model was used to map accessible nature capacity. In the first step, accessible green spaces were mapped. These were determined from OS Mastermap Greenspace data, and data sets on local nature reserves, accessible woodlands and others. Greenspaces that did not have full public access (e.g. golf courses, institutional grounds) were removed from further analysis. The retained areas were then scored for their perceived level of naturalness, with scores taken from the scientific literature. Naturalness was scored in a 300m radius around each point, representing the visitors' experience within a short walk of each point.

The resulting map shows accessible areas, with high values representing areas where habitats have a higher perceived naturalness score. Scores are on a 1 to 100 scale, relative to values present within the study area. White space shows built areas or areas with no public access. Larger continuous blocks of more natural habitat types will have higher scores than smaller isolated sites of the same habitat type.

A2.11 Accessible nature demand

This indicates where there is greatest demand for accessible nature, which is strongly related to where people live. Research, including large surveys such as the Monitor of Engagement with the Natural Environment (MENE), have shown that there is greatest demand for accessible greenspace close to people's homes, especially for sites within walking distance.

This model maps sources of demand, taking no account of habitat, based on three indicators: population density (based on 2011 census data), health scores (from the Index of Multiple Deprivation), and distance to footpaths and access points. The three indicators are calculated at three different scales as demand is strongly related to distance. Data from six years of the Monitor of Engagement with the Natural Environment (MENE) survey were used to determine approximate distances. The distances chosen (and rationale) were: 600m (approximately 10 minutes walking distance, often an aim for universal access to greenspace), 3.2 km (67% of all visits and 90% of visits by foot in MENE were within this distance), and 16 km (89% of all visits in MENE were within this distance).

The three indicators were normalised from 0-1, then combined with equal weighting at each scale and then the three different scales of analysis were combined and projected on a 0 to 100 scale. High values (red) indicate areas (sources) that generate the greatest demand for accessible nature.

Section B

Valuation methodology

This appendix provides details of the methods used to value the following ecosystem services:

- Carbon sequestration
- Timber / woodfuel production
- Air pollution regulation
- Recreation
- Physical health

The annual physical and the monetary flows of each service were calculated, and all values were also presented as Present Values over a 50 year time period.

B1.1 Carbon sequestration

The physical flow of this service was calculated as in A2.2 above. Monetary flows were calculated using the government's non-traded central carbon price for each year for the next 50 years, starting in 2019 (DBEIS 2019). We use the non-traded carbon price because it is a better reflection of the 'real' value of carbon sequestration if it were to be exchanged, than market prices. Using the latter reflects the current institutional set up of carbon markets, rather than the true value of carbon sequestration. The present value (PV) of the ability of the woodland to sequester carbon into the future was calculated by summing the values for each year over the 50-year project period, after discounting using the discount rate suggested in HM Treasury (2018) of 3.5%, and the formula within ONS (2016). The HM Treasury also provides low and high estimates of current and future non-traded carbon prices. These can be used to provide a sensitivity analysis to the economic valuation of this ecosystem service.

B1.2 Timber/woodfuel production

For existing woodland, annual physical flows of timber/woodfuel production were calculated in terms of average annual yield, by multiplying the yield class of the different species by the area of each woodland type. The average yield classes for each species of woodland type were derived from the woodland carbon code.

The monetary flows for the woodland areas were calculated by multiplying the yield (calculated above) by the standing price of timber or woodfuel, and multiplying by the standard government discount rate for each respective year over 50 years. The average price for softwood in 2019 was taken from the Forestry Commissions Coniferous Standing Sales Price Index (Forestry Commission 2019). The price for broadleaved timber in 2015 ranged from £15 to high quality timber reaching £250 per m^3 standing (ABC 2015). As a large proportion of the woodland in the LCR is the Mersey Forest, and this is managed for a range of hardwood products (woodfuel through to higher quality products), we have assumed a

2019 value £64.93 (approximately one third of the broadleaved timber value range). The present value of the ability of the woodland created to provide timber into the future was calculated by summing the discounted values over a 50-year period. It was assumed that the area of woodland remains static and the unit price was also assumed to be constant.

B1.3 Air quality regulation

The ability of the woodland and grassland vegetation in LCR to absorb two key pollutants, particulate matter ≤2.5µm in diameter ($PM_{2.5}$) and sulphur dioxide (SO_2), was measured. Woodland, parkland (20%), dense scrub (50%) and grassland was included. Quantifying the physical flow of the air quality regulation service provided by the woodland and grassland was based on the absorption calculation in Powe & Willis (2004) and the method in ONS (2016). The deposition rates for PM_{10} and SO_2 in coniferous woodland, deciduous woodland, and grassland were taken from Powe & Willis (2004). PM_{10} was converted to $PM_{2.5}$ following the Defra (2019) conversion factor. Average background pollution concentrations for PM_{10} and SO_2 were calculated using Defra data (Modelling of Ambient Air Quality 2018 and 2001).

The surface area index of coniferous and deciduous woodlands in on-leaf and off-leaf periods was taken from Powe & Willis (2004). The proportion of dry days in 2018 (rainfall <1mm) for north-west England was estimated using MET office regional value data (http://www.metoffice.gov.uk/climate/uk/summaries/datasets). The proportion of on-leaf relative to off-leaf days was estimated at the UK level using the average number of bare leaf days for five of the most common broadleaf tree species (ash, beech, horse chestnut, oak, silver birch) in the UK using the Woodland Trust data averages tool (http://www.naturescalendar.org.uk/findings/dataaverages.htm).

The air quality regulation service was valued using guidance from Defra that provides estimates of the damage costs per tonne of emissions across the UK (Defra 2019). These are social damage costs based on avoided mortality and morbidity. Therefore, it was assumed that the value of each tonne of absorbed pollutant by the tree stock was equal to the average damage cost of that pollutant. The central damage cost for SO_2 across all locations was £6,498 (£/tonne, 2019 prices). The $PM_{2.5}$ damage cost estimates depend on the location (urban size or rural) and source of pollution. Considering the distribution of the woodland and grassland across the City Region we used three central damage cost estimates: rural (62%), urban small (19%) and urban big (19%), and the central damage costs are presented. When calculating the present value over 50 years, the absorption rate was assumed to be constant. The damage cost of $PM_{2.5}$ and SO_2 was adjusted to reflect inflation up to 2019 from 2017, and the value was also subject to an uplift of 2% per annum to reflect the assumption that willingness to pay for health will rise in line with economic growth, as recommended by Defra (2019).

B1.5 Recreation

Recreation was estimated for each of the local authorities within the Liverpool City Region using the University of Exeter's Outdoor Recreation Valuation Tool (ORVal) version 2. This tool uses a Recreational Demand Model to predict the number of visits that are made to currently accessible greenspaces by adult residents of England. The number of visits are modelled using data from the Monitor of Engagement with the Natural Environment (MENE) survey, and adjusted based on factors such as socioeconomic characteristics of people, the day of the week, attributes of the greenspace, as well as the availability and quality of any alternative greenspaces. See the advanced technical report for details: https://www.leep.exeter.ac.uk/orval/pdf-reports/ORValII_Modelling_Report.pdf.

B1.6 Physical health

There is now a growing body of evidence to show the positive effect that the natural environment can have on human health and well-being. Monetising these benefits remains a challenge, with mental health in particular lacking a generic measure that is commonly applied, making it very difficult to value at present (Binner et al. 2017). Physical health is more commonly valued, although methods are still being refined.

We measured physical health using the recreational visits as estimated by the ORVal tool (see (iv) above) and converted these into the number of visitors by dividing by a visit rate to green spaces derived from averaging across 5 years of the Natural England MENE survey (83.5), and using the proportions of visitors that meet physical activity guidelines in White et al. (2016). These were translated into Quality Adjusted Life Years (QALYs) scores, with 30 minutes of moderate to intense physical activity (if taken 52 weeks a year) being equal to 0.0107 of a QALY. QALY scores have an associated monetary value through estimated savings in health care costs. The physical health benefit was valued by calculating the total number of QALYs by active visitors to sites that meet guidelines, and multiplying this by the QALY value. The social value of one QALY has been estimated to be worth £20,000 (White et al. 2016). Note, however, that the HM Treasury has recently published an update to the Green Book (the Government's key guidance document on appraisal and evaluation), in which the value associated with one QALY has been increased to £60,000 (HM Treasury 2018). Given the large monetary benefit that would be assigned if using the higher QALY figure and the large number of assumptions involved in calculating this value, we have taken a conservative approach and used the £20,000 value for our central estimate, as has been used in previous natural capital assessments. We would, however, suggest the use the £60,000 estimate for our upper estimate of value, highlighting that the value of physical health could be considered to be much higher.

The present value (PV) of the area to deliver physical health benefits into the future was the sum of annual values over the 50-year period, using the discount rates suggested in HM Treasury (2019). Discount rates for QALY effects are recommended at 1.5%, (differing from the 3.5% rate recommended for other service indicators).

A number of assumptions are used in these calculations and the results should therefore be interpreted with caution; it is the ecosystem service with the greatest degree of uncertainty out of all those assessed.

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